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## Network planning methods in project management: Overview of software products

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**Abstract.** Ukraine is experiencing challenging economic instability that is affecting various economic sectors. Due to military actions and infrastructure destruction, there is an urgent need for rapid and effective reconstruction. Network planning methods help optimise resources and minimise costs, which is particularly relevant in conditions of limited funding. These methods enable the coordination of numerous projects, ensure their timely completion, and contribute to better synchronisation between different project stages, reducing the likelihood of errors and delays. This study aimed to analyse network planning methods in project management, examine their key advantages and disadvantages, and justify the feasibility of using different project management software in conditions of economic instability and uncertainty. The article presented an analysis of two primary network planning methods – Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM). A network diagram for the reconstruction of a production unit was developed. It has been proven that precise planning, resource optimisation, and effective risk management enhance the overall efficiency of project implementation, which is crucial for improving the competitiveness of Ukrainian enterprises. The study confirmed that the relevance of PERT and CPM in modern project management is due to their ability to ensure efficient planning, control, and resource management. The development of information technologies has opened new opportunities for the implementation of automated project management systems. It has been established that network planning methods can be easily integrated with modern software solutions, thereby increasing project management efficiency. An overview of key project management tools was conducted, and their applicability for network diagram construction was examined. The use of network planning methods in Ukraine is essential for effective project management, resource optimisation, and enhancing the country's competitiveness

**Keywords:** network diagram; Gantt chart; critical path method; program evaluation and review technique; optimisation

### Introduction

The increasing global competition required Ukrainian enterprises to enhance the efficiency and quality of project management in order to maintain their positions in the global market. Project management enabled enterprises and organisations to allocate resources optimally, minimise existing risks, and achieve strategic objectives, which was particularly important under conditions of economic instability. Knowledge in this field contributed to the enhancement of employees' professional competence, which, in turn, improved the quality of management and organisational productivity. In the context of the need to rebuild various sectors of the national economy and a severe shortage

of financial resources, the question of their maximally efficient use arose. In 2024, Ukraine actively attracted the attention of foreign investors to develop infrastructure, energy, and other key sectors of the economy. Project management was critically important for the effective utilisation of these investments and the implementation of not only large-scale infrastructure projects but also projects in the small and medium-sized business sector. Considering the situation with military actions as of mid-2024, post-war reconstruction would require significant efforts in planning, coordination, and project execution to restore destroyed cities, infrastructure facilities, and the economy as a whole.

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The evolution of project management in the digital economy was reflected in the work of the scholar A. Cabeças (2022). The author analysed how digital technologies, particularly Big Data, AI, blockchain, and hybrid management models, transformed project implementation methods. The concept of green project management (GPM), which combined traditional and agile approaches with a focus on sustainable development, was presented. Special attention was paid to the adaptation of project managers to new digital challenges and the selection of optimal methodologies to enhance project success. The main advantages of digital technologies (process automation, increased decision-making efficiency, and global team integration) were identified, along with the main challenges (cybersecurity, automation risks, and labour market changes). A historical analysis of the development of project management from PERT, CPM to Agile, Scrum, and Kanban was conducted, and the use of hybrid models was justified. The emergence of GPM as a sustainable project management approach was also explored.

The application of network planning as a method for managing IT projects was comprehensively studied by H.Yu. Rodashchuk *et al.* (2023). The authors analysed key issues associated with IT project management, such as increasing complexity and the risks of exceeding deadlines and budgets. A focus was placed on graph theory and the use of network models to identify the critical path and time reserves. The use of MS Excel for the visualisation and analysis of network models was proposed, simplifying the calculation of time parameters and optimising task execution. Network planning was recognised as a powerful tool for enhancing the efficiency of IT project management. Although the main focus was placed on MS Excel, it was noted that modern project management tools (Jira, Microsoft Project, Primavera) could provide more automated planning capabilities.

The importance of project management in the IT sector and its role in the development of Ukraine's economy was demonstrated in the study by D. Olkhovskiy *et al.* (2023). The authors conducted an analysis of key software tools for IT project management, such as Jira, Miro, Figma, as well as popular alternatives including Lucidchart, Cacao, RealtimeBoard, and Conceptboard. The importance of automation in project management, which facilitated business process optimisation, improved communication within teams, and enhanced IT company performance, was substantiated. The study included an overview of the capabilities of these tools and provided recommendations for their use. The concept of information support for managing innovative projects in the digital economy was reflected in the scientific work of Y. Panas (2024). The role of metadata in decision-making processes, the classification of project management software, and the functional capabilities of such solutions were analysed. A model of information support that contributed to the improvement of innovative project efficiency and the creation of a corporate knowledge base was proposed. Recommendations for the selection of project management software products based on the analytics of platforms such

as Capterra, G2, and Software Advice were justified. According to O. Vagonova *et al.* (2024), the application of agile methods and modern technologies was of primary importance for optimising enterprise business processes. It was demonstrated that agile methodologies enabled rapid adaptation to changing project implementation conditions. Planning and control methods allowed the evaluation of project performance in terms of cost and time.

The characteristics of popular project management methods and their risk management aspects were studied by Z. Zhygalkevych & V. Chuhlib (2019). The authors classified methods into rigid and agile approaches. Rigid methods (e.g., the "iterative waterfall" model) were suited for traditional formalised processes, while agile methods (Agile, Scrum, Lean, Kanban, PRINCE2) allowed quicker responses to changes and were more effective for dynamic projects. Wide opportunities for the use of various software products for building Gantt charts and network planning were highlighted. Attention was drawn to simple tools such as Excel and Smartsheet, as well as professional products like Microsoft Project and Primavera. It was concluded that the introduction of agile methods such as Lean and Agile would enable enterprises to rapidly adapt to market changes, while risk management was recognised as a key factor for successful project management.

Current methodologies for managing IT project teams, including Scrum, Kanban, XP, Lean, and Six Sigma, were thoroughly examined in the study by I. Blyznyukova *et al.* (2020). The authors highlighted the importance of effective team formation for successful project execution, especially in environments characterised by high dynamics and uncertainty, typical of the IT sector. Agile management approaches allowed faster responses to change, shortened development cycles, and improved product quality. The choice of a specific methodology was suggested to depend on the project's characteristics, team qualifications, and the desired level of management flexibility. The objective of this article was to study network planning methods in project management, to assess their strengths and weaknesses, and to determine their efficiency and feasibility of using specialised software under conditions of economic turbulence.

## ■ Materials and Methods

To construct the network diagram, the entire project was divided into separate, independent activities (tasks), for which the scope, resources, and execution conditions were defined. In the network model, there had to be exactly one initial (starting) and one final event. Each activity (stage, task) was designated by two events that determined its unique code (e.g., task 1-2). Dead ends (i.e., events, apart from the final one, from which no task originates) were not permitted in the diagram. No closed loops were allowed either. It was advisable to visually distinguish node events, for instance, by using a different graphic representation. At the work execution management stage, a network diagram needed to be presented in calendar form. All tasks in the network model were evaluated using identical units of time measurement.

During the construction of the network diagram, it was customary for the preceding event of any given task to be denoted by the index  $i$ , and the subsequent event to be denoted by the index  $j$ , with the completion time of the task represented as  $t_{ij}$ . The longest path from the initial to the final event in the model was identified as the critical path. Tasks located along this path were regarded as critical. Time parameters were calculated in the following sequence: the duration of each task ( $t_{ij}$ ), the duration of the critical path ( $T_{cr}$ ) in comparison with the directive time ( $T_{dir}$ ), the earliest possible occurrence time of each event ( $T_i^e$ ), the latest possible occurrence time ( $T_i^l$ ), the event float ( $R_i$ ), the task floats – free ( $FF_{ij}$ ) and total ( $TF_{ij}$ ) – and the start and end times of the tasks. Two approaches were applied for determining  $t_{ij}$ : the first involved defining the duration based on normative data or previous experience; the second was used in cases where the duration could not be defined precisely due to multiple uncertainties. In such cases, the PERT method was utilised. This required three estimates: the optimistic duration ( $t_{min}$ ), the pessimistic duration ( $t_{max}$ ), and the most likely duration ( $t_{ml}$ ). The expected duration was calculated using the following equation:

$$t_{ij} = \frac{t_{min} + 4t_{ml} + t_{max}}{6}, \tag{1}$$

the duration of the critical path was:

$$T_{cr} = \sum_m t_{ij}, \tag{2}$$

where  $m$  denoted the number of activities lying on the critical path. In order to complete the entire work package, a directive time  $T_{dir}$  had been set in advance, and it was therefore necessary to satisfy the condition:

$$T_{cr} \leq T_{dir}, \tag{3}$$

if this condition was not met, the schedule needed to be revised or the duration of activities located on the critical path had to be reduced. Subsequently, the parameters of the events were calculated, and the path duration was determined. The path duration  $t(L)$  represented the total duration of activities along any given path on the network diagram, i.e.:

$$t(L) = \sum_n t_{ij}, \tag{4}$$

where  $n$  denoted the number of activities along the given path. The earliest possible occurrence time of an event  $T_i^e$  was determined as the sum of the durations of the activities lying on the longest path from the initial to the respective event:

$$T_i^e = t(L_i^e), \tag{5}$$

where  $t(L_i^e)$  represented the duration of the longest path from the initial event to event  $i$ . The latest possible occurrence time of the event,  $T_i^l$  was defined as the difference between  $T_{cr}$  and the maximum duration of the path from the final event of the network diagram to the event under consideration,  $t(L_i^l)$ :

$$T_i^l = T_{cr} - t(L_i^l), \tag{6}$$

for events that lie on the critical path, it was always the case that  $T_i^l = T_i^e$ . Based on the values of  $T_i^e$  and  $T_i^l$ , the event time float  $R_i$  was determined:

$$R_i = T_i^l - T_i^e, \tag{7}$$

only events that were not located on the critical path possessed time floats. For each event, three parameters were calculated:  $R_i$ ,  $T_i^e$ ,  $T_i^l$ . The float was calculated for each of the activities that were not located on the critical path. Within the network model, two main types of floats were computed – free float  $FF_{ij}$  and total float  $TF_{ij}$ . The free float of an activity is calculated as the difference between the earliest possible time of occurrence of event  $T_i^e$  and  $T_j^l$ , minus the duration of the activity  $t_{ij}$ , namely:

$$FF_{ij} = T_j^e - T_i^e - t_{ij}, \tag{8}$$

the total float  $TF_{ij}$  of an activity is calculated as the difference between the latest permissible time of occurrence of event  $T_i^l$  and the earliest time of occurrence of event  $T_j^e$ , minus the duration of the activity  $t_{ij}$ , that is:

$$TF_{ij} = T_j^l - T_i^e - t_{ij}, \tag{9}$$

it is advisable to consider the basic principles of constructing a network diagram using a simplified example. Based on the initial data (Table 1), the following parameters were calculated:  $T_{cr}$ ,  $T_i^e$ ,  $T_i^l$ ,  $R_i$ ,  $FF_{ij}$ ,  $TF_{ij}$ ; a network model was constructed, with all time parameters and the critical path indicated. For the purpose of simplification, the activity durations according to the PERT method had already been predefined.

**Table 1.** List of operations and duration for completing the project work package

| Nº | Independent activities (individual tasks) | Task code | Time for task execution, weeks |
|----|---|-----------|--------------------------------|
| 1  | Document review                           | 1-2       | 4                              |
| 2  | Delivery to site                          | 2-3       | 2                              |
| 3  | Equipment installation                    | 3-4       | 6                              |
| 4  | Equipment setup and connection            | 4-11      | 4                              |
| 5  | Receipt of apparatus and accessories      | 2-7       | 1                              |
| 6  | Apparatus installation                    | 7-8       | 6                              |
| 7  | Apparatus testing                         | 8-11      | 8                              |
| 8  | Instruction preparation                   | 2-9       | 4                              |
| 9  | Staff training                            | 9-10      | 4                              |
| 10 | Staff examination                         | 10-13     | 1                              |
| 11 | Premises reconstruction                   | 1-5       | 8                              |

Table 1. Continued

| Nº | Independent activities (individual tasks) | Task code | Time for task execution, weeks |
|----|---|-----------|--------------------------------|
| 12 | Equipment acceptance                      | 2-5       | 4                              |
| 13 | Equipment installation and mounting       | 5-6       | 6                              |
| 14 | Adjustment of devices and equipment       | 11-12     | 2                              |
| 15 | General adjustment                        | 12-13     | 4                              |
| 16 | Device commissioning                      | 6-13      | 3                              |
| 17 | Object acceptance                         | 13-14     | 2                              |

Source: compiled by the author

To identify the key advantages and disadvantages of project management software, a comparative analysis method was employed. This approach involved the systematic comparison of several objects, products, methods, or systems according to defined criteria in order to assess their strengths, weaknesses, and overall effectiveness. The primary aim of the analysis was to select the optimal option based on specific requirements. The comparison was carried out according to the following criteria: functionality, ease of use, cost, integration with other tools, flexibility, and support. Initially, the key comparison criteria were identified, followed by the selection of software products for evaluation. The subsequent stage involved the collection of data and the assessment of each software solution in accordance with the established criteria. A final analysis and comparison of the results obtained were then undertaken. Both paid and free software products were analysed. Based on the findings of the study, ProjectLibre was selected for more detailed analysis.

■ Results and Discussion

The network diagram illustrated the sequence and order of the project’s main tasks and was used to monitor the progress of work. Regardless of the project’s type or size, the primary factors remained time, cost, and resource availability. The core purpose of network diagrams lay in

tracking all these factors separately and in various combinations. The key elements of the network diagram comprised: an activity, an event, and a path. An activity represented a process that required time, resource expenditure, or involved waiting. An activity always took place over a period of time. As an additional element, a dummy activity could be introduced into the network model to define the required connections between specific events (a dummy activity involved no consumption of time or resources). An event referred to a specific state of the work package during its implementation. It resulted from the completion of one or more partial tasks and enabled the commencement of subsequent activities. A sequence of interrelated activities and events formed a path in the network model. In the diagram, an activity was represented by an arrow (a dummy activity by a dashed arrow), an event by a circle, and a path by consecutively connected arrows and circles.

Figure 1 presented the network diagram constructed based on the data from Table 1. Upon calculating the time parameters for each task, they were added to the network model. The number of weeks required to complete each task was indicated beneath the corresponding arrow (with the time reserves of the tasks shown in parentheses). Tasks and events situated along the critical path were highlighted in red.

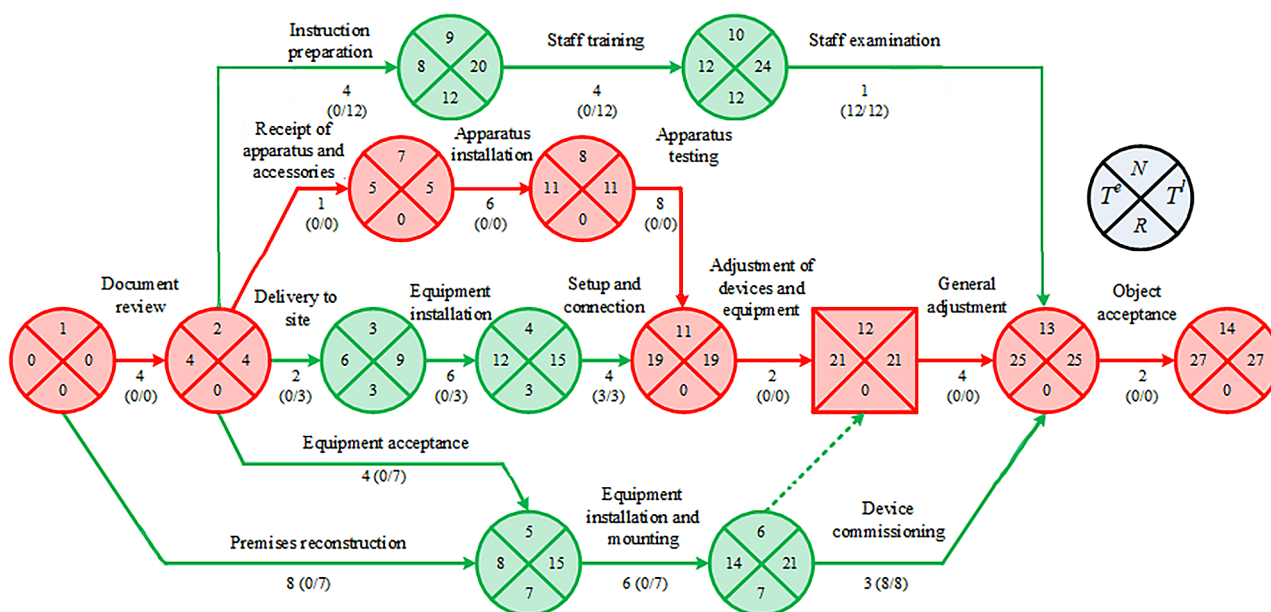


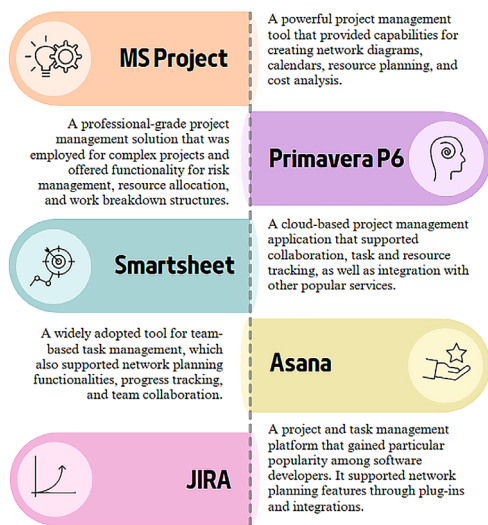
Figure 1. Network diagram of the production unit reconstruction project

Source: constructed by the author

The necessity of employing network diagrams in contemporary project management had been determined by several key factors. The diagrams provided a visual representation of all project tasks, their interconnections, and sequences, which enabled detailed planning and control over project execution. They assisted in the identification of the project's critical path, that is, the tasks that influenced the overall duration of the project, and enhanced understanding of which activities had the most significant impact on project timelines and required particular attention. By means of these diagrams, resources could be allocated more effectively, taking into account their availability and workload. This contributed to the avoidance of conflicts and idle time while optimising resource utilisation. They also facilitated the identification of potential risks and their impact on the project, thereby allowing the development of strategies to mitigate adverse effects and ensure the successful completion of the project. The visual depiction of the project in the form of network diagrams supported a clearer understanding among all project participants concerning its structure, deadlines, and tasks. It also improved communication and coordination within the team and with external stakeholders. These diagrams enabled prompt responses to changes within the project, allowed for necessary

adjustments, and ensured resource redistribution. This was especially important in a rapidly changing business environment. They served as essential tools for documenting the project and preparing reports for stakeholders, contributing to increased transparency and accountability. Project managers received the necessary information for making well-informed decisions regarding resource allocation, execution timelines, and risk management.

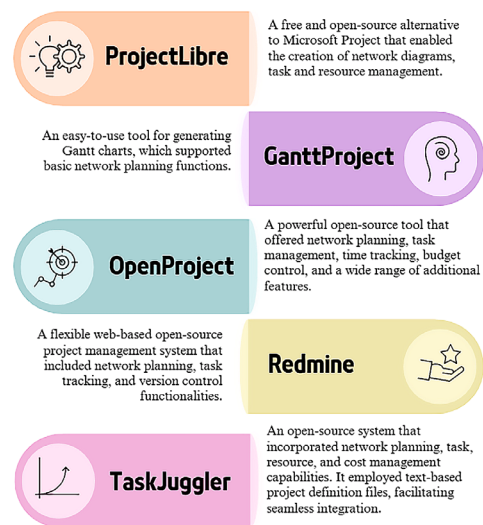
Given the complexity and time consumption associated with building network diagrams, the effective utilisation of software products became increasingly relevant. Such products enabled the tracking of project progress, the timely implementation of corrections, and the control of milestone achievement. Software designed for building network diagrams automated routine tasks, such as schedule updates, recalculations of durations and costs, thereby significantly reducing the workload for project managers. A general overview of the most popular software solutions that could prove beneficial for network planning was presented in Figure 2. In addition to commercial software products, several widely used open-source (free) tools for network planning were identified, which proved beneficial for project management. Their general characteristics were presented in Figure 3.



**Figure 2.** Most popular software products for project management

**Source:** compiled by the author based on: Microsoft Project (n.d.), Oracle (n.d.), Smartsheet (n.d.), Asana (n.d.), Atlassian (n.d.)

Microsoft Project (n.d.) was a widely used tool for project management, providing functionality for planning, monitoring, and controlling tasks, resources, and budgets. The software offered robust planning and scaling capabilities, enabling detailed task scheduling, dependency mapping, Gantt chart construction, and network diagram development, thus allowing a clear visualisation of project progress. Among the drawbacks of MS Project were its complexity for beginners, high resource requirements, and relatively high cost, which could pose a challenge for



**Figure 3.** Most popular open-source software products for project management

**Source:** compiled by the author based on: ProjectLibre (n.d.), GanttProject (n.d.), OpenProject (n.d.), Redmine (n.d.), TaskJuggler (n.d.)

small businesses and individual users. Primavera P6 (n.d.) was considered one of the most popular tools for managing large-scale projects, particularly in the construction, engineering, and energy sectors. It enabled efficient planning, monitoring, and control of project implementation across various stages. The programme supported Gantt chart creation, network diagramming, and critical path analysis. Primavera P6 was specifically designed for large projects involving a substantial number of tasks and resources. However, its limitations included a steep learning curve,

especially for novices. Being a commercial product, Primavera P6 required considerable financial investment for licensing and support. Although powerful, the high cost, complexity, and hardware requirements made it less accessible to some users. Smartsheet (n.d.) combined spreadsheet functionality with Gantt charts, collaboration tools, and process automation features. The software had a user-friendly interface resembling traditional spreadsheets, making it accessible even to those without prior experience in project management. Users were able to work on projects simultaneously, exchange comments, share documents, and view updates in real time, thereby improving team collaboration. It allowed for the creation of Gantt charts, enabling task scheduling and progress tracking. However, Smartsheet was a subscription-based service, which might be costly for some users or small companies compared to other alternatives on the market. For very large projects with hundreds or thousands of tasks, Smartsheet might not offer sufficient scalability or management convenience. Furthermore, as a predominantly cloud-based solution, some functionalities were limited without an Internet connection.

Asana (n.d.) was project and task management software that enabled teams to plan, organise, and monitor progress in real time. The application provided a simple and intuitive interface, which facilitated the creation and organisation of tasks by users, including those with no prior experience. Various organisational methods were available, such as task lists, boards, calendars, and Gantt charts, which allowed the software to be adapted to different working approaches. Teams were able to collaborate concurrently on tasks, exchange comments, attach files, and co-edit plans, which improved team productivity. However, many valuable features, such as Gantt charts, advanced reporting, and additional integrations, were only accessible through paid versions. The software did not include built-in functionality for constructing PERT or CPM diagrams. As with Smartsheet, Asana was primarily a cloud-based application. Jira (n.d.), developed by Atlassian, was designed mainly for software development, testing, and task management in Agile environments. The software offered extensive customisation options, enabling adaptation to the requirements of various teams and projects. It allowed the configuration of workflows, fields, statuses, reports, and other components. Agile methodologies, including Scrum and Kanban, were supported. Owing to its scalability, Jira was suitable for both small and large teams. Nonetheless, the complexity of the software resulted in a steep learning curve. The pricing structure, which was based on the number of users and available features, was relatively high. The functionality for constructing PERT or CPM diagrams was not included. In addition, the extensive range of settings, plugins, and features often led to an interface that appeared overwhelming to new users. Similar to other tools discussed, Jira required a stable Internet connection to function fully.

ProjectLibre (n.d.) was a free alternative to Microsoft Project, offering tools for project management, task planning, and resource allocation. The tool had been utilised across sectors such as business, construction,

IT, and others to visualise work schedules and optimise timelines. It featured an interface similar to MS Project, facilitating ease of adaptation for users with experience in commercial solutions. The software included graphical data representation, enabling straightforward project progress analysis. It supported Gantt charts, Critical Path Method (CPM) analysis, and the management of resources and budgets. It also allowed effective task distribution among teams and tracking of dependencies between project phases. Among the drawbacks were the lack of direct integration with cloud services, the absence of an online version, and a somewhat outdated interface in comparison with MS Project. The application did not support simultaneous multi-user collaboration on a single project, which posed a significant limitation for large organisations. GanttProject (n.d.) was an open-source, free software solution designed for creating and managing Gantt charts used in task planning and tracking within projects. The tool granted unrestricted access to its full range of features and permitted code customisation to meet specific requirements. It provided an intuitive interface, allowing users to quickly create and organise tasks via Gantt chart visualisations. The software supported task-to-resource assignments and resource management. However, GanttProject lacked the scalability required for extensive projects, had no built-in integrations with other widely-used project management tools, and offered limited functionality for generating complex reports or analytics. OpenProject (n.d.) was an open-source tool that supported task management, planning, monitoring, and team collaboration. It offered capabilities suitable for Agile environments, waterfall models, and projects involving numerous dependencies. Key advantages included its free availability and high configurability, allowing it to be tailored to specific organisational needs. The software supported both flexible methodologies (Agile, Scrum, Kanban) and traditional approaches (Waterfall), rendering it a versatile solution for teams employing varied project management styles. It featured robust planning capabilities, including Gantt chart support, task and sub-task creation. Collaborative features were also included, such as task commenting, file sharing, notifications, and integration with external systems. However, it presented challenges in configuration for new users and exhibited limitations in scalability and performance for very large projects. Full customer support was not available in the free version and remained restricted to commercial plans.

Redmine was an open-source project management system that supported multi-functional planning, task tracking, resource management, and integration with other tools. The software could be used free of charge and was customisable to suit specific needs. It proved flexible and adaptable to various project management methodologies, including Agile, Scrum, and Waterfall. It enabled the configuration of workflows, tasks, statuses, and other components. Built-in features allowed for the tracking and management of tasks, including the ability to create subtasks,

assign responsibilities to users, define dependencies, and set priorities. Nevertheless, the tool was associated with a complex interface, limited documentation, the requirement for manual configuration, and constraints when employed by large teams. TaskJuggler (n.d.) adopted a declarative approach to planning, contrasting with conventional Gantt chart-based tools. A Gantt chart represented a visual instrument for project planning and control, depicting tasks as horizontal bars along a timeline. Its key characteristics included graphical representation of processes, identification of task dependencies, monitoring of deadlines, and progress tracking. The core feature of TaskJuggler lay in its automated scheduling of tasks, taking into account dependencies, resource availability, and imposed constraints. Unlike MS Project and similar software, TaskJuggler autonomously calculated the most optimal task schedule under given limitations. The tool also supported critical path calculation and multi-user collaboration. However, it lacked a graphical user interface; Gantt charts were generated automatically in reports but were non-interactive. The need to learn a declarative scripting language made it less accessible for beginners. Additionally, it lacked support for cloud storage or a web-based version.

Project management software provided the essential functionality for efficient project administration, while also

permitting users to customise and expand it in accordance with specific requirements owing to its open-source characteristics. An analysis was undertaken concerning the applicability of one of the most recognised programmes, namely ProjectLibre, by means of a project-based example. ProjectLibre enabled the visual representation of the project in two primary formats: as a Gantt chart and as a network diagram (Figs. 4 and 5). Network-based planning and control methods were predominantly utilised to address complex issues associated with project or workflow management. The central element of this method was the network diagram (also referred to as a chart or model), which depicted the project or the set of activities as distinct tasks segmented into principal phases. This diagram made it possible to determine the optimal execution route for the project through quantitative analysis and, during implementation, facilitated real-time supervision and monitoring of the project's advancement. Contemporary project management processes were observed to be considerably more sophisticated than the mere creation of network diagrams. Nevertheless, the application of diagrammatic tools permitted efficient modifications to project plans, identification of critical paths, monitoring of schedule compliance, and adaptation to evolving conditions and requirements, thereby contributing to the overall improvement of managerial effectiveness.

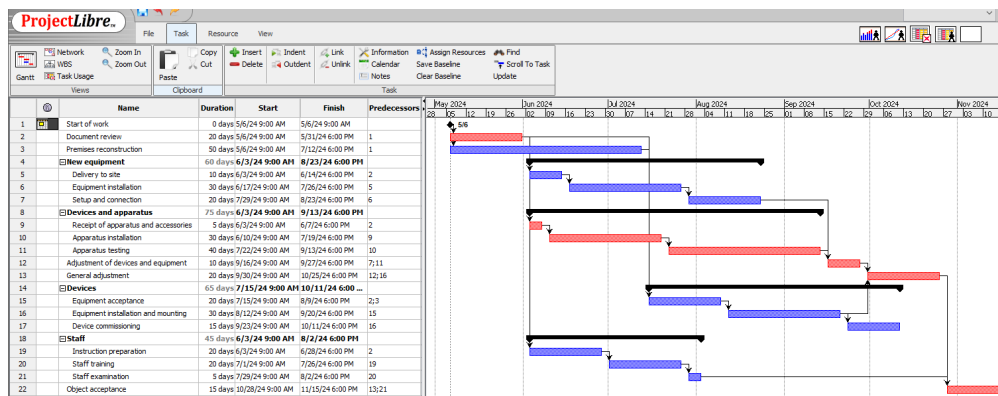


Figure 4. Gantt chart of the production unit reconstruction project

Source: developed by the author using ProjectLibre (n.d.)

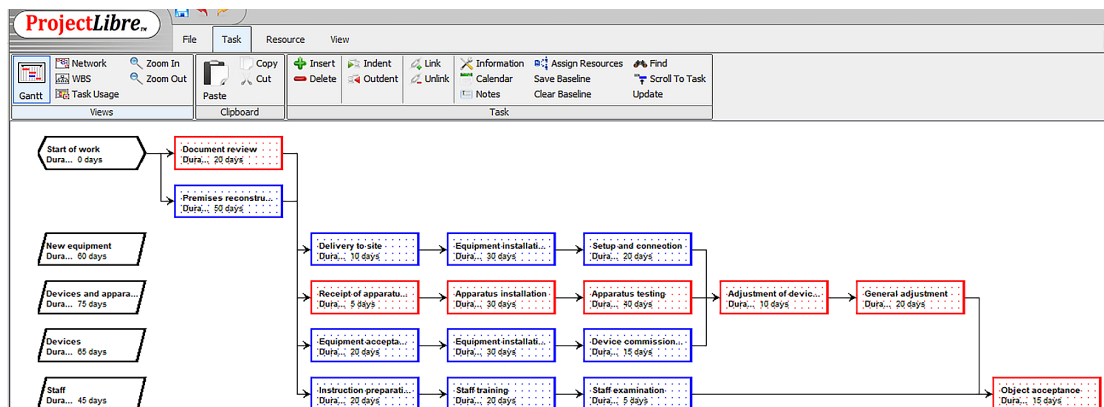


Figure 5. Network diagram of the production unit reconstruction project

Source: developed by the author using ProjectLibre (n.d.)

Project management has faced numerous challenges associated with delays in task execution, budget overruns, and discrepancies with initial schedules. These issues have been particularly prevalent in the construction sector, where task dependencies, resource constraints, and uncertainty have played a decisive role in the success of projects. Traditional planning methods, such as Gantt charts, have failed to account for the complex interdependencies between work phases and have proven inadequate for effectively forecasting delay-related risks. In this context, network planning methods, notably PERT and CPM, have acquired particular significance. The PERT (Programme Evaluation and Review Technique) method was employed for analysing and estimating project completion time by modelling the dependencies between tasks. The method relied on a probabilistic approach, calculating task durations based on three estimates: optimistic, most likely, and pessimistic. The CPM (Critical Path Method), in contrast, was used to identify the longest sequence of interdependent tasks (the critical path), which determined the minimum time required for the overall project completion.

The application of these methods has proven essential for ensuring the efficiency of project planning, optimising resource allocation, and minimising risks, thereby rendering them indispensable tools in the management of complex projects. To compare the results obtained, reference was made to contemporary research in the field of project management, as well as to the practical experience of implementing network planning in various types of projects. The International Project Management Association (IPMA), which brought together project management associations from various European countries, had been established in Europe as early as 1967. In the United States, the Project Management Institute (PMI) was founded in 1969 with the objective of improving project management practices. PMI initiated the development of the Project Management Body of Knowledge (PMBOK), which defined standards and practical guidelines. It encompassed five core process groups: Initiating, Planning, Executing, Monitoring and Controlling, and Closing (Project Management Institute, 2021).

The economic environment was marked by rapid and unpredictable changes, driven by a variety of factors including globalisation, digitalisation, technological progress, the implementation of artificial intelligence, and crises of different scales. These factors represented key characteristics of the Fourth Industrial Revolution, which had profoundly reshaped all dimensions of production, business, and societal functioning on a global scale. The integration of quantum computing and communication technologies significantly altered traditional approaches to project management (Cabeças & Marques da Silva, 2021). The conventional model of the “triple constraint” (time, cost, scope) evolved into frameworks that additionally incorporated considerations of social responsibility, environmental sustainability, and resilience. The achievement of success in project management increasingly depended on the ability to respond promptly to changes and

to introduce innovation. Tools such as artificial intelligence, process automation, and data analytics contributed to the enhancement of operational efficiency and the mitigation of risks. Modifications were also identified within the methodological and conceptual framework of project management (Pilyukov, 2024). Diverse models of the project life cycle and related methodologies – including CPM/PERT, WBS, and CPA – as well as internationally recognised standards such as ISO and the PMBOK Guide, were subject to ongoing development and refinement.

In project management, alongside classical approaches such as PRINCE2 and Waterfall, which have been oriented towards clearly structured processes and sequential task execution, flexible methods – Agile frameworks including Scrum, Kanban, and Lean – have been actively evolving to ensure adaptability, self-organisation, and rapid responsiveness to change (Bokovets & Zaiats, 2022). The most well-known network planning techniques in project management have included the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM). Both methodologies were developed in the mid-twentieth century. The PERT method was introduced by the United States Navy in collaboration with the consulting firm Booz Allen Hamilton for the management of the Polaris missile project (Watt, 2014). The CPM method was created by leading engineers Morgan R. Walker and James E. Kelley while working at DuPont, for the purpose of scheduling and monitoring the progress of tasks (Kelley *et al.*, 1989).

The Critical Path Method (CPM) has been employed in the development of Gantt charts, which represent task sequences as horizontal bars along a timeline. These charts have enabled the clear visualisation of schedules, task sequences, durations, and interdependencies. Research conducted by Y. Novak *et al.* (2023) confirmed the effectiveness of Gantt charts in constructing a hierarchical structure of tasks and monitoring project implementation. The authors demonstrated that the use of network diagramming techniques contributed to the optimal establishment of relationships between individual project operations. Both approaches enabled the monitoring of actual task execution against planned timelines, thereby allowing for timely adjustments in the event of deviations. The conducted analysis indicated that combining these methods not only facilitated the tracking of real-time progress, but also enhanced the capacity to respond promptly to potential delays, contributing to successful project delivery. The effectiveness of integrating Gantt charts with CPM was objectively validated by S. Lee & O.A. Shvetsova (2019) in their study of technology transfer processes within the automotive industry. The findings showed that the combination of these methodologies improved planning and management of technology transfer projects, thus supporting sustainable development in a global context. The critical path and operational floats in the network diagram optimised the scheduling of technology transfer, enabled the identification of bottlenecks, and facilitated targeted resource allocation to resolve issues – ensuring adherence

to project timelines and budgets. The study conclusively demonstrated that applying the CPM technique within a network diagram allowed for the identification of the longest sequence of dependent tasks, which defined the overall project duration.

The suitability of the PERT method for constructing a network diagram, identifying the critical path, calculating the expected project completion time, and assessing the probability of meeting deadlines was substantiated by N.P. Akpan & G.O. Agadaga (2020). Their study was based on a real case involving the reconstruction of a building at 48 Forces Avenue in Port Harcourt, Nigeria, implemented by Mega Star Technical and Construction Company. The authors provided a justified rationale for the application of this method in the management of both large-scale and small-scale projects, aiming to ensure accurate time estimations and enhance the likelihood of project completion within defined deadlines. The findings reinforced the relevance of PERT as a reliable technique for improving time forecasting and schedule adherence across various project scopes.

Researchers H.A. Ba'Its *et al.* (2020) also substantiated the necessity of applying the PERT and CPM methods for the optimisation of construction project planning, highlighting the limitations of Gantt charts. The study confirmed that the integration of PERT and CPM significantly enhanced construction planning by providing greater flexibility and accuracy in deadline forecasting. These methods facilitated the identification of critical stages requiring special attention in order to avoid delays. The research further demonstrated the advantages of modern project management methodologies in improving construction efficiency.

Researcher A.A. Hlushenkova (2024) conducted an analysis of the fundamentals of project management under conditions of digital transformation. The role of digital tools in time management, resource allocation, project team coordination, scientific research, engineering development, and risk management was examined. The key risks associated with digital transformation were identified, including technical difficulties, cybersecurity threats, and inadequate legislative regulation. The study demonstrated that digitalisation facilitated process automation, improved productivity, and contributed to the success of innovative projects in a dynamic market environment. Digital transformation was recognised as a key success factor, ensuring flexibility, efficiency, and enterprise competitiveness. It was concluded that the utilisation of digital tools enabled process automation, cost reduction, and increased project team productivity.

Authors M. Slabinoha & T. Mykhailov (2023) explored the application of expert estimation methods for forecasting the duration of IT projects. Particular attention was paid to the issues of overestimation and underestimation of tasks, which remained common in software development. The primary research method involved case analysis comparing traditional single-point estimation with the PERT estimation technique. It was reasoned that expert

estimations, although based on professional judgement, were susceptible to cognitive biases. Issues arose due to subjectivity and insufficient experience, potentially leading to inaccurate assessments of task durations, as evidenced by IT project management practice. In contrast, the PERT method assisted in mitigating these issues by offering a range of estimates, including the best-case, most likely, and worst-case scenarios. It proved to be a more effective tool for forecasting task durations, offering flexibility and enhanced precision. The use of the expected value formula contributed to improved accuracy. Minimisation of subjectivity and the implementation of advanced estimation techniques reduced the risk of deadline and budget overruns, thereby improving project outcomes and stakeholder satisfaction.

In the study conducted by I.P. Zasukha (2021), an enhancement of project management methods for digitalisation was proposed through the utilisation of stochastic networks, particularly the GERT (Graphical Evaluation and Review Technique) networks, which were considered more complex compared to deterministic networks such as PERT and CPM. GERT networks enabled the analysis of multiple variants of interconnections between events within a single network and allowed flexible selection of project development paths during implementation, differing from those predefined. Particular importance was placed on accounting for alternative activities within the network, especially in cases where the project description was of a stochastic nature. It was demonstrated that PERT and CPM methods remained limited when modelling projects characterised by randomness.

The study on the specifics of IT project management using the Agile methodology, conducted by O. Khrapkin *et al.* (2023), demonstrated the appropriateness of applying the following free tools: KanbanTool, Pipefy, Wrike, Yodiz, and Zoho Sprints. However, the use of these tools proved ineffective for managing projects through PERT and CPM methods. The authors also highlighted the potential of using commercial applications such as Ayanza, Trello, ClickUp, Notion, Asana, Microsoft Project, Wrike, Basecamp, Hive, Project Planner, and Jira. Nevertheless, not all of the listed tools supported network planning capabilities.

The researchers I. Martyniak & I. Bakushevych (2024), in their study on hybrid project management models under conditions of sustainable development and the digital economy, analysed the characteristics of project management associated with the simultaneous implementation of sustainable development principles and the concept of the digital economy. Changes in approaches to project management within the economy were identified, particularly concerning the application of hybrid models that integrated both traditional and modern methods to achieve efficiency under digitalisation and sustainability conditions. Due to the rapid development of technologies, a continuous renewal of knowledge regarding new software products, which could significantly enhance the effectiveness of project planning and management, was necessitated.

The justification for assessing project management maturity was reflected in the academic work of L. Batenko *et al.* (2020). Particular attention was given to addressing this issue for small enterprises in Ukraine, which often neglected professional project management methods. Based on an analysis of existing maturity models, the researchers proposed an original simplified model for assessing project maturity, which allowed the current development level of the project management system to be determined using 24 indicators. The proposed model underwent pilot testing at six small enterprises and demonstrated its effectiveness in improving the quality of project implementation. The results of the conducted study confirmed the conclusions of numerous scholars. The PERT method indeed helped to partially mitigate issues associated with the use of expert estimates, which were often subject to cognitive biases. The subjectivity and limited experience of experts could result in overestimation or underestimation of task durations. The PERT method incorporated three estimates (optimistic, likely, and pessimistic), which allowed the influence of subjectivity to be smoothed and the accuracy of forecasts to be improved.

The analysis of the network diagram constructed using ProjectLibre showed that the CPM method helped to identify the longest sequence of tasks in the network diagram, which determined the total duration of the project. This enabled the identification of the most critical tasks affecting project deadlines; the detection of potential problem areas that could cause delays; and the optimisation of resource allocation to accelerate the execution of important tasks. Time reserves accounted for uncertainty in task execution and made it possible to minimise risks, which allowed: the reduction of delay likelihood at critical points of the project; a flexible response to unforeseen changes without violating the overall schedule; and the optimisation of budget and resource usage by directing them to problematic tasks. Overall, the application of the critical path and operational reserves in the network diagram proved to be an effective project management approach, as it ensured adherence to timelines and budgets. Gantt charts provided a visual representation of the work structure and enabled task execution to be monitored according to the schedule. The combined use of Gantt charts and network diagrams allowed not only the monitoring of actual progress but also the prompt identification and correction of deviations, which contributed to the successful completion of the project.

## ■ Conclusions

The primary methods that ensured effective network planning, monitoring, and execution of projects, while enabling sequential tracking of implementation stages and optimisation of their duration, when necessary, were the PERT and CPM methods. The analysis conducted indicated that the choice of project management software depended on several key factors: project scale, team structure, industry domain, and the specific nature of business processes. For companies managing large, long-term projects, Microsoft

Project or Primavera P6 were found to be the most suitable options. When flexibility and ease of use were required, Smartsheet or Asana were recommended. For Agile teams and software development, Jira remained the leading solution. Despite significant advantages, each of the reviewed tools had certain limitations. MS Project, Primavera P6, and Jira were commercial products, and their cost represented a considerable barrier for small businesses and individual users. These tools offered extensive functionality, but at the same time were time-consuming to master, particularly for beginners. Smartsheet and Asana operated on a subscription basis, restricting full functionality access. Moreover, while convenient, they proved less effective for very large projects, as they lacked sufficient flexibility and advanced resource management features. Smartsheet, Asana, and Jira were cloud-based solutions, making their performance dependent on stable internet connectivity. Asana, Jira, and Smartsheet did not include built-in support for critical path calculation or network diagram construction.

The free project management tools examined in the study also demonstrated a wide range of capabilities. ProjectLibre was a powerful free alternative to MS Project, though it lacked an online version and cloud integrations. GanttProject was well-suited for basic project planning but did not provide scalability or advanced analytics. OpenProject combined both traditional and Agile approaches, offering flexible configuration and collaborative features; however, scalability remained limited. Redmine offered a flexible solution for Agile project tracking and integration with other systems but featured a complex interface and required extensive setup. TaskJuggler stood out for its automatic scheduling and critical path calculations, though the absence of a graphical interface and its complexity in use rendered it less accessible to a wider user base. These tools were effective free alternatives to commercial solutions such as MS Project or Primavera P6 and could be employed for both simple and complex projects. OpenProject proved to be the most feature-rich free tool, supporting Agile, traditional methods (Waterfall), Gantt charts, CPM, team collaboration, and a cloud-based version. However, it required more complex configuration, and some features were available only in the paid version. For offline use requiring powerful planning capabilities, ProjectLibre was identified as the optimal choice.

Promising areas for further research included the application of artificial intelligence for automating critical path calculations, forecasting task completion times, and assessing time-related risks. It was also deemed important to explore the potential of cloud technologies, which could facilitate access for all project participants and support the analysis of large data volumes. Additional attention should have been given to the use of quantum computing and visual technologies to improve project management processes.

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■ **Conflict of Interest**

None.

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## Методи сітьового планування в управлінні проєктами: огляд програмних продуктів

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■ **Анотація.** Україна переживає складний період економічної нестабільності, що впливає на різні галузі економіки. Через військові дії і руйнування інфраструктури виникає необхідність швидкої та ефективної реконструкції. Методи сітьового планування допомагають оптимізувати ресурси та мінімізувати витрати, що актуально в умовах обмеженого фінансування, дозволяють координувати чисельні проєкти і забезпечують їх своєчасне виконання, сприяють більш чіткій координації між різними етапами проєкту, що зменшує ймовірність помилок і затримок. Метою статті був аналіз методів сітьового планування в управлінні проєктами, вивчення їх основних переваг і недоліків, обґрунтування доцільності використання різних програмних продуктів з управління проєктами в умовах економічної нестабільності та невизначеності. В статті проведено аналіз двох основних методів сітьового планування – Program Evaluation and Review Technique (PERT) та Critical Path Method (CPM). Побудовано сітьову діаграму проєкту реконструкції виробничого підрозділу. Доведено, що завдяки чіткому плануванню, оптимізації ресурсів та ефективному управлінню ризиками, вказані методи сприяють підвищенню загальної ефективності реалізації проєктів, що є надзвичайно важливим для підвищення конкурентоспроможності українських підприємств. В статті доведено, що доцільність застосування методів PERT і CPM в управлінні проєктами обумовлена їх здатністю забезпечувати ефективне планування, контроль і управління ресурсами. Розвиток інформаційних технологій відкрив нові можливості для впровадження автоматизованих систем керування проєктами. Встановлено, що методи сітьового планування легко інтегруються з сучасними програмними засобами, підвищуючи ефективність управління проєктами. Проведено огляд основних програмних продуктів та вивчено можливості їх використання для побудови сітьових діаграм. Застосування методів сітьового планування в умовах України є необхідним для ефективного управління проєктами, оптимізації ресурсів і підвищення конкурентоспроможності країни

■ **Ключові слова:** сітьова діаграма; діграма Ганта; метод критичного шляху; метод оцінки та перегляду програм; оптимізація

## Social entrepreneurship as a direction for the development of entrepreneurial initiatives by war veterans in Ukraine

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■ **Abstract.** The relevance of the issue of entrepreneurship development for improving employment and the overall economic situation, supporting categories of citizens who need special protection from the state in wartime (in particular, war veterans and their families), and solving important social problems – all this determines the need for social business development in the context of stimulating entrepreneurial initiatives among war veterans. The scientific article was devoted to identifying the theoretical and practical aspects of the development of social entrepreneurship among war veterans in the context of their professional adaptation to civilian life in Ukraine. As a result of the study, the key features of social entrepreneurship as a direction for the development of entrepreneurial initiatives of war veterans were highlighted, an overview and assessment of current trends in the functioning of social business in Ukraine was conducted, and the prospects for the development of social entrepreneurship among war veterans in Ukraine were determined. Based on the theoretical justification of the essence of social entrepreneurship, its key features in the context of the development of veteran business were identified: a clear social orientation, the implementation of the principle of social responsibility, an innovative orientation, and the synergistic effect of combining the processes of professional adaptation of war veterans and the development of social entrepreneurship initiatives. Obstacles to the development of social business among war veterans were identified, including: problems with attracting financial resources, a lack of knowledge and information in the process of starting a business, and the problem of legislative consolidation of social entrepreneurship and veteran business. Promising areas for the development of social entrepreneurship among war veterans were identified, including: regulatory and legal, financial and economic, educational, and information and consulting. The practical value of the study was consisted in the development of recommendations and the identification of areas for the development of social entrepreneurship among war veterans, taking into account the realities of wartime in Ukraine

■ **Keywords:** veteran business; social business; professional adaptation; business initiatives; veteran policy

### ■ Introduction

The conditions for the functioning of the economy and the social sphere are characterised by an intensification of negative trends associated with the start of the full-scale Russian-Ukrainian war in 2022. These include rising unemployment and a growing imbalance between labour supply and demand in the labour market, a deterioration in household welfare, an increase in the number of Ukrainian citizens living below the poverty line, a decline in real incomes, rising inflation and depreciation of the national currency, the loss of labour and intellectual potential due to an increase in the number of emigrants, the internal

displacement of citizens to safer places, and negative demographic trends and processes (increased mortality, declining birth rates, ageing population, deterioration in the quantitative and qualitative structure). A separate problem is the issue of supporting those categories of citizens who need special protection in conditions of martial law – war veterans and their families. They are the ones who need help in reintegrating into civilian life, which requires professional, psychological and medical rehabilitation, as well as information and counselling assistance in resolving pressing issues facing war veterans and their families.

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The development of veteran entrepreneurial initiatives is not only an important priority for ensuring their professional reintegration, but also a tool for future economic recovery through the strengthening of economic activity and the development of small and medium-sized businesses as the basis for the stable functioning of the economy in the future. In the context of martial law and the prospect of Ukraine's post-war recovery, it is advisable to prioritise social entrepreneurship, which will become a leading factor in ensuring social security and the well-being of citizens, a source of solutions to pressing social problems, improving employment and filling the revenue side of the state budget by increasing tax revenues (Kadakure & Twum-Darko, 2024). Achieving a synergistic effect from the combination and development of two extremely important components – veteran business and social entrepreneurship – is of particular importance in this area. S. Bacq & E. Alt (2018), S. Teasdale *et al.* (2023) noted that the phenomenon of social entrepreneurship lies in taking into account the innovative component of business development. This is also mentioned in the work of P. Dickel & G. Eckardt (2020), whose research is devoted to highlighting the values of social entrepreneurship, taking into account relevant business models and strategies. Researchers Z. Xu *et al.* (2022) and F. Koehne *et al.* (2022) concluded in their work that social entrepreneurship, which combines the desire to solve social problems with market instruments, cannot be completely deprived of economic and social value.

The work of A.D. Berger (2020) provides a definition of the categorical apparatus in the field of social entrepreneurship. Particular attention is paid to the existing structures of business models used in the process of conducting social business and to defining the fundamental differences between social entrepreneurs and entrepreneurs who focus their activities on making a profit. Researchers V.P. Gorin & V.M. Bulavynets (2021), in addition to highlighting the theoretical aspects of social entrepreneurship, identify the prospects for stimulating the development of social business, arguing that despite the underdevelopment of the institutional environment, social entrepreneurship has a number of advantages, is an alternative to budgetary financing for meeting social needs, and contributes to the formation of social welfare. The work of authors H.M. Zavadskykh & V.M. Tebenko (2020) highlights the peculiarities of social business development from a practical point of view. In particular, it is determined that the main tasks in the process of developing social entrepreneurship in Ukraine are to improve the regulatory and legal framework, develop special programmes for lending and loan guarantees for organising and running one's own business, and promote social entrepreneurship among the population.

The problems of entrepreneurship development in conditions of economic and social instability were studied by T.V. Omelianenko & K.O. Korotkova (2020). They found that there are exogenous and endogenous factors that influence the development of entrepreneurship in Ukraine. Among the exogenous factors, the authors note the imperfection

of the tax system, economic instability and imperfect legislation, the lack of an effective mechanism for state support of small businesses, market monopolisation, corruption and bureaucracy. At the same time, endogenous factors include insufficient material and technical support for enterprises, ineffective management decisions, and the combination of several types of activities within a single small enterprise. The aim of the scientific article was to determine the theoretical and methodological foundations and develop practical recommendations for the development of social entrepreneurship among war veterans as a direction for their professional adaptation to civilian life in Ukraine.

## ■ Materials and Methods

The theoretical and methodological basis of the study was provided by fundamental aspects of modern economic knowledge on the development of social business, scientific works by scholars on social entrepreneurship and veteran business. The study used the method of analysis of scientific sources to identify the characteristics of social entrepreneurship. The works of A.Yu. Ramskyi (2023) and V. Kifiak & L. Malysh (2020) were analysed, which made it possible to identify the characteristic features of social enterprises. To study the current trends in the development of social entrepreneurship in Ukraine, the research of L.O. Valus (2023) was analysed. In order to study the characteristics of social business in the context of fulfilling a social mission and solving priority problems of society (employment of socially vulnerable categories of citizens, ensuring an effective institutional environment for the development of local communities, solving environmental issues, promoting a healthy lifestyle), the work of H.M. Zavadskykh & V.M. Tebenko (2020).

Among the general scientific methods used were analysis and synthesis, induction and deduction in the process of developing the scientific and theoretical basis and formulating conclusions and author's proposals. Generalisation and systematic analysis were developed in the course of systematising scientific approaches to highlighting the theoretical aspects of social entrepreneurship and veteran business. The classification and analytical method was used to substantiate the peculiarities of social entrepreneurship in the context of the development of veteran business. The comparative analysis method was used to assess current trends in the development of social entrepreneurship. In particular, the differences in the manifestation and functioning of social entrepreneurship and corporate social responsibility were analysed, and obstacles to the development of social entrepreneurship were identified, taking into account the peculiarities of the activities of social enterprises in modern conditions (in particular, data on the distribution of social businesses by type of activity and sources of financial resources). The prospects for social entrepreneurship in the context of developing entrepreneurial initiatives among war veterans were substantiated using the abstract-logical method and the method of systematic generalisation. As a result, problems were identified in the

process of attracting financing, a lack of knowledge and information regarding the development of entrepreneurial initiatives, as well as the legislative consolidation and regulatory framework for social business in the context of veteran entrepreneurship. In addition, the application of the above methods made it possible to substantiate promising areas for the development of social business among war veterans and their families.

The study included a content analysis of key regulatory and legal acts, in particular Draft Law of Ukraine No. 2710 (2015) and Draft Law of Ukraine No. 10258 (2023). The analysis made it possible to identify the main legislative approaches to defining the status of social enterprises, the principles of state veteran policy, and tools for supporting veteran businesses. Particular attention was paid to the policy documents of the Cabinet of Ministers of Ukraine (Veteran's Assistant ..., 2023, The government has approved the veteran policy strategy ..., 2024, Strategy for the formation of a system ..., 2024), which were identified as strategic guidelines for policy formation in the field of veteran entrepreneurship. The data obtained formed the basis for the construction of an analytical model of state support for veteran entrepreneurial initiatives.

## ■ Results and Discussion

According to estimates by experts and researchers, after the end of hostilities and the end of martial law in Ukraine, more than 4 million war veterans and their families will need special assistance and support from the state (Veteran's Assistant ..., 2023). In order to improve the effectiveness of the state support system for war veterans, work is underway to develop a whole range of policy and regulatory documents to facilitate the process of adaptation of demobilised military personnel and their families to life outside military service. At its meeting on 29 November 2024, the Cabinet of Ministers of Ukraine adopted the Veteran Policy Strategy for the period up to 2030 and approved a plan of measures for its implementation for 2024-2027. The strategy defines three strategic objectives, including: restoring the human capital and well-being of veterans and their families, respect and honour, and ensuring national security and defence capability. Objective No. 1 (restoring human capital and well-being) provides for the coordination of state veteran policy, the activities of service providers for veterans, ensuring the accessibility of services for the target audience; restoring and supporting the physical and mental health of veterans; supporting the families of war veterans, family members of deceased (deceased) Defenders of Ukraine (hereinafter referred to as family members); economic independence; state guarantees. Goal No. 2 (respect and honour) defines the need to form a social culture and conduct appropriate events aimed at ensuring respect for veterans, as well as honouring deceased veterans. Goal No. 3 (ensuring national security and defence capability) provides for the protection of the interests of veterans (combatants) and their family members during military service, including during service in the military reserve, the

participation of veterans and their family members in the preparation of national resistance (The government has approved the veteran policy strategy ..., 2024).

The development of veteran businesses is in line with strategic objective No. 1 in the context of economic independence and well-being for combatants, war veterans and persons with war-related disabilities. Another important policy document is the Strategy for the formation of a system of transition from military service to civilian life for the period up to 2032 (2024). It defines the priority goals and objectives, expected results from the process of socio-economic reintegration of war veterans and their families through the provision of social services, psychological assistance, medical and physical rehabilitation, professional adaptation and integration into civilian life. In 2021, work began on developing a strategy for the development of entrepreneurial initiatives for war veterans until 2030, The aim of this strategy is to ensure favourable conditions for encouraging the establishment and development of entrepreneurship among war veterans and to increase its competitiveness in order to solve the problem of reintegrating veterans into civilian life and to contribute to the achievement of Ukraine's sustainable development goals. The importance of this policy document lies in the fact that, among other areas, the strategy defines the improvement of the regulatory and legal framework for the development of entrepreneurial initiatives among war veterans and the promotion of veteran businesses in domestic and foreign markets (Draft strategy for the development of entrepreneurial initiatives..., 2024).

K. Bondarevska (2023) determined that a distinctive feature of the new veteran policy in Ukraine is its focus on establishing institutional foundations for the provision of high-quality services and the corresponding infrastructure, stimulating economic activity through the development of veteran businesses, and a number of other important areas (medical rehabilitation, providing opportunities for affordable housing and land plots, and honouring the military's achievements). It should be noted that the issue of developing entrepreneurship among war veterans and their families falls within the competence of both state and non-state structures. It is precisely because of this fact that the process of forming an effective mechanism for the development of veteran entrepreneurship is only possible through the joint interaction of the state, non-governmental institutions, and infrastructure entities, with the mandatory involvement of international support and the implementation of global experience.

Social entrepreneurship successfully combines the advantages of entrepreneurial activity, the professional fulfilment of war veterans and the resolution of pressing social issues. The fundamental difference between this type of business and other forms of entrepreneurial activity is its focus on achieving clearly defined social goals. Social entrepreneurship, like other types of business activity, is an important source of tax revenue, a tool for creating new jobs and restoring the economy in the long term.

Social entrepreneurship fulfils an important social mission, which, in addition to the above, contributes to social development, restoration and preservation of human potential through the realisation of needs for employment, improvement of material conditions, professional self-realisation, acquisition of new skills and experience.

At the same time, it is necessary to distinguish between the concepts of “social entrepreneurship” and “corporate social responsibility” (CSR). The main difference is that a social enterprise has a clear social orientation aimed at achieving a specific social goal. Meanwhile, when implementing the principles of corporate social responsibility, voluntary deductions from the profits of a business entity for social purposes are envisaged. It is appropriate to define social entrepreneurship as entrepreneurial activity aimed at implementing a clearly defined social mission and achieving social goals in the context of satisfying both the material and non-material needs of society. A similar point was made in a study by A.Yu. Ramskyi (2023), which defined social entrepreneurship as entrepreneurial activity aimed at solving social problems and contributing to the satisfaction of society’s needs. It can be said that social entrepreneurship is a unique opportunity to combine a social mission with the desire to earn money, provide a range of services and/or sell goods.

According to V. Kifiak & L. Malysh (2020), a social enterprise is a complex category that, on the one hand, defines the mission and direction of the enterprise and, on the other hand, the nature of business processes. In other words, social entrepreneurship is a new approach to the functioning and activities of both for-profit and non-profit organisations. Based on the theoretical justification of the essence of social entrepreneurship, it is advisable to identify

its key features, particularly in the context of the development of veteran businesses. These include: a clear social focus (solving social problems in society while achieving the social mission of reintegrating war veterans into civilian life); implementation of the principle of social responsibility, taking into account the prospects for improving the socio-economic situation in the country and post-war recovery; an innovative focus in the context of developing and implementing the latest approaches and tools in the process of conducting socially oriented entrepreneurial activities; the synergistic effect of combining and developing two extremely important components: the professional adaptation of war veterans and the development of socially oriented entrepreneurial initiatives.

In the work of L.O. Valus (2023) it was indicated that there are more than 1,000 organisations in Ukraine that can be classified as “social businesses” based on various criteria. From 2018 to 2024, the number of social enterprises grew by 82% (Social entrepreneurship in Ukraine..., 2020). The mission of the vast majority of social businesses in Ukraine belongs to the social sphere. This includes employment of socially vulnerable categories of citizens, creation of a favourable environment for the development of local self-government and local communities, promotion of a healthy lifestyle, and solving environmental problems. Social enterprises pursue their mission through various means and tools, including: selling their own products and providing social services, supporting projects in the social, sports, health, cultural and other spheres of activity, and providing jobs for people with disabilities and other socially vulnerable groups (Zavadskykh & Tebenko, 2020). At the same time, a single social enterprise may engage in various types of activities (Table 1).

**Table 1.** Results of the distribution of social enterprises by type of activity in 2020

| Types of activities                                      | Share of social enterprises (%) |
|--|---------------------------------|
| Employment of socially vulnerable categories of citizens | 35                              |
| Generating the profit for the organisation               | 24                              |
| Generating the profit for the service provision          | 19                              |
| Financing the certain types of services                  | 14                              |
| Solving the environmental problems                       | 8                               |

**Source:** developed by the author based on Social entrepreneurship in Ukraine: Economic and legal analysis (2020)

The structure of social enterprises’ activities demonstrates a focus on addressing priority social issues through the active involvement of vulnerable groups in economic activities. This indicates the organisations’ desire to combine their social function with elements of economic independence. At the same time, less attention is paid to areas such as environmental responsibility or the provision of certain services, which may be a consequence of both limited funding and insufficient institutional support for relevant initiatives. The ratio between these types of activities indicates the dominance of short-term, practically oriented strategies over more comprehensive approaches to sustainable development. This situation highlights the need to expand support tools that would stimulate

the diversification of social entrepreneurship activities. The main ways of reinvesting profits from social business activities can be identified as follows: directing profits from activities to social goals (only a certain percentage is directed to the functioning/development of the business); partial reinvestment (only part of the profits are reinvested in social goals), which is more common for public and charitable organisations, in which case there is a combination of economic and social components; full reinvestment of profits from activities into the expansion of activities (a particularly common type of reinvestment for enterprises founded by persons with disabilities or other socially vulnerable categories of citizens) (Bondarevska, 2024).

75% of the funding for social enterprises comes from their own resources, 15% from grants and sponsorship contributions, and 10% from credit resources (Social entrepreneurship in Ukraine..., 2020). Business entities operating in the social business sector in Ukraine are financed by a regional fund, which is funded by the United States through the services of the United States Agency for International Development (USAID) Western NIS Enterprise Fund (WNISEF). Loans under the programme are provided at an interest rate of 5% to 10% per annum, with priority given to social businesses whose main focus is helping people affected by the war in Ukraine (like internally displaced people, people with war-related disabilities, low-income families, etc.) (Ukraine-Moldova American Enterprise Fund, n.d.).

It should be noted that there are a number of obstacles to the development of social entrepreneurship among war veterans. In addition to the problem of attracting financial resources, there is a lack of knowledge and information in the process of starting a business. According to the results of the national survey "The Needs of Veterans 2023", conducted on the initiative of the Ukrainian Veterans Fund, 63.6% of respondents among war veterans would like to engage in entrepreneurship, which indicates the importance of the need to develop entrepreneurial initiatives (The needs of veterans..., 2023). It is becoming increasingly important to train military personnel who have completed their military service in the basics of entrepreneurial activity, grant writing and the specifics of business planning. In 2023, the Ministry of Veterans Affairs of Ukraine launched the "Veteran's Assistant" project, which aims to help veterans adapt to civilian life and professional realisation by forming a new category of employees from among veterans and their family members who, based on the principle of "equal to equal", will help, inform and advise on social, economic, medical and other issues after the end of military service. The pilot project was launched in the summer of 2023 in the Dnipropetrovsk, Vinnytsia, Lviv and Mykolaiv regions, and in autumn 2023, local communities in Zakarpattia, Kyiv, Sumy, Poltava, Kharkiv regions and the city of Kyiv joined it (Veteran's Assistant..., 2023). In 2024, this project was transformed into a system for training and employing specialists to support war veterans and demobilised persons, who interact with veterans and demobilised military personnel after their return from the front in the form of individual support, initial counselling and comprehensive support for integration into civilian life. The relevant professional standard has already been updated and entered into the classification register. Training of specialists takes place at veteran development centres.

In the Dnipropetrovsk region, the function of training war veterans and their family members who work or plan to work as support specialists is performed by the Veteran Development Centre at the University of Customs and Finance. It provides professional training for veterans' assistants and, now, for specialists in supporting war veterans and demobilised persons, covering all aspects of case

management in supporting war veterans and demobilised persons, which enables them to carry out their professional activities. The main areas of the training programme include social and legal protection of war veterans, demobilised persons and their families, case management in working with war veterans, demobilised persons and their families, adaptation of war veterans and demobilised persons to life in the local community, professional documentation and reporting, and psychosocial support for war veterans, demobilised persons and their families. Among the important areas of training, a prominent place is given to familiarising war veterans with business financing opportunities and the specifics of starting their own business, grant programmes at both the national and international levels, and the regulatory and organisational foundations of doing business. Specialists supporting war veterans will be able to pass on all this knowledge to their clients in the course of their work, providing relevant information and advisory support on a peer-to-peer basis. Following the training of specialists in supporting war veterans and demobilised persons, successful training was conducted for specialists already working at the Administrative Service Centres and local government bodies of the territorial communities of the Dnipropetrovsk region (University of Customs and Finance, 2023).

Attention needs to be paid to resolving the issue of establishing a legislative framework for the development of veteran entrepreneurship, particularly in the social sphere. In Ukraine, an attempt was made to legislate social entrepreneurship by developing a draft law that defines this concept. According to Draft Law of Ukraine No. 2710 (2015), social entrepreneurship is a business entity whose priority is to achieve social goals and results, in particular in the medical and educational spheres, in the fields of science, culture, environmental protection, the provision of social services and social support to vulnerable groups of the population (people with disabilities, the poor, the unemployed, the elderly, internally displaced persons, etc.). At the same time, it is important to declare state support for social enterprises: tax incentives, incentives for investment activities, land issues, financial assistance, loans, support in placing state orders and implementing state target programmes, employment of socially vulnerable categories of citizens, etc. It should be noted that the above-mentioned draft law is still under consideration, similar to Draft Law of Ukraine No. 10258 (2023), which defines veteran entrepreneurship as independent, proactive, systematic, and risk-bearing economic activity carried out by veteran entrepreneurs with the aim of achieving economic and social results and generating profit. Separately, the draft law enshrines the concept of "veteran social entrepreneurship", which is "entrepreneurship aimed at achieving specific socially useful material or immaterial results aimed at solving social and/or environmental problems of certain categories of individuals or population groups". The following are among the main measures of state policy in the field of entrepreneurial initiatives of war veterans: tax incentives

for veteran businesses; priority involvement of business entities established by war veterans in the implementation of scientific, technical, and socio-economic programmes; state support through state lending programmes, partial compensation of interest rates on loans, guarantees for the fulfilment of loan obligations, repayable and non-repayable financial assistance, state support for the restoration and stabilisation of veteran entrepreneurship; development of infrastructure to support veteran businesses; involvement of international financial organisations in the preparation and implementation of investment projects by veterans' businesses; stimulation of the development of veterans' social entrepreneurship and a number of other important measures.

A pressing issue in the development of social entrepreneurship among war veterans is finding sources of business financing. Among the sources of financing for veteran businesses, the following should be highlighted: investments, crowdfunding, fundraising, grants, credits, and loans. The tools for attracting investment include active participation in business communities in order to find investors. Crowdfunding involves raising funds from a large number of donors through the use of special platforms (Crowdfunding vs. traditional fundraising..., 2021). Fundraising refers to a type of financing that raises funds for clearly defined socially significant goals for non-profit organisations. In this case, it is worth distinguishing between sponsors, donors and patrons: while a sponsor can be either a natural or legal person whose assistance may be free of charge and reimbursed for the dissemination or promotion of information about the sponsor, a donor is a natural or legal person who makes free contributions or provides competitive grant funding. A patron is a person who makes free donations. Grants provide funding for entrepreneurial initiatives through the involvement of public, private and international funds (grants are most often used when financing start-ups, small businesses and small-scale production). In terms of the use of credit and loan sources of financing, it is worth highlighting programmes for businesses, in particular, "Affordable loans 5-7-9%" and loans at 0% per annum. The most common sources of funding, particularly in the context of developing veteran initiatives, are grants related to opportunities to raise funds for the implementation of interesting and meaningful entrepreneurial ideas. In this area, both international and Ukrainian grant programmes supporting veteran businesses can be noted. Among the state programmes in effect for 2025 are the "eROBOTA" programme and microfinancing for businesses owned by veterans and their family members. Under the "eROBOTA" programme, veterans can receive a grant of UAH 250,000 to implement their own business ideas, while spouses of combatants can receive UAH 500,000. UAH 1 million for a war veteran who is already registered as an individual entrepreneur (IE) and has been operating for at least three years. For grants of UAH 500,000 and UAH 1 million, funding is provided on a percentage basis: the programme covers 70% of the project cost, and the grant recipient covers 30%.

A mandatory condition for receiving this grant is the creation of 1 to 4 jobs, depending on its type (eROBOTA..., 2023). The effectiveness of the programme is evidenced by the fact that between 22 July 2022 and 24 May 2023, 4,600 people received grants totalling 3 billion hryvnia to start and develop their own businesses, including 4,189 grants totalling 1 billion hryvnia. These are microgrants of up to UAH 250,000 (A study of post-war reconstruction initiatives, 2023).

Among microfinance programmes, it is worth noting the Ukrainian Veterans Fund programme to reimburse the cost of goods and equipment for war veterans and their families, as well as families of deceased military personnel, in the amount of UAH 20,000. Since the beginning of the war, grant competitions have been announced several times under the #VARTO programme on the initiative of the Ukrainian Veterans Fund. In the last competition under the #VARTO programme alone (from 27 June 2023 to 13 July 2023), the amount of funding ranged from UAH 500,000 to UAH 3 million (Worthwhile: Supporting veteran businesses, 2023). Among the international programmes, the following deserve attention: the EU's Single Market programme (Business Bridge and Erasmus for Young Entrepreneurs-Ukraine) with a budget of €4.2 billion; the European Union and Food and Agriculture Organisation of the United Nations (FAO) programme for entrepreneurs in Lviv, Ivano-Frankivsk, Zakarpattia and part of Chernivtsi regions, with funding ranging from \$1,000 to \$25,000; the USAID AGRO programme for the development of agricultural processing into products and biofuels, worth UAH 185 million, distributed among 10 sub-grants, taking into account co-financing; the USAID Competitive Economy of Ukraine programme for small and medium-sized women's and family businesses worth between \$10,000 and \$35,000, which is intended for relocation and development of entrepreneurial activity; grants from the European Bank for Reconstruction and Development (EBRD); a project by the Ministry of Agrarian Policy, the State Food and Consumer Service, and the Swiss Quality FOOD Trade Program in Ukraine, aimed at reviving organic dairy production in Ukraine; programs by the International Organization for Migration (A study of post-war reconstruction initiatives, 2023).

When looking at other countries and their experience in supporting entrepreneurial initiatives by war veterans, it is worth noting the positive experience of the United States. The vast majority of veterans in the United States are employed in small and medium-sized businesses, pay the vast majority of taxes and employ citizens. The state, in turn, supports veteran businesses through licensing and capacity building. War veterans receive free training in the basics of entrepreneurship from both government and non-governmental organisations. Another support tool is government contracts involving large enterprises. For example, if a large business entity fulfils a government order, it must include a representative of veteran entrepreneurship among its subcontractors. Each year, up to 3% of

annual federal procurement contracts in the United States are allocated to small veteran-owned businesses, and there are plans to increase this level to 20%. In addition, war veterans who are entrepreneurs receive comprehensive support from the state in the form of consulting, credit and loans, and grant financing. As of 2023, US veterans own more than 2.5 million companies, whose tax payments bring more than \$1 trillion to the state budget annually (Veteran business..., 2023). This experience demonstrates that, provided there is an effective support mechanism from the state and society, veteran entrepreneurship can not only develop but also benefit the state and its citizens. Expanding the list of components of state support in Ukraine and involving charitable and public organisations are all things that should be incorporated into Ukrainian practice. Promising areas for the development of social entrepreneurship among war veterans include regulatory and legal, financial and economic, educational, and information and consulting (Fig. 1).

Key aspects of veteran policy in the context of entrepreneurship development, employment and professional adaptation of war veterans are identified in the work of K.M. Kraus *et al.* (2023). Their study notes that there are two aspects to the development of veteran entrepreneurship in Ukraine: legislative (drafting a bill that will

enshrine the concept of veteran business in law) and practical (the use of financial instruments and levers of influence). Researchers R. Korinets & O. Protchenko (2023) believed that the basis for the development of business initiatives among war veterans is the importance of understanding the veteran environment and the need to assess veterans' readiness for entrepreneurship. In addition, the need to teach war veterans the basics of entrepreneurship and finding sources of funding is of particular importance. Researchers M. Bugera & A. Omelchenko (2024) defined veteran entrepreneurship as part of the important mission of reintegrating war veterans into civilian life and meeting the needs of veteran communities. The researchers noted the importance of state support in launching initiatives to support veteran entrepreneurship, educational activities for training veterans, the formation of a network support structure, psychological assistance and awareness raising. In a way, these facts correlate with the results of the study, but the difference lies in the identification of four areas of social entrepreneurship development, which, according to the authors, are multi-level in nature, as measures within them can be implemented at the state, regional and local levels. In particular, this study identified the importance of legislative, financial and economic, educational, informational and consulting directions.



**Figure 1.** Directions of the development for social entrepreneurship among war veterans

**Source:** developed by the author based on his own research

Researcher Ya. Tanchak (2024) identified the problems and obstacles faced by war veterans in the process of finding employment. These include a decline in employers' willingness to hire war veterans, a lack of opportunities for training and retraining, and the personal and psychological changes that military personnel undergo. It is considered appropriate to add to this list the challenges that war veterans face in starting their own businesses as a source

of professional fulfilment and financial security. These include problems with attracting financial resources, a lack of knowledge and information in the process of starting their own business, the need to resolve legal issues, and the problem of legislative consolidation of both social entrepreneurship and veteran business in Ukraine. O. Petryk (2022) noted that one of the modern tools for the professional realisation of war veterans is the establishment of

social businesses. In this regard, it is extremely important to develop an effective mechanism for state regulation of the functioning of such entrepreneurial initiatives, in particular through the clarity and quality of regulatory and legal regulation.

The results of the analytical report within the framework of the EU4Youth project – Unlocking the potential of young social entrepreneurs in Moldova and Ukraine (Social entrepreneurship in Ukraine..., 2020) deserve special attention. This study analysed the current socio-economic and legal status of social entrepreneurs in Ukraine, as well as alternative ways to improve the social entrepreneurship ecosystem in the context of improving interaction with the state. The importance of developing veteran businesses creates an objective need to develop prospects for entrepreneurial initiatives among war veterans. Their development is based on the results of a study of the needs of war veterans in Ukraine, which included such aspects as: studying the self-identification of war veterans in society, their attitude to benefits in the healthcare and medical services system, research into the financial security of veterans and their families, resocialisation through employment in civilian life, and the attitude of male and female veterans to participation in various political forces (The needs of veterans in 2023, 2023). An overview of some relevant international and Ukrainian programmes to support veteran businesses is provided in a study of post-war reconstruction initiatives in Ukraine (A study of post-war reconstruction initiatives, 2023). This research project, initiated by the Initiative Centre for the Promotion of Activity and Development of Public Initiatives “Yednannia”, was carried out by the Kyiv International Institute of Sociology as part of the project “Initiative for Sectoral Support of Civil Society in Ukraine”. In the future, it is planned to conduct our own research to identify the needs of war veterans in wartime conditions, particularly in the context of improving the well-being of veterans and their families, as well as updating existing programmes to support socially oriented veteran businesses. Given the numerous achievements of researchers in the field of social business and veteran entrepreneurship, it is worth noting that there is an urgent need to assess the current opportunities and future prospects for the development of veteran businesses, taking into account the risks and threats of wartime and the complex socio-economic situation in the country.

## ■ Conclusions

The development of social entrepreneurship, which is focused on achieving specific social goals and performing socially useful functions, is particularly relevant in times of war. As a result of the study, theoretical and methodological foundations were identified and practical recommendations were developed for the development of social entrepreneurship among war veterans in the context of the importance of their professional adaptation to civilian life in Ukraine. Among the key features of socially oriented veteran businesses, the following were identified: a clear

social focus, the need to adhere to the principle of social responsibility, innovative business ideas, and the achievement of a synergistic effect through the combination of two important components of socio-economic policy: the professional adaptation of war veterans and the development of socially oriented entrepreneurial initiatives. Among the obstacles to starting and running a social business among war veterans were noted: the need to find effective sources of funding, insufficient knowledge and information necessary to start one's own business, and the problem of forming the legislative framework for the functioning of social business and veteran entrepreneurship. In order to develop social entrepreneurship initiatives among war veterans and their families, it is important to implement a set of legislative, financial and economic, educational, informational and consulting measures.

The legislative component of the measures included the formation of a legislative regulation mechanism through the adoption of draft laws “On Veteran Entrepreneurship” and “Social Entrepreneurship”. Financial and economic measures include finding and attracting international partners, using state programmes to financially support the development of veteran businesses, tax tools to support entrepreneurial activity, and implementing investment programmes for social enterprises. The educational component included training, retraining and professional development for war veterans in selected areas of educational training (in particular, at veteran development centres), the development and implementation of courses on starting and organising one's own business, and training in the basics of social entrepreneurship. Strengthening cooperation between educational institutions and the State Employment Service, the Ministry of Veterans Affairs, state and local government bodies, charitable and public organisations. The informational and consulting area involves building entrepreneurial infrastructure based on the use of digital tools and the creation of special information platforms for current and future social entrepreneurs to exchange experience, ideas and consulting support.

Given the importance of preserving human potential in wartime and the need to address important social issues in society, it should be noted that the spread of social business practices among war veterans is one of the important factors in the recovery of the economy and the social sphere. The development of social business will not only contribute to the professional fulfilment of war veterans and the well-being of their families, but will also provide jobs for Ukrainian citizens (including socially vulnerable groups), help overcome the consequences of social threats, and ensure Ukraine's post-war recovery. Further research should look at how to use the best international practices for developing social businesses and entrepreneurial initiatives by military folks who've left the service, taking into account the current situation in Ukraine.

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None.

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## Соціальне підприємництво як напрям розвитку підприємницьких ініціатив ветеранів війни в Україні

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■ **Анотація.** Актуальність проблеми розвитку підприємництва задля покращення стану зайнятості та загальної економічної ситуації, підтримка категорій громадян, які потребують особливого захисту з боку держави в умовах воєнного часу (зокрема, це ветерани війни та їх родини), вирішення важливих соціальних проблем – все це визначає необхідність розвитку соціального бізнесу у контексті стимулювання підприємницьких ініціатив ветеранів війни. Наукова стаття була присвячена визначенню теоретико-практичних аспектів розвитку соціального підприємництва серед ветеранів війни у контексті їх професійної адаптації до цивільного життя в Україні. У результаті дослідження було висвітлено ключові особливості соціального підприємництва як напрямку розвитку підприємницьких ініціатив ветеранів війни, проведено огляд та оцінку сучасних тенденцій функціонування соціального бізнесу в Україні, визначено перспективи розвитку соціального підприємництва серед ветеранів війни в Україні. Виходячи із теоретичного обґрунтування сутності соціального підприємництва, було визначено його ключові особливості у контексті розвитку ветеранського бізнесу: чітку соціальну спрямованість, реалізацію принципу соціальної відповідальності, інноваційну спрямованість, синергетичний ефект від поєднання процесів професійної адаптації ветеранів війни та розвитку підприємницьких ініціатив соціального спрямування. Було відзначено перешкоди розвитку соціального бізнесу ветеранів війни, серед яких: проблеми залучення фінансових ресурсів, дефіцит знань та інформації у процесі започаткування бізнесу, проблема законодавчого закріплення соціального підприємництва та ветеранського бізнесу. Обґрунтовано перспективні напрями розвитку соціального підприємництва серед ветеранів війни, серед яких: нормативно-правовий, фінансово-економічний, освітній, інформаційно-консультаційний. Практична цінність дослідження полягала у розробці рекомендацій та визначенні напрямів розвитку соціального підприємництва серед ветеранів війни з урахуванням реалій воєнного часу в Україні

■ **Ключові слова:** ветеранський бізнес; соціальний бізнес; професійна адаптація; бізнес-ініціативи; ветеранська політика

## Integral assessment of phased investment scenarios of post-war development

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■ **Abstract.** The purpose of the article is to develop a theoretical and methodological model of the recovery of the national economy of Ukraine in the post-war period based on an integrated approach to the analysis of the investment process. The study used formalised economic and mathematical modeling, scenario analysis, elements of dynamic programming, and a critical review of current scientific literature on post-crisis management. The empirical basis was the analytical materials of international financial organisations on the assessment of damage and recovery needs. As a result, a three-phase structure of the transformation process (survival, reconstruction, growth) was formed, for each of which the corresponding accumulation integral  $\int f(t) \cdot \omega(t) dt$  was built. The proposed model allows quantifying not only the volume of investments, but also the strategic feasibility of their placement over time. Three recovery scenarios were modelled: inertial, optimistic-coordinated and fragmented. The results showed that the synchronisation of investments with the phase logic of transformation, and not just their absolute volume, is a crucial factor in efficiency. The model also proved to be adaptable to changes in the pace of funding and allowed for the assessment of critical time windows for action. It made it possible to interpret investments not as one-off injections, but as a continuous process of strategic alignment. This approach opened up new analytical horizons for the development of sustainable economic recovery policies. The practical value of the model was the ability to identify critical time windows for the most effective investment, build phase budgets taking into account not only macro-financial volumes but also their temporal structure, adapt recovery policies to spatial and temporal asymmetries (regional phase analysis), and strengthen the role of international partners in shaping not just funding flows but their predictable temporal architecture

■ **Keywords:** post-war reconstruction; investment integral; scenario modelling; phase integral; investment strategy; time weighting function; strategic management

### ■ Introduction

The full-scale invasion of Ukraine by the Russian Federation in 2022 caused an unprecedented economic shock that transformed time from a background variable to a key factor in economic analysis. In the context of deep turbulence, time is not only a dimension of duration, but also a strategic resource that needs to be managed. The timeliness and coherence of investment flows in the postwar period determined not only the speed but also the quality of economic

recovery. In this regard, there is a need to build an analytical model that would allow assessing the integral effect of investments, taking into account their time dynamics, and identifying optimal scenarios for the transition to growth.

According to the World Bank, the European Commission, and the UN, the direct costs of the war reached USD 135 billion, while the total needs for recovery and reconstruction were estimated at USD 411 billion

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(Poharska, 2023). Ukraine's economy suffered the deepest decline in the history of independence: real gross domestic product in 2022 decreased by 29.1%. This was accompanied by the destruction of critical infrastructure, the breakdown of logistics chains, the decline of industrial production, and the forced migration of millions of citizens (Voloshchuk *et al.*, 2025). At the same time, according to O. Poharska (2023), the adaptability of economic actors to new conditions allowed us to talk about the potential for a rapid transition to the recovery phase in the presence of a systematic investment approach.

The problem of economic recovery after shocks has been the subject of active research in recent years. In particular, S.T. Rachev *et al.* (2011) considered integral mathematical models in the context of market instability, demonstrating that the effectiveness of economic policy increases significantly when using time-effect aggregation operators. Their approach to the analysis of financial processes in a turbulent regime aimed at identifying the hidden temporal logic of crisis phenomena, which has direct application in the Ukrainian context. D.M. Cutler & E.L. Glaeser (2022) studied the geography of urban economic recovery after systemic crises. The authors concluded that the key role in recovery is played not so much by the volume of investment as by its distribution in time and space. This confirmed the thesis that it is necessary to take into account the phase logic of investment when building models of national-level recovery. Considerable attention was paid to the time dimension of economic transformations in the study by D. Acemoglu & P. Restrepo (2022), who modeled the long-term impact of automation on the US labor market. They used an integral approach to assess the effects that do not appear instantly but accumulate over time. This method allowed them to identify the delayed effects of structural changes – similar to the effects of investments in the Ukrainian economy in the post-crisis recovery phase.

Ukrainian scientist T.T. Kovalchuk (2020) proposed a model of economic and mathematical modeling under risk, which included the concept of “integral adaptation” – the cumulative ability of the system to recover, which depends on the pace and structure of investment flows. This approach has also been used in simulations for post-conflict countries in Africa, which makes it relevant for Ukraine as well. According to P. Lecca *et al.* (2010), dynamic models of capital accumulation in the macroeconomy allowed not only to analyse current processes but also to predict development trajectories under different investment scenarios. Their study focused on the role of integrals in the formation of sustainable economies, which can be adapted to the phase recovery model. Researchers C. Ruza *et al.* (2019) studied the effects of interest rate burden on the fiscal sustainability of banking systems in developing countries. Using weighted integrals, they identified critical time frames for interventions in the financial system, demonstrating the value of time-dependent analysis in a crisis.

Also important was the study by V. Krey *et al.* (2014), which modeled the transformation of energy systems by

2100. Their model included a time weighting function that allowed for the identification of critical periods for investment, a concept that directly resonates with the concept of “efficiency windows” developed in this article. The purpose of this study was to create a conceptual model that interpreted the process of postwar recovery of Ukraine through the prism of the phase integral of investment. The use of the functional formula  $\int f(t) - \omega(t) dt$  allowed not only to formalise investment flows but also to take into account their temporal weight, i.e., the strategic importance of certain moments of time for each of the phases: survival, reconstruction, and growth.

## ■ Materials and Methods

This study used a comprehensive interdisciplinary approach that combined formal economic and mathematical modelling, scenario analysis, elements of dynamic programming, and a critical review of relevant scientific literature. This approach allowed to substantiate the conceptual and formal structure of the phase integrated model of investment in the context of post-crisis recovery. The theoretical basis was the concept of an integral as an aggregating tool in the context of temporal unevenness of impact. The economic-mathematical modelling was applied to construct a certain integral  $\int f(t) - \omega(t) dt$  as the basis of the analytical function of investment accumulation in each of the phases: survival, reconstruction, and growth. The modelling assumed that the function  $f(t)$  described the intensity of the investment flow, while the weighting function  $\omega(t)$  reflected the time priority or strategic importance of moment  $t$  for achieving the desired effect. This structure allowed us to move away from the traditional approach of analysing momentary values in favour of taking into account the dynamics of the accumulation of effects over time (Rachev *et al.*, 2011).

Scenario analysis was used to model three alternative recovery trajectories: inertial, optimistic-coordinated, and fragmented. To develop each scenario, the conditional parameters of the functions  $f(t)$  and  $\omega(t)$  were first set based on empirical assumptions about the pace, structure, and timing of investment inflows. In the fragmented scenario, the function  $f(t)$  was modelled as a discrete wave with asynchronous pulses, and  $\omega(t)$  was modelled as flat or non-systematic. For the optimistic scenario, a phase maximum in the function  $t$  was set in the reconstruction phase, which corresponded to the idea of a “window of opportunity” (Brundiers & Eakin, 2018).

For each scenario, we calculated conditional phase integrals: survival integral (S), recovery integral (R), and growth integral (G). These integrals allowed us to estimate how much investment was accumulated in the respective phase and to identify the dependence of efficiency on the synchrony of the functions  $f(t)$  and  $\omega(t)$ . To calculate the integrals, we used numerical approximation methods (trapezoidal rule) implemented in Python with the numpy and scipy libraries. Dynamic programming elements were used to build a conditional matrix of transitions between

phases. This made it possible to model at what volumes of the integral  $S$  it was possible to move to phase  $R$  without systemic losses, as well as to identify critical accumulation thresholds below which the launch of the next phase would be inefficient or risky.

To develop the model, a critical review of the current scientific literature on the topics of recovery economics, intertemporal planning, and phase investment was conducted. In particular, the approaches to macroeconomic modelling of economies in crisis were analysed, as outlined in D.M. Cutler & E.L. Glaeser (2022), D. Acemoglu & P. Restrepo (2022), V. Krey *et al.* (2014). The theoretical justification for intertemporal investment and the use of integrals in planning was provided by the concepts of F.P. Ramsey (1928), S.T. Rachev *et al.* (2011), T.T. Kovalchuk (2020). The ideas of sustainable recovery, behavioural consumption, and intertemporal choice were taken into account based on the works of K. Brundiers & H.C. Eakin (2018), O.P. Attanasio & G. Weber (1995). On their basis, the expediency of an integral approach to the analysis of economic dynamics in disasters was substantiated. As for the input materials, the generalised estimates of the international financial organisations World Bank (2023) and UNDP (n.d.), as well as analytical materials on Ukraine's recovery plans, in particular the report of the Recovery and Reconstruction Planning Platform (G7..., 2024), were used as an empirical basis. All data were used in the form of conditional approximations of investment flows broken down into phase intervals.

## ■ Results and Discussion

Integration as a tool of economic analysis had both formal and conceptual nature. The idea of treating economic changes as a set of small, continuous increments was developed in the classical intertemporal model of F.P. Ramsey (1928), which was later rethought through the prism of behavioural economics and dynamic programming. In modern scientific literature, integral approaches have been actively used in the context of analysing long-term investment processes. In S.T. Rachev *et al.* (2011), it was proposed to use integral operators to model market changes with regard to time disturbances. The authors proved that cumulative effects make sense only when the time factor is integrated into the formal structure of the model. The study by D.M. Cutler & E.L. Glaeser (2022) analysed the role of time lags in urban economic recovery. The authors emphasised the need to take into account inertial processes in investment policy and stressed that the formal integration of such delays can improve the accuracy of growth potential assessment. The defined integral was presented as a way to model the accumulated impact of investment flows over time.

The paper by D. Acemoglu & P. Restrepo (2022) use integral functions to describe long-term changes in employment as a result of the cumulative impact of technological transformation. This approach is an example of the use of variable-density integrals to measure the impact of innovation on macro parameters. In the Ukrainian context, the

study by Kovalchuk (2020) is promising, analysing integral models for optimising investment decisions for economies recovering from disasters. The author introduces the concept of “integral adaptation” – a function that determines the accumulation of institutional resilience as a derivative of the volume and rhythm of investments in restored infrastructure. Thus, economic thought is increasingly turning to integral models as a way to capture the complex dynamic relationships between time, capital and effect. This approach is especially relevant in cases of structural disruption of the economic process, such as war, pandemic, or systemic recession. At the level of recovery theory, the key study was by K. Brundiers & H.C. Eakin (2018), which first formalised the concept of “windows of opportunity” in post-disaster periods. In this model, the integral efficiency of investment is maximised in a narrow time interval, which is consistent with the idea of the weighting function  $\omega(t)$  in this model. Similarly, in V. Krey *et al.* (2014) used time weights in the analysis of the climate transformation of energy systems – the authors emphasised that the moment of implementation has a greater weight than the total cost.

The integral is also widely used in the analysis of intertemporal preferences and welfare. For example, in the intertemporal theory of consumption, the discounted integral of the utility function is used to determine the trajectory of rational choice O.P. Attanasio & G. Weber (1995). This model allowed to study the trade-offs between current and future welfare in the process of making strategic economic decisions. Thus, the integral in economics was not only an analytical tool, but also a conceptual bridge between point impact and systemic effect. Its application allowed us to formalise the ideas of cumulation, latent impact, inertia and lag, which were particularly important in the context of structural transformations, such as war or environmental crisis.

In the classical integral calculus, all elements of the subintegral domain had an equal contribution to the result – the function was integrated over the interval  $[t_0; t_1]$  with equal weight. However, in economic analysis, it was extremely important to take into account the uneven importance of different time points. For this purpose, the concept of the weight function  $\omega(t)$  was introduced, which allowed to differentiate the impact of a certain time period on the integral result. The integral with the weight function had the following general form:

$$I = \int_{t_0}^{t_1} f(t) \cdot \omega(t) dt, \quad (1)$$

where  $\omega(t) \geq 0$  was a weighting function that reflects the priority of moment  $t$ .

Weight integrals have been widely used in finance to account for time preferences or risks. For example, in D. Debortoli *et al.* (2017) showed that welfare functions in macro-financial models take the form of integrals with an exponential weighting function. This function focused on the part of the time axis closer to the present. This design allowed political and economic agents to balance current pressures with a strategic long-term goal. In the framework

of intertemporal optimisation, in particular in the analysis of dynamic household equilibrium, the weight function  $\omega(t)$  was interpreted as a discount factor – that is, a subjective assessment of the value of the future (Krusell & Smith, 1998). In modern DSGE models, welfare integrals often have the form

$$\int U(c(t)) \cdot e^{-\rho t} dt, \quad (2)$$

where  $\rho$  is the rate of intertemporal preference.

In the development of this logic, J. Crespo Cuaresma *et al.* (2020) focus on weighted investment indices that take into account not only the amount of capital but also the time of its placement. In the context of post-crisis recovery, they propose to use a weighting function  $\omega(t)$  that increases during the reconstruction phase and peaks at the moment of structural break - when each invested unit has the highest multiplier effect.

The approach outlined in K. Brundiers & H.C. Eakin (2018), where  $\omega(t)$  is used in modelling windows of opportunity in post-disaster recovery. In this interpretation, the weighting function took the form of a temporary impulse – a narrow interval  $t \in [t_1; t_2]$ , in which each investment had a maximum impact, after which its effectiveness rapidly declined. This approach was extremely relevant for Ukraine as a country in the reconstruction phase. In post-war planning, these approaches will help determine exactly when to invest – not just how much. Post-crisis economies have functioned in disparate phases, each of which requires a different pace, structure and purpose of investment. To formalise these phases, it was necessary to introduce three integral aggregates of resource time: survival integral, recovery integral and growth integral. They allowed not only to quantify cumulative investment efforts in each period, but also to determine their systemic function.

Firstly, the Survival integral, denoted as  $S = \int_{t_0}^{t_1} f_s(t) dt$ , accumulated resource flows aimed at supporting the functioning of critical systems: medical, humanitarian, and security. Its economic sense was to accumulate the minimum amount of resources necessary to prevent systemic collapse. In this context, it was appropriate to analyse the dynamic resilience model K. Martínez *et al.* (2025), where the system's survival is linked to the lower bound of the resource flow required to maintain basic functionality. Secondly, the Recovery integral,  $R = \int_{t_1}^{t_2} f_r(t) dt$ , reflected the recovery and reorganisation phase, when resources were directed to the resuscitation of economic infrastructure, the financial system, and domestic production.

This stage was not a direct continuation of the previous one, but rather a transition to a new economic configuration. According to the approach of A. Bénassy-Quéré & B. Weder di Mauro (2020), the recovery had to be not only cumulative but also “qualitatively driven” – that is, it had to be aimed at structural transformation. Third, the Growth integral,  $G = \int_{t_2}^{t_3} f_g(t) dt$ , aggregated the investment flows that triggered long-term economic growth. He envisaged a change in the logic of investment: from emergency to systemic, from reactive to strategic. In G. Schwartz *et*

*al.* (2020) emphasised that effective growth after a shock is only possible if investment is targeted to take into account climate, institutional, and social parameters – that is, the growth integral has become a function of many vectors. All three integrals could be presented as phase components of the overall development integral:

$$I\Sigma = S + R + G = \int_{t_0}^{t_1} f_s(t) dt + \int_{t_1}^{t_2} f_r(t) dt + \int_{t_2}^{t_3} f_g(t) dt. \quad (3)$$

The formalisation of this approach allowed not only to describe the trajectory of post-crisis recovery, but also to model the policy of resource allocation over time in accordance with strategic priorities. It was important to note that the phase division was not purely chronological, but also structural: each phase required separate institutional mechanisms for implementation and performance evaluation. Thus, the introduction of the three phase integrals allowed us to move from a linear view of recovery to a multi-level, integral architecture of economic time. This opened up the possibility of adaptive resource management in the face of radical uncertainty. The next logical step was to build the formal structure of an integral model of investment reconstruction in Ukraine, which mathematically and conceptually combined what had been introduced earlier (survival, recovery, growth integrals) into a single economic and mathematical framework. The model was based on the notion of post-war economic recovery as a sequence of phases with different structures of investment flows accumulated over time. The general integral expression was as follows:

$$I\Sigma = \int_{t_0}^{t_1} f_s(t) \cdot \omega_s(t) dt + \int_{t_1}^{t_2} f_r(t) \cdot \omega_r(t) dt + \int_{t_2}^{t_3} f_g(t) \cdot \omega_g(t) dt, \quad (4)$$

where  $f_s(t)$ ,  $f_r(t)$ ,  $f_g(t)$  are functions of investment flows in the phases of survival (S), recovery (R) and growth (G), respectively;  $\omega_s(t)$ ,  $\omega_r(t)$ ,  $\omega_g(t)$  are weight functions that reflect the priority of time points in each phase;  $[t_0; t_3]$  is the time horizon of post-war reconstruction.

The key in the model was not only the amount of resources invested, but also their distribution over time, as the impact of  $f(t)$  depended on the weighting function  $\omega(t)$ , which is determined by the specifics of needs and windows of efficiency. This was in line with the idea of time-sensitive accumulation, first substantiated in the study by M. Forni & L. Gambetti (2016), where the authors found that the distribution of stimuli over time had a much greater impact on long-term GDP than the size of the fiscal package itself. In the first phase (survival),  $\omega_s(t)$  had the form of a dampened function, which decreased the priority of spending over time, while  $f_s(t)$  was usually an exogenous variable determined by humanitarian aid. In the second phase,  $\omega_r(t)$  took the form of an impulse function with a maximum at time  $t^*$ , which corresponded to the “window of opportunity” for the restoration of critical infrastructure T. Ylä-Anttila *et al.* (2023). The third phase was described by  $\omega_g(t)$ , which was an increasing function, as the efficiency of each additional investment increased with the restoration of market mechanisms.

In contrast to the classical models of R.M. Solow (1956) or F.P. Ramsey (1928), the proposed construction assumed that the function  $f(t)$  was not smooth but had a fragmented structure due to the shock nature of war and political lags in financing. In this context, it was appropriate to use the Lebesgue integral, which allowed aggregating  $f(t)$  even in the presence of discrete jumps in the investment flow. This approach was in line with modern practices in modelling economic processes with discrete shocks, where traditional integration methods might not be sufficient for accurate analysis (Tao, 2010; Nunes & Pimentel, 2015). Taken together, the model allowed us to quantify the minimum funding threshold for the transition between phases, model the impact of delayed investment in the recovery phase on future growth (i.e., the derivative of  $G$  in  $t_2$ ), and determine the optimal form of  $\omega(t)$  for each phase by minimising welfare losses or delayed effects.

This approach allows political and economic actors (government, donors, development banks) to synchronise investment flows with the institutional dynamics of the system and the logic of strategic development. The high adaptability of the model also made it possible to incorporate additional weighting factors: risk ( $\rho(t)$ ), social effect ( $\sigma(t)$ ), climate impact ( $\kappa(t)$ ), etc. The next step was scenario modelling – how different profiles  $f(t)$  and weighting functions  $\omega(t)$  within the survival, recovery, and growth phases affected the result of the  $\int \omega f$  integral. A formalised scenario analysis based on economic logic was carried out. This made it possible to show how variations in  $f(t)$  and  $\omega(t)$  affected the amount of accumulated investment in each phase and the overall recovery effect.

The integral reconstruction model has emerged not only as an analytical construct, but also as an applied tool for forecasting the results of investment strategies in the time perspective. To verify its applied potential, three conditional scenarios are considered: the inertial scenario (I): investment flows  $f(t)$  are unevenly distributed, with concentration in the later phases ( $t_2 \rightarrow t_3$ ), weight functions  $\omega(t)$  have low sensitivity to time; the optimal scenario (O):  $f(t)$  is balanced in accordance with the priority of phases, weight functions  $\omega(t)$  have a pronounced maximum in the respective phase centres; fragmented scenario (F): investments are impulsive and random,  $f(t)$  is discrete,  $\omega(t)$  does not correlate with the moments of structural needs. The calculation of the  $\int \omega f$  integral in each scenario (with conditional equations  $f(t)$  and  $\omega(t)$  that can be adapted to the model simulator) showed the critical importance of the time factor. In the F scenario, the value of  $\int \omega f$  could even exceed the optimal scenario, but would have a smaller systemic effect due to the disturbed cumulation.

From an applied point of view, scenario modelling has made it possible to predict the costs of delays or lack of coordination: in real time, this is reflected in lost opportunities to rebuild infrastructure, loss of donor confidence, or irreversible decline in human capital potential. This model could also be the basis for building digital tools to support government planning, as was done in the Recovery Plan Simulator for the Balkan countries, OECD (2022). The integral model, based on phase functions  $f(t)$  with appropriate weighting coefficients  $\omega(t)$ , allowed for comparative scenario modelling of recovery. This approach has been widely used in studies by the World Bank, IMF, and UNDP for countries recovering from military or environmental shocks (World Bank, 2023; UNDP, n.d.). Therefore, it was appropriate to present a conditional simulation based on three scenarios:

The first was the inertial scenario for minimal and delayed investment. In this case, the functions  $f_s(t)$ ,  $f_r(t)$ ,  $f_g(t)$  were low-amplitude, and  $\omega(t)$  was either constant or growing late. The accumulated survival integral was sufficient to avoid systemic collapse, but the recovery integral was underestimated and stretched in time. Consequently, the growth integral was shifted to the future and has a low efficiency ratio. This scenario was described in the study by G. Ferrari (2016) on the post-conflict economy of South Sudan, where the delay in recovery led to the loss of the “window of transformation”. The second is an optimistic scenario, namely phase-coordinated investment. Here, the function  $f(t)$  had a maximum in phase R, and  $\omega(t)$  was constructed as an impulse function with a time focus in  $t_1-t_2$ . This corresponded to the “build back better” scenario of the post-war reconstruction strategy in Croatia or Bosnia, when large-scale and rapid investment in infrastructure had a cumulative effect on the entire economy. In the simulation, this scenario showed maximum R values and high G growth already on the medium-term horizon (Callegaro *et al.*, 2019).

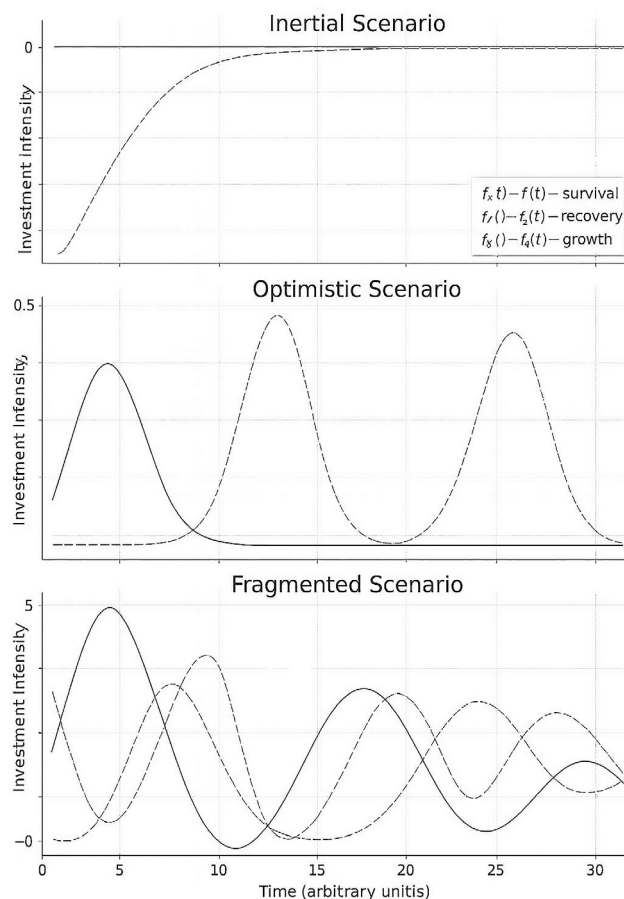
The third was a fragmentary scenario for uncoordinated sources and asynchronous phases. This variant was characterised by a wave-like structure of  $f(t)$  and  $\omega(t)$ , with local extrema that do not coincide in time. For example, large donor injections in phase G in the absence of adequate S or R created systemic inefficiency. The S and R integrals did not provide a foundation, so even large late investments lose their multiplier effect. This approach was modelled in S. Barakat (2009), where it was shown that chaotic post-crisis investment in MENA countries led to “institutional decay”. The volume of phase integrals of survival, recovery and growth under alternative development scenarios is presented in Table 1.

**Table 1.** Phase integrals, priority and expected effects as post-war recovery scenarios

| Scenario    | $\int f_s(t) dt$ (S) | $\int f_r(t) dt$ (R) | $\int f_g(t) dt$ (G) | Expected effect           |
|-------------|----------------------|----------------------|----------------------|---------------------------|
| Inertial    | ~ sufficiently       | ~insufficiently      | ~ postponed          | Slow growth               |
| Optimistic  | adequately           | maximum              | active               | Structural reconstruction |
| Fragmentary | chaotically          | failure              | late/ineffective     | No growth occurs          |

Source: compiled by the authors

The table shows that the volume of integrals was not decisive in itself: the critical factor was the relationship between the moment of maximum  $\omega(t)$  and the efficiency  $f(t)$  at that moment. That is,  $G$  depends on the synchrony of the phases, not just the sum of the inputs. Three graphs (Fig. 1) showed the phase structure of investment flows  $f(t)$  in three scenarios: inertial – slow, uncoordinated financing with a delayed effect, optimistic – coordinated and timely investment in all phases, fragmented – chaotic structure with asynchrony between phases.



**Figure 1.** Graphs of three scenarios  $f(t)$  with superimposed  $\omega(t)$

**Source:** compiled by the authors

The next step was the political and strategic interpretation of the model, which allowed us to translate the formalised integral construct (survival, recovery, growth integrals) into the policy plane, namely to answer the question of how this model could be used to develop real strategies at the level of the state, international partners and regions. The integral model of investment reconstruction allowed not only to quantitatively model the post-crisis transition, but also to formulate strategic recommendations for the allocation of resources over time. Its key value for public policy lies in its ability to make visible the critical relationship between the timing of investment, institutional capacity, and economic inertia.

At the level of public policy, the model required the creation of a mechanism for phased recovery management. Each phase (survival, recovery, and growth) required not only different amounts of funding but also specific institutions. Survival integral was implemented through rapid response mechanisms: National Platform for Humanitarian Coordination, support for internally displaced persons, and reserve funds. The Recovery integral was to be structured through the creation of a reconstruction investment framework focused on the effective use of external sources. This was in line with the UNOPS (2025) approach, which recommended the creation of Recovery Coordination Units as separate governing bodies under the Cabinet of Ministers.

In the growth phase, according to the recommendations of the G7 Multi-agency Donor Coordination Platform for Ukraine (2024), it was critical to institutionalise Growth integral in the form of medium- and long-term structural transformation plans: tax system reform, digitalisation of registers, and transparency of concessions. All three phases had to be stitched together into a single time programme with the logic of continuity and priority  $\omega(t)$ . The integral model directly pointed to the critical role of rhythmicity and predictability of external financing. In the study by B. Eichengreen & V. Rashkovan (2025) emphasised that most reconstruction failures in post-conflict countries were caused not by a lack of funds, but by the asynchrony of their flow. Approaches based on a “lagging infusion” without taking into account the time weighting function proved to be ineffective.

Therefore, international partners had to move from an ex post grant mechanism to an ex ante budget programming system with clear time mandates. The  $\omega(t)$  model had to be aligned with macrofinancial stabilisation policies, in particular, under the IMF’s Extended Fund Facility 2023-2027 programme. As noted in the European Investment Bank’s report (2025), time structured investment yielded higher returns than volume. The application of integral logic at the regional level made it possible to identify areas with a critical gap or excessive concentration of resources in one phase. This opened up the possibility of creating a phase recovery index – the S:R:G ratio in each region, with further optimisation of distribution. In the work of S. Hanandeh *et al.* (2018) proposed the use of spatial-weight integrals as a way to prioritise infrastructure restoration in a resource-limited environment. Regional administrations could use such models to submit funding requests that are aligned with the national phase logic. This created transparency and competition for investment resources based on analytical indicators rather than administrative pressure. A diagram that visualises the strategic synchronisation of the investment reconstruction phases according to the integral model, namely the survival phase (S) – the first 10 units of time, the recovery phase (R) – the next 10, and the growth phase (G) – the final 10, is presented in Table 2.

**Table 2.** Phase synchronisation of investment reconstruction

| Recovery phase                            | Actors   | Tools   | Type of control                  |
|---|--|---|----------------------------------|
| Survival Integral (humanitarian needs)    | - International organisations<br>- Government services<br>- Volunteer networks | - Direct humanitarian aid<br>- Emergency budgets  | Reactive management              |
| Recovery Integral (system rehabilitation) | - Ministries<br>- Recovery agencies<br>- State-owned banks                     | - Rebuilding infrastructure<br>- Programme lending<br>- Energy modernisation programmes | Strategic planning               |
| Growth Integral (structural growth)       | - Private sector<br>- Local investors<br>- Development clusters                | - PPP<br>- Capital investments<br>- Innovative projects                                 | Visionary development management |

**Source:** compiled by the authors

Thus, the results of the modelling demonstrated the high sensitivity of the integrated phase indicators to the synchronisation of investment flows with time priorities. Regardless of the volume of  $f(t)$ , it was the shape and shift of the weighting function  $\omega(t)$  that determined in which phase the main recovery effect would be concentrated. This led to the conclusion that effective management of post-crisis investments is not only about securing funding, but also about its correct rhythmic allocation over time. These results have laid the groundwork for the development of new strategic approaches to planning the recovery economy, taking into account its phased nature.

## ■ Conclusions

The integral model of investment reconstruction developed in this article offers a fundamentally new framework for understanding the post-war economic development of Ukraine. Its main intellectual innovation is the transition from the analysis of momentary (static) parameters to the model of accumulation of the effect over time. In the context of the catastrophe that destroyed the linearity of economic dynamics, it is the integral – as a mathematical and conceptual tool – that allows us to record not only the volume of resources, but also their strategic synchronisation. In the framework of the study, an integral model of phase investment was built, which allows assessing the effectiveness of economic recovery, taking into account the time dynamics. A three-phase structure of recovery was formulated: survival, reconstruction and growth, each of which was characterised by a separate time interval and specific dynamics of investment needs. For each phase, a separate integral was constructed in the form  $\int f(t) \cdot \omega(t) dt$ , where the function  $f(t)$  described

the intensity of the investment flow, and  $\omega(t)$  was the time weight reflecting the priority of the moment of implementation. Thus, the proposed approach provided a quantitative assessment of not only the volume, but also the feasibility of investments, taking into account their placement in time.

Using scenario analysis, three conditional scenarios were modelled: inertial, fragmentary and optimistic (coordinated). For each scenario, conditional phase integrals were calculated, which made it possible to assess the extent to which different structure  $\omega(t)$  affects the recovery efficiency. It was confirmed that even with the same  $f(t)$ , the efficiency varied significantly depending on the synchrony with  $\omega(t)$ , which proved the crucial role of rhythmic and timely investment. The study also confirmed the suitability of the Lebesgue integral for aggregating discrete investment spikes, which was particularly relevant in the context of post-war financing, which was characterised by uneven revenues. This made it possible to provide adequate mathematical treatment of even fragmented flows characteristic of war and crisis delays. Further research involves the empirical formalisation of  $\omega(t)$  and the development of an optimisation unit for finding investment trajectories in a changing environment.

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## ■ Conflict of Interest

None.

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## Інтегральна оцінка фазових інвестиційних сценаріїв післявоєнного розвитку

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■ **Анотація.** Метою статті була розробка теоретико-методологічної моделі відновлення національної економіки України в поствоєнний період на основі інтегрального підходу до аналізу інвестиційного процесу. У дослідженні було використано формалізоване економіко-математичне моделювання, сценарний аналіз, елементи динамічного програмування, а також критичний огляд актуальної наукової літератури з питань післякризового управління. Емпіричною основою слугували аналітичні матеріали міжнародних фінансових організацій щодо оцінки збитків і потреб у відновленні. У результаті було сформовано трифазну структуру процесу трансформації (виживання, реконструкція, зростання), для кожної з яких побудовано відповідний інтеграл накопичення  $\int f(t) \cdot \omega(t) dt$ . Запропонована модель дозволила кількісно оцінити не лише обсяг інвестицій, але й стратегічну доцільність їхнього розміщення в часі. Було проведено моделювання трьох сценаріїв відновлення: інерційного, оптимістично-скоординованого та фрагментарного. Результати показали, що вирішальним фактором ефективності є синхронізація інвестицій з фазовою логікою трансформації, а не лише їх абсолютний обсяг. Модель також виявилася адаптивною до змін у темпі фінансування та дозволила оцінювати критичні часові вікна для дій. Вона забезпечила можливість інтерпретації інвестицій не як одноразових вливань, а як безперервного процесу стратегічного вирівнювання. Такий підхід відкрив нові аналітичні горизонти для розробки політик сталого економічного відновлення. Практична цінність моделі полягає в можливості визначення критичних часових вікон для максимально ефективного інвестування, побудови фазових бюджетів з урахуванням не тільки макрофінансових обсягів, а й їх темпоральної структури, адаптації політики відновлення до просторової й часової асиметрії (регіональний фазовий аналіз), посилення ролі міжнародних партнерів у формуванні не просто потоків фінансування, а їхньої передбачуваної часової архітектури.

■ **Ключові слова:** післявоєнне відновлення; інтеграл інвестицій; сценарне моделювання; фазовий інтеграл; інвестиційна стратегія; вагова функція часу; стратегічне управління

## The impact of uncertainty on strengthening the economic security of enterprises of the unified energy system of Ukraine

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■ **Abstract.** The importance of studying the issue of processes of strengthening the economic security of enterprises was quite justified in view of the military situation in Ukraine and the deterioration, in this regard, of the economic situation of enterprises. Conditions of uncertainty are normative for economic entities, but they acquired a new meaning and became basic for enterprises. The goal was to form a theoretical and methodological basis for the processes of strengthening the economic security of enterprises in the energy sector of Ukraine based on the theory of uncertainty. The work was based on an approach to separating the stages of the uncertainty assessment process, dividing the main products of enterprises into components and using the method of analysis of hierarchies (MAI). As a result of the analysis of a wide range of scientific literature, it was determined that within the framework of the methodology of economic security, it is customary to use the tools of the theory of riskology and the corresponding methods and models of management. This work revealed the theory and practice of economic security of energy enterprises through the concept of uncertainty theory. A classification by types of uncertainty and the conditions of its occurrence for enterprises of the Unified Energy System of Ukraine (UES-U) was highlighted, which helped to choose the necessary tool for analysis. The conclusions obtained have significant methodological value for forecasting the development of the Unified Energy System of Ukraine as a whole, aiming for the lowest possible level of uncertainty. This was possible because the modelling of the Unified Energy System of Ukraine began with components that had a lower level of uncertainty and was subsequently expanded to include other energy facilities, which were coordinated with the configurations of the initial group. The results obtained made it possible to carry out comprehensive forecasting of the development of the Unified Energy System of Ukraine, taking into account factors of economic security and aiming to minimise the impact of uncertainty.

■ **Keywords:** sustainable development; risks; analysis of hierarchy's method; energy industry; economic sustainability; modeling of energy system development; forecasting

### ■ Introduction

In the unstable economic environment of enterprises, risks and threats that arise in situations of uncertainty are of key importance. Martial law and constant destruction exacerbated the deterioration of the situation. In this regard, the issue of risk management and their impact on the economic

security of enterprises required attention. Some aspects of the study of risk management are presented among scientists. O.V. Varaksina *et al.* (2023) noted that an important aspect of risk management at enterprises was the definition of their circle of internal and external representatives

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and the use of combined management tools to avoid any consequences associated with the further impact on the activities of the enterprise. Researchers emphasised the relevance of covering these issues and highlighted the issue of identifying threats as a priority in the direction of timely confrontation with them in order to achieve the best results of conducting economic activities. Researcher V.V. Kovalenko (2018) studied in depth the issue of the impact of risks on the economic security of enterprises and highlighted that the main factor of influence is uncertainty, which becomes a prerequisite for choosing means of combating and countering any threats. The author revealed the issue of obtaining positive consequences from any risks while minimising the negative manifestation. In this case, reasonable risk management will lead to their neutralisation. This position deserves attention and more broadly reveals the essence of the mechanism for creating conditions for improving the economic security of enterprises through risk management. It is also worth noting G.O. Seleznyova & R.D. Stepanenko (2023), who paid attention to modern types of risks and focused on digitalisation processes, which is an updated direction for identifying types of threats in modern business conditions of enterprises. They determined that an important aspect is the implementation of economic security monitoring based on a risk-based approach, as well as modeling organisational design for enterprise stakeholders. It is the implementation of modern methods and tools that can help facilitate and accelerate the processes of identifying potential threats to the economic security of enterprises. Accordingly, such an approach can be considered a further development of theoretical developments that deserves attention.

According to O.V. Toporkova *et al.* (2019), the essence and target nature of “risk management” were determined, which plays a significant role in making management decisions under conditions of uncertainty and can contribute to improving the activities of business entities due to their sustainable growth, reducing costs, profitable investment of capital and obtaining greater profits. The work of the scientists investigated the issue of financial risks, which is generally a rather narrow subject of analysis, but the results presented by them demonstrate the importance of using management reports for conducting economic and mathematical modeling in the process of internal economic risk control. Such a proposal is sound and creates the prerequisites for the further development of a general system of indicators for strengthening the economic security of enterprises. Risk management was covered in detail by N.S. Skopenko & I.V. Yevseeva (2020), who presented this direction of management in the general system of ensuring the economic security of enterprises. The authors thoroughly described the types of risks and proposed the author’s vision of forming a concept of decision-making under the conditions of determining the impact of risks on the activities of enterprises. In development of the above, it is worth noting the work of L. Sarana *et al.* (2021), who identified six main interrelated stages of risk management, which

has a positive effect on reducing additional costs of enterprises. Scientists have paid sufficient attention to risk management and its consequences for the formation, provision and strengthening of economic security of enterprises, but the diversity of approaches creates a wide field of ramified approaches and, accordingly, the lack of a stable statement and systematisation.

The study of scientific literature on the processes of strengthening and ensuring economic security through the prism of risk management provides answers to the questions of how to manage them at the moment of their occurrence, but there are no approaches to changing circumstances and the environment. Such conditions are partially described in the work of A. Sokolov (2024), in which the author drew attention to the enterprise’s response to manifestations of external and internal risks through adaptive management. And he provided recommendations for the implementation of artificial intelligence tools for risk forecasting, which indicates the intention to predict all possible conditions of uncertainty. But it is worth noting that the author described only the financial and economic factors of enterprise security and exclusively for the maritime logistics industry, which is not unified and requires further development for wider application in other sectors of the economy. All the presented developments expand scientific searches for the development of the methodology of economic security and create a basis for further research in the direction of presenting the processes of determining possible risks and identifying uncertainty, which certainly affect the processes of its strengthening. The goal was to provide a theoretical and methodological justification for mechanisms for strengthening the economic security of enterprises of the unified energy system of Ukraine in conditions of uncertainty by formalising influential factors, prioritising risks, and determining directions of strategic response.

## ■ Materials and Methods

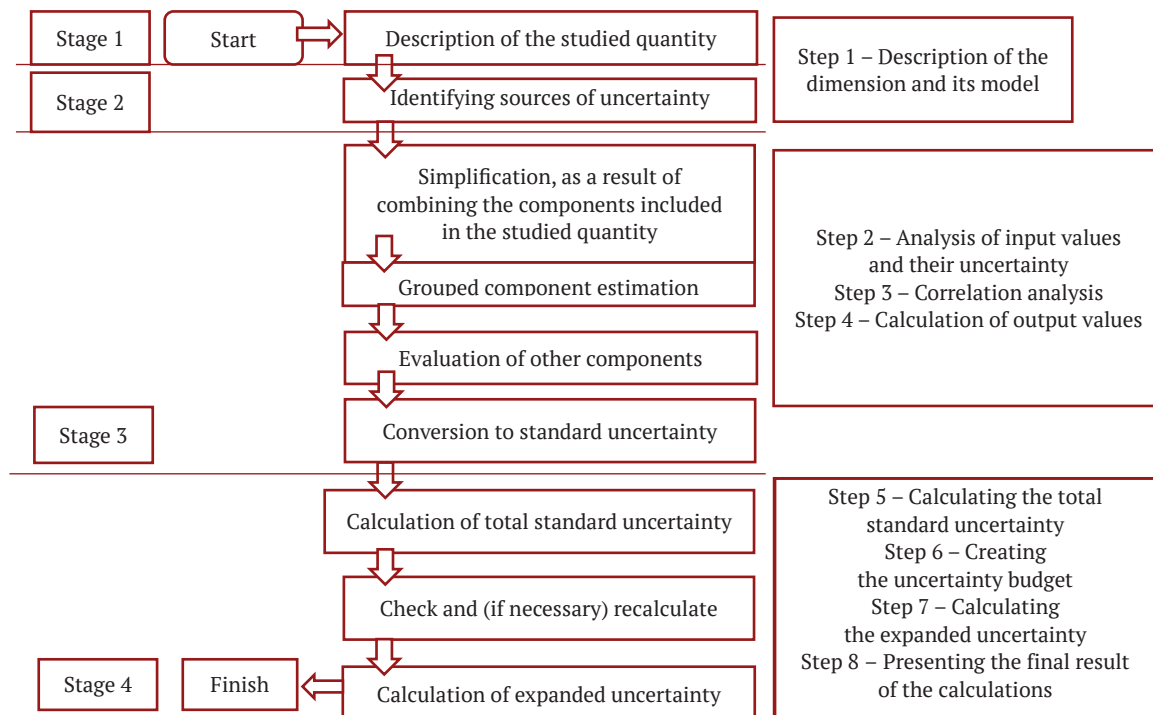
To determine the impact of risks, threats and uncertainty on the processes of forming and strengthening the economic security of enterprises of the unified energy system of Ukraine, uncertainty, its components and impact on strengthening economic security were analysed in more detail. Summarising the results of the analysis of a wide range of literary sources within the framework of the methodology of economic security, it was decided to use the tools of the theory of riskology and the corresponding methods and models of management.

As part of the methodological approach to the study of the formation of economic security of energy sector enterprises, the specifics of the impact of uncertainty on strategic management processes were taken into account. The theoretical basis was the concept of uncertainty theory, according to which uncertainty is divided into structured and unstructured. Based on previous work (Bahuguna *et al.*, 2022; Andriushchenko & Lezina, 2024), attention was focused on predictive unstructured uncertainty in the

dynamic environment of the energy sector of Ukraine. Within the framework of the study, the classification of uncertainties proposed by V.I. Korcheva & N.M. Kriuchkova (2015) was used as a theoretical basis, according to which a preliminary division of risks associated with the economic security of enterprises was carried out. This made it possible to structure the sources of uncertainty and adapt the subsequent assessment to the specifics of each type (epistemological, model, parametric, random).

An important aspect was the chosen field of study and its features, which included: the level of reliability of power equipment, stability of energy generation, constant operating modes of generating and distribution equipment, professionalism and competence of workers, regular renewal

of fixed assets (including planned and current repairs), close attention to working conditions and compliance with safety rules in places of increased danger (generation facilities), etc. In view of this, an assessment was presented in four stages or eight steps: description of the measurement and its model; analysis of input quantities and their uncertainty; correlation analysis; calculation of the total standard uncertainty; calculation of the values of the output value; calculation of the expanded uncertainty and presentation of the final result of the calculations (Fig. 1). Each stage of the presented uncertainty assessment was aimed at obtaining general information about risks and their impact on the processes of forming, ensuring and strengthening the economic security of enterprises.



**Figure 1.** Uncertainty assessment process

**Source:** developed by the authors

The methods are also based on the method of analysis of hierarchies (AHI) (Saaty, 1980). When building a hierarchical model, it was necessary to determine the composition of the most important components of the Unified Energy System and the factors that affect the uncertainty of its development prospects. The number of both should not be large, so as not to clutter the model with insignificant details, not to complicate the preparation of initial information and the interpretation of the calculation results. Guided by this, the characteristics of the following components were selected, which are part of (full or partial components) the main types of work for all the enterprises studied in this work: coal mining; natural gas mining; electricity production by nuclear carriers; electricity production by hydro carriers; heat energy production using combustible substances; use of alternative renewable

energy (which can be estimated through their share in the production of electricity and heat energy); Thus, the six main characteristics (electricity production; gas production; coal production; alternative energy; heat production; oil product production) of the Unified Energy System (UES-U) that shape its dynamics were studied for the enterprises of the Unified Energy System (JSC NNEGC Energoatom, NEC Ukrenergo, JSC Ukrhydroenergo, JSC NJSC Naftogaz of Ukraine, PJSC DTEK Kyiv Regional Networks, JSC DTEK Zakhidenergo, JSC DTEK Dniproenergo and PJSC Centrenergo).

A 9-point comparison scale was used, in which each score was given a weight in accordance with the impact on uncertainty and its impact on the level of economic security of enterprises. The factors of the probability of coincidence of events A and B were applied according to the

gradation, under which these events are different and radically different from each other. In this case, each of their coincidences has its own score on the comparison scale. It was proposed to determine odd coincidences, where 9 points means that factor A absolutely exceeds factor B in significance; 7 – that A is clearly more important than B; 5 – A is much more important; 3 – A is slightly more important than B; 1 – A and B are equally important. Even scores 8, 6, 4 and 2 express intermediate gradations of assessments. A necessary requirement when using the hierarchy analysis method was compliance with transitivity and good indicators of consistency of the initial data in the matrices of pairwise comparisons. If these requirements were violated, which is especially often the case when working with a group of experts (representatives of enterprises involved in determining indicators, audit companies, state authorities, etc.), other methods were used. It is worth noting that the experts were heads of departments of the specified enterprises, who were surveyed in 2024 in an online format through an anonymous questionnaire in compliance with ethical standards, distributed by the strategic planning department of each enterprise (National commission for the protection of human subjects of biomedical and behavioral research, 1979). The representatives of the experts in the analysis were employees of the companies (under the conditions of participation, the information is confidential and makes distribution impossible) and general data of the State Statistics Service of Ukraine (2024). If paired assessments are given by one expert, then performing a fairly simple preliminary ranking procedure allows avoiding transitivity violations and keeping the consistency indicators of pairwise comparison matrices within the required limits. This procedure was also applicable during the work of a group of experts.

## ■ Results and Discussion

The Unified Energy System of Ukraine is a complex hierarchical system that operates in conditions where the initial data are not defined, local goals are not coordinated, and the internal organisation is disrupted due to new properties that arise when achieving a global goal. The analysis involved enterprises with different forms of ownership, covering a wide geography of activity and representing the main areas of the energy sector of Ukraine, in particular: JSC NNEGC Energoatom, NEC Ukrenergo, JSC Ukrhydroenergo, JSC NJSC Naftogaz of Ukraine, PJSC DTEK Kyiv Regional Networks, JSC DTEK Zakhidenergo, JSC DTEK Dniπροenergo and PJSC Centrenergo. For energy enterprises, the most inherent and effective is the original method that allows assessing the probability of the occurrence of predicted events through a matrix of posterior forecasting errors and a matrix of refined estimates obtained on the basis of new information. The product of these matrices carries complete information about the errors inherent in the expert when making forecasts. The vector of probabilities of the occurrence of predicted events is an eigenvector of this complete matrix of forecast errors, which cor-

responds to its unit eigenvalue. When assessing forecasts as indicators of forecast uncertainty, the standard deviation of individual forecasts relative to the median agreed forecast was used (Bahuguna *et al.*, 2022; Andriushchenko & Lezina, 2024). A probabilistic-statistical approach is also widely used in energy research. The dependence of demand and prices for energy resources in the region is studied in the context of the complexity of the interrelationships of the economy and energy and the increase in uncertainty about the future development of the country and territories. The behavior of energy suppliers and large consumers is simulated depending on changes in energy prices, the capabilities of existing and new technologies, energy saving measures, etc.

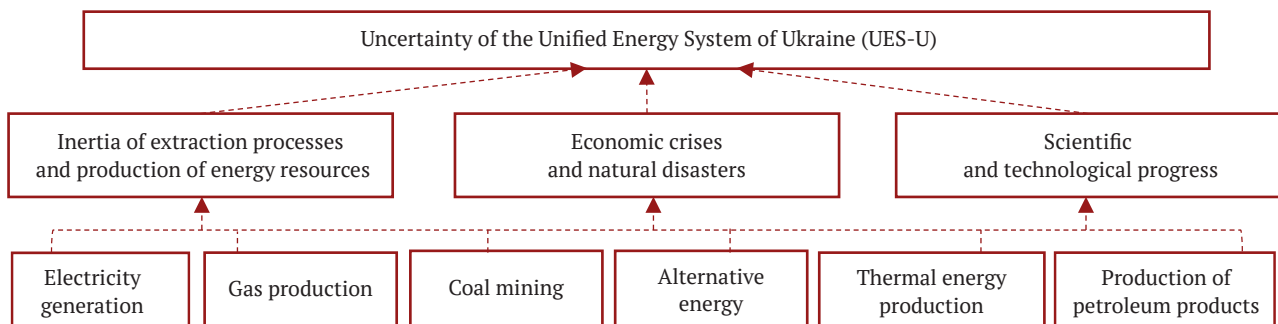
Accordingly, for the task of assessing the levels of uncertainty of information required for forecasting the prospects for the development of energy enterprises, the probabilistic-statistical approach will be inoperable due to rapidly changing external conditions, when retrospective information quickly becomes outdated. When building forecasting models of the fuel and energy complex and its branches, the problem of assessing the adequacy of the model output data to the forecasting goals, as well as the possibilities of improving their quality in information aspects, is relevant. At the initial stages of modeling, it is necessary to have an idea of what size and complexity of models it makes practical sense to develop and apply. The pursuit of size and complexity should not be an end in itself – only a harmonious combination of model and information components will contribute to the success of forecasting research. Given the increasing volatility of social and economic processes in the environment in which the enterprises of the unified energy system operate and develop, the uncertainty that accompanies attempts to forecast its prospects is also growing. Therefore, the pursuit of quantitative accuracy of forecasts loses practical significance (Korobskyy & Siroshtan, 2018).

Accordingly, it is appropriate to identify means, indicators and tools with which it is possible to record the proportionality of model constructions and the quality of available information. The difficulty lies in the fact that this information is of a qualitative nature (including completeness, reliability and other aspects). Its quantitative content (set of indicators, their dynamics over time) is of secondary importance. Among the methods that work with qualitative indicators, it is worth noting the method of analysis of hierarchies (AHI), developed by the American mathematician T.L. Saaty (1980). Based on pairwise comparisons of the influence of features or factors, it ultimately forms a generalised assessment of their significance, expressed in dimensionless units (fractions or percentages). AHI is just right for solving the task of qualitatively assessing the information component of forecasting studies of the Unified State Economic System, since this problem lends itself well to hierarchical structuring. Since for many tasks of economics and management related to relations between people, it is not possible to operate with clearly defined results of

numerical measurements, the MAI in such a situation gives researchers the opportunity to obtain stable and realistic results, having as initial information comparative expert assessments of a qualitative nature, obtained by pairwise comparison of factors and indicators.

Factors affecting the uncertainty of forecasts include the following – volatility of energy consumption and production caused by crisis phenomena in the world economy and natural disasters; inertia of energy extraction and production processes; scientific and technological progress that determines the competitiveness of traditional and new alternative energy sources, including renewable ones. These factors have different effects on the uncertainty of forecasting results. The method of analysis of hierarchies (AHI) by expert comparison of the influence of a particular factor of each pair of indicators allows us to numerically assess the generalised uncertainty of forecast estimates in relative units (or percentages). Thus, a basis appears for ranking the reliability (as a value, inverse uncertainty) of

forecasts. The above characteristics of the Unified Energy System form the lower level of the hierarchy, and the factors – the middle one. The model closes at the upper level with a final indicator – uncertainty (Fig. 2). The hierarchy constructed in this way is complete, which simplifies the work with it and the interpretation of the obtained calculation results, and increases their reliability. After constructing the hierarchy, it is necessary to conduct a pairwise evaluation of the factors and enterprises of the Unified Energy System of Ukraine and record the obtained estimates in the form of inversely symmetric matrices. This method is universal, although it is worth noting that other scientists, such as M. Potomkin *et al.* (2020) and M.B.G. Isaksen & K.R. McNaught (2023), use a wider range of alternatives. In their work, seven factors are identified, which leads to a greater variety of possible combinations between the hierarchy and alternatives. In this case, experts must evaluate and predict the combination of a larger number of coincidences, which leads to a larger analysis.



**Figure 2.** Hierarchy of UES-U enterprises

**Source:** developed by the authors

To solve the task of finding the uncertainty levels of the forecasts of the enterprises of the Unified Energy System, a  $3 \times 3$  inverse-symmetric matrix for uncertainty and three  $7 \times 7$  matrices for factors affecting uncertainty will be filled with pairwise estimates. All their elements are evaluated by experts. It is worth noting that such opinions differ. And in the work of O.O. Zrobok (2023), military aggression against Ukraine is also included in the uncertainty factors, which is a significant factor. The author gave this element significance due to the lack of a specific time frame and in connection with the significant loss of a large number of fixed assets of energy enterprises due to attacks. In the case when any factor can be associated with a quantitative indicator, the values of the latter are converted into qualitative estimates using a 9-point scale used in the MAI (Saaty, 1980). When filling in the matrix of pairwise comparisons of factors to describe their impact on the final indicator, one should be guided by the following result of the preliminary ranking procedure: crises – inertia – scientific and technological progress. In this case, the significance of the first factor in comparison with the second exceeds the significance of the second factor in comparison with the third, which is expressed by the following pairwise estimates:

$$\begin{bmatrix} 1; \frac{1}{3}; 3 \\ 3; 1; 6 \\ \frac{1}{3}; \frac{1}{6}; 1 \end{bmatrix}. \quad (1)$$

In this matrix, the factors in the rows and columns are arranged in the same order as in the previous formula (1). The normalised eigenvector of this matrix, corresponding to its largest eigenvalue, is [0.250, 0.655, 0.095], and the consistency ratio (SR) is 0.016, which is significantly less than 0.1 – the permissible upper limit of the consistency ratio values. Data on the significance of the components of the OES-U for the factors are presented in the form of matrices, the columns and rows of which correspond to the components of the OES-U in the order specified in formula (1). For the first factor – inertia of the processes of extraction and production of energy resources – the ranked series (in descending order) looks like this: electricity – thermal energy – coal – gas – oil – oil products – alternative energy sources, and the matrix of pairwise comparisons – with its own normalised vector [0.351, 0.066, 0.104, 0.160, 0.031, 0.241, 0.045], the value of relative consistency (VU)=0.025. The order of the components of the Unified Energy System-U corresponds to the order of formula (2):

$$\begin{bmatrix} 1; 5; 4; 3; 7; 2; 6 \\ \frac{1}{5}; 1; \frac{1}{2}; \frac{1}{3}; 3; \frac{1}{4}; 2 \\ \frac{1}{4}; 2; 1; \frac{1}{2}; 4; \frac{1}{3}; 3 \\ \frac{1}{3}; 3; 2; 1; 5; \frac{1}{2}; 4 \\ \frac{1}{7}; \frac{1}{3}; \frac{1}{4}; \frac{1}{5}; 1; \frac{1}{6}; \frac{1}{2} \\ \frac{1}{2}; 4; 3; 2; 6; 1; 5 \\ \frac{1}{6}; \frac{1}{2}; \frac{1}{3}; \frac{1}{4}; 2; \frac{1}{5}; 1 \end{bmatrix} \quad (2)$$

For the second factor – the state of war in the country and natural disasters – the ranked series is as follows: oil – oil products – electricity – non-traditional energy sources – coal – gas – thermal energy. The pairwise comparison matrix is represented by the formula (3) with the normalised eigenvector [0.160, 0.351, 0.045, 0.068, 0.104, 0.031, 0.241] and the value of relative consistency (RC)=0.025:

$$\begin{bmatrix} 1; \frac{1}{3}; 4; 3; 2; 5; \frac{1}{2} \\ 3; 1; 6; 5; 4; 7; 2 \\ \frac{1}{4}; \frac{1}{6}; 1; \frac{1}{2}; \frac{1}{3}; 2; \frac{1}{5} \\ \frac{1}{3}; \frac{1}{5}; 2; 1; \frac{1}{2}; 3; \frac{1}{4} \\ \frac{1}{2}; \frac{1}{4}; 3; 2; 1; 4; \frac{1}{3} \\ \frac{1}{5}; \frac{1}{7}; \frac{1}{2}; \frac{1}{3}; \frac{1}{4}; 1; \frac{1}{6} \\ 2; \frac{1}{2}; 5; 4; 3; 6; 1 \end{bmatrix} \quad (3)$$

For the third factor – scientific and technological progress – the following series was obtained: alternative energy sources – electricity – petroleum products – gas – oil –

thermal energy – coal. The matrix of pairwise comparisons for scientific and technological progress is as follows, represented by formula (4):

$$\begin{bmatrix} 1; 4; 3; 6; \frac{1}{2}; 5; 2 \\ \frac{1}{4}; 1; \frac{1}{2}; 3; \frac{1}{5}; 2; \frac{1}{3} \\ \frac{1}{3}; 2; 1; 4; \frac{1}{4}; 3; \frac{1}{2} \\ \frac{1}{6}; \frac{1}{3}; \frac{1}{4}; 1; \frac{1}{7}; \frac{1}{2}; \frac{1}{5} \\ 2; 5; 4; 7; 1; 6; 3 \\ \frac{1}{5}; \frac{1}{2}; \frac{1}{3}; 2; \frac{1}{6}; 1; \frac{1}{4} \\ \frac{1}{2}; 3; 2; 5; \frac{1}{3}; 4; 1 \end{bmatrix} \quad (4)$$

With a normalised eigenvector [0.241, 0.068, 0.104, 0.031, 0.351, 0.045, 0.160] and a relative consistency value (RS)=0.025. As a result of the presented calculations using formulas 1-4, we can say that the original data are of fairly high quality - all matrices satisfy the transitivity requirements, and their relative consistency indicators are much less than 0.1. After multiplying on the right side of the 7 × 3 matrix, consisting of columns of normalised eigenvectors of all three factor matrices, by the normalised eigenvector of the uncertainty matrix of forecasts of the components of the Unified Energy System-U, a vector was obtained, the components of which are the weights (numerical indicators of relative importance) of the seven considered components, which form the lower level of the hierarchy in Figure 1 – 0.215, 0.254, 0.065, 0.087, 0.110, 0.085, 0.184. As a result, the following ordered sequence of uncertainty indicators in relative values was obtained (Table 1)

**Table 1.** Uncertainty indicators of the components of the UES-U

| Component                                | Uncertainty, % |
|--|----------------|
| Coal mining                              | 25.4           |
| Natural gas mining                       | 21.5           |
| Electricity generation (nuclear energy)  | 18.4           |
| Electricity generation (hydro energy)    | 10.9           |
| Thermal energy generation (combustibles) | 8.7            |
| Energy generation (alternative sources)  | 8.5            |

**Source:** calculated by the authors

It is noticeable that the components of the unified energy system of Ukraine are clearly divided into two groups by the magnitude of uncertainty, which are accompanied by forecasts of their development. This is of important methodological importance for obtaining forecasts of the development of the unified energy system of Ukraine as a whole and with the minimum, if possible, level of uncertainty. This is possible if the modeling of the Unified Energy System of Ukraine begins with components with a lower level of uncertainty, and then complements the model with options for other remaining energy facilities, related (co-ordinated) with the options of the industries from the first group (Korcheva & Kriuchkova, 2015).

It is also worth noting that the level of uncertainty in percentages for such energy components as coal and natural

gas, the indicators of which are quite large, therefore it is worth considering the opinions of other scientists, such as Yu.T. Matveeva & I.A. Vakulenko (2022) and H. Pudycheva (2021), who paid significant attention to the processes of decarbonisation of the energy sector of Ukraine. Thus, in the study of the first scientist, the environmental aspects of enterprise development are dictated by the increasing use of green energy sources, which forms their social responsibility and support for a thrifty attitude to available resources. The analysis of recent publications in the most authoritative scientific publications highlighted in the work demonstrates a high level of interest among the scientific world community in these issues, and the high level of citations indicates the relevance of the issues studied. In this case, the general trend towards decarbonisation of

economic activities of enterprises on the global scale forms a modern orientation towards socially responsible conduct of business. In continuation of the above analysis, the second author further developed the presented theory of decarbonisation in the direction of adding aspects of decentralisation and digitalisation in these processes, which is formed as a concept of “3D”. In this direction, the author determines the importance of autonomy in making decisions on the economical use of energy resources using modern tools of digital transformation, which form an updated paradigm of energy market trading. In this case, the sustainable development of energy enterprises through decarbonisation, decentralisation and digitalisation, prompts the need for a complete reformatting of the market, which further changes the chain from production to final consumption of any types of energy.

Over the past six years (since 2019), the development of our state has had a vector towards the European Union, which encourages a reduction in carbon dioxide emissions into the atmosphere. From the point of view of the economy and strengthening the economic security of energy enterprises, this issue has not been widely analysed. The results of the research by V. Omelchenko *et al.* (2022) were correct, who identified the features of changes in economic indicators as a result of the implementation of decarbonisation of the energy sector. These changes are significant factors of uncertainty, especially in the aspect of the presented research on the involvement of investors in energy transition projects. In this case, it is the theoretical foundations of uncertainty and the theory of fuzzy sets that play a significant role in predicting the results of financial investments and forming the prospective level of receipt of income from investments. A proposal has been formulated for expected results, which include decarbonisation of the energy sector through the transition to low-carbon energy systems, development of clean electricity and heat, increased energy efficiency and energy conservation in all sectors of the economy and at civilian facilities.

In continuation of this issue, the results of K. Gura & V. Petruk (2021), which are based on the results of the global trend towards decarbonisation processes, are quite relevant. The highlighted aspects of the transition to new energy-saving technologies in the USA, European countries, Japan, and Asia are presented in a comparative form in accordance with climate changes, which record a constant stable increase in temperatures as a result of the use of carbon-containing energy sources. At the same time, there is an opinion that uncertainty is an important aspect of the enterprise's activities, because it is through risks and failures that it is possible to achieve the desired. The works of S.S. Horvey & J. Odei-Mensah (2023) and A. Qazi & M.C.E. Simsekler (2021) pay attention to risks as management factors in conditions of uncertainty, but the works are more generalising and theoretical in nature, which is not supported by analytical calculations.

The authors present a study of the theoretical basis of the theory of uncertainty and determine its further

development by implementing enterprise management through risks. But this opinion is not supported by practical results, which casts doubt on the proposed theory and, accordingly, leaves it at the level of a theoretical hypothesis. Instead, V. Grushko *et al.* (2021) pays great attention to uncertainty and its etymology, the work distinguishes uncertainty and risks, the causes and consequences of their occurrence. It already describes in more detail the practical aspects of the occurrence of risks in various forms of occurrence. In general, it is worth saying that the presented developments give an idea of the further development of the energy industry, taking into account the trends in the development of modern digital technologies, but requires significant elaboration of the consideration of aspects of uncertainty as an important factor in the probability of the occurrence of any events in the future.

## ■ Conclusions

The analysis of uncertainty for the enterprises of the unified energy system of Ukraine based on the selected stages of these processes helped to generalise information about the data and determine the structure of information search, its reliability and general characteristics. In the future, this contributed to the presentation of the development based on hierarchical modeling of a method for finding a comparative assessment of the uncertainty of the components of the unified energy system of Ukraine (by division into its main products - coal mining, natural gas, nuclear, hydroelectric power, thermal energy and energy from alternative sources) made it possible to distinguish between them two groups that have significantly different levels of uncertainty of the information necessary to obtain forecasts. The results obtained regarding the most uncertain components of the Unified Energy System of Ukraine include coal mining (25.4%), and the smallest – alternative energy sources – 8.5%, formed an idea based on the presented results regarding the most vulnerable areas of energy supply.

On the one hand, coal and natural gas production are characterised by high uncertainty, and on the other hand, the production of thermal energy, electricity (for various carriers), as well as alternative and renewable energy sources are characterised by moderate uncertainty. In this case, taking into account the theory of uncertainty, in the processes of modeling future promising directions of sustainable development of enterprises in the energy sector of Ukraine, it is worth simultaneously paying attention to the economic security of these enterprises, because its correctly formed and secured components also reduce the likelihood of risks in the future and, through the effect of synergy, contribute to minimising threats in general, which is especially relevant in conditions of martial law. That is, for future searches for the impact of risks in conditions of uncertainty, which is the basic provision of the theoretical concept of the system of economic security of enterprises, on the sustainable development of this industry, it is quite natural to conduct an in-depth analysis of these risks (if reliable information about them is available) as well as

harmonisation of their impact on the processes of economic activity of enterprises in order to eliminate any manifestations of negative impact. To do this, it is necessary to expand the search for scientific justification and feasibility of applying methods and tools of uncertainty theory to the processes of strengthening the economic security of enterprises and to deepen the foundation in the direction of improving methodological tools.

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#### ■ Conflict of Interest

None.

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## Вплив невизначеності на зміцнення економічної безпеки підприємств об'єднаної енергетичної системи України

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■ **Анотація.** Важливість вивчення питання процесів зміцнення економічної безпеки підприємств є досить обґрунтованою з огляду на військовий стан України та погіршення, в зв'язку з цим, економічного становища підприємств. Умови невизначеності є нормативними для суб'єктів господарської діяльності, але набувають нового сенсу та стають базовими для підприємств. Метою було формування теоретичного та методологічного підґрунтя процесів зміцнення економічної безпеки підприємств галузі енергетики України на основі теорії невизначеності. В роботі за основу обрано підхід щодо виокремлення етапів процесу оцінювання невизначеності, поділу основних продуктів підприємств на складові та використання методу аналізу ієрархій (MAI). В результаті аналізу широкого спектру наукової літератури було визначено, що в рамках методології економічної безпеки прийнято використовувати інструментарій теорії ризикології та відповідні методи і моделі менеджменту. В даній роботі було розкрито теорію й практику економічної безпеки енергетичних підприємств через концепцію теорії невизначеності. Виділено класифікацію за видами невизначеності та умовами її виникнення для підприємств об'єднаної енергетичної системи України (ОЕС-У), що допомогло обрати необхідний інструмент для аналізу. Отримані висновки мають важливе методологічне значення для прогнозів розвитку об'єднаної енергетичної системи України загалом та із мінімальним, по можливості, рівнем невизначеності. Це можливо, якщо моделювання ОЕС-У почати зі складових з меншим рівнем невизначеності, а потім доповнювати модель варіантами інших об'єктів енергетики, що залишилися, пов'язаними (узгодженими) з варіантами галузей з першої групи. Отримані результати дозволяють здійснювати цілісне прогнозування розвитку об'єднаної енергетичної системи України з урахуванням чинників економічної безпеки та мінімізацією впливу невизначеності

■ **Ключові слова:** сталий розвиток; ризики; метод аналізу ієрархій; енергетична галузь; економічна стійкість; моделювання розвитку енергосистеми; прогнозування

## Development of small tourism businesses under regional regulations in Croatia

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■ **Abstract.** The purpose of this article was to examine the impact of regulatory requirements on the economic performance and occupancy rates of small tourism enterprises in Croatia. The research methodology combined legal analysis of regulatory acts with statistical processing of data from eVisitor, the Croatian Bureau of Statistics, and international sources, which enables an assessment of the influence of regulations on the operations of small tourism businesses. Between 2015 and 2019, the development of small tourism enterprises in Croatia was characterised by a steady increase in the segment of private rooms and apartments: the number of arrivals rose from 4.934 million in 2015 to 8.135 million in 2019. At the same time, tourist apartments, after a short-term increase in 2016, demonstrated a gradual decline: arrivals decreased from 207,000 in 2015 to 198,000 in 2019 (after peaking at 230,000 in 2016), while the average length of stay shortened from 6.36 to 5.72 days. The subsequent period, 2020-2024, was marked by a sharp drop in indicators due to the COVID-19 pandemic; however, private apartments and family homesteads quickly regained their positions and became the cornerstone of post-pandemic recovery. In 2024, the number of arrivals in private rooms and apartments reached 8.3 million, while total tourism revenues amounted to USD 16.4 billion, surpassing pre-crisis levels. At the same time, tourist apartments continued to exhibit stagnation, indicating a gradual loss of competitive advantage. The research findings highlighted the need for an integrated approach to supporting small tourism businesses, which should include the simplification of regulatory procedures, reduction of administrative costs, and promotion of digitalisation through targeted investments and staff training. The obtained results may serve national and municipal authorities in formulating support policies for small tourism enterprises by improving information and technological infrastructure, developing digital skills, subsidising internet access, and implementing standardised digital solutions

■ **Keywords:** financial performance; electronic reporting; online booking; information and communication infrastructure; regulatory challenges; competitiveness

### ■ Introduction

Tourism is one of the key sectors of the Croatian economy, contributing significantly to the formation of gross domestic product (GDP) and employment generation. Small tourism businesses – including family-run hotels, apartments, private estates, and small guesthouses – play a vital role in preserving regional identity and creating a competitive offer that attracts international visitors. In recent years, however, the Croatian government and municipalities have intensified the introduction of new regulatory requirements aimed at enhancing market transparency,

improving service quality control, ensuring compliance with environmental standards, and balancing the load on the infrastructure of tourism regions. On the one hand, these changes align with contemporary challenges of sustainable development and the need for integration into the European legal framework. On the other hand, for small tourism businesses, the new regulations entail additional costs associated with licensing, facility modernisation, and adaptation to digital accounting and taxation systems. This generates risks of reduced profitability and unequal

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competition conditions between large hotel chains and small entrepreneurs, particularly in rural and less tourism-developed communities.

The analysis of academic sources reveals the multidimensional nature of issues related to the development of small tourism enterprises within the context of regulatory requirements and digital transformation. In a study by S. Asthana *et al.* (2022), the authors traced the evolution of academic discourse on family business in tourism and hospitality. They demonstrated that this segment is essential for preserving local identity and ensuring sustainable growth. However, it was found that family enterprises are often vulnerable to regulatory constraints and less inclined towards large-scale digitalisation, which underscores the need for tailored support instruments. H.M. Benassi (2025) emphasised the importance of cross-border cooperation in sustainable tourism development through the example of Interreg projects. The research confirmed that integration between Croatia and neighbouring countries not only generates economic benefits but also strengthens the capacity of local businesses to adapt to regulatory and technological changes. The author noted that joint initiatives reduce administrative and digital infrastructure costs.

The empirical study by I. Bujan (2020) provided evidence that owners of family tourism enterprises often perceive their business as part of their personal identity, which fosters resilience to market risks. However, the study also showed that this management model is frequently accompanied by a lack of strategic innovation and difficulties in complying with evolving regulations. Thus, I. Bujan's findings confirm the limited human and organisational resources of small operators, complicating their adaptation. In I. Čapeta's (2023) article, the role of family entrepreneurship as a catalyst for transformational change in Croatian tourism was examined. The author argued that these enterprises can stimulate local innovation processes but remain excessively dependent on external regulatory frameworks.

The research of S.S. Iriani *et al.* (2024) demonstrated that the competitiveness of tourism villages depends on rational resource utilisation and digital technology integration. The authors established that the long-term efficiency of such enterprises relies on the combination of traditional practices with modern management approaches. Findings from T. Miljak *et al.* (2025) showed a direct correlation between financial managers' decisions and the performance of small and micro-enterprises in Croatia. It was determined that financial planning errors or a focus on short-term gains significantly increase business vulnerability to regulatory changes, leading to the conclusion that sound financial management is fundamental for technological and organisational adaptation. I. Šulc & B. Fuerst-Bjeliš (2021) identified significant shifts in tourism trajectories in the post-pandemic world. The authors emphasised that COVID-19 acted as a catalyst for digitalisation but simultaneously exacerbated unequal access to technology among small enterprises. G. Vojković (2025)

explored the impact of Croatia's new legislation on beach concessions and "concessions on demand", concluding that the legal environment substantially transforms the economic opportunities of small tourism enterprises, often creating additional barriers to resource access.

Particular attention should be paid to studies examining the development of small and family hotels. For instance, L. Barić & I. Smoje (2022), using the case of Hotel Adria, demonstrated that effective management of small hotel facilities requires a balance between maintaining family traditions and adopting contemporary managerial tools. The authors stressed that service and marketing innovations are critical for sustaining the competitiveness of family-run hotels within regional markets. The study by J. Kranjcevic & S. Hajdinjak (2019) highlighted the phenomenon of "tourism urbanisation" using the examples of Poreč in Istria and Makarska in Dalmatia. The authors proved that rapid growth in tourist flows and infrastructural change lead to socio-spatial transformations that significantly affect local communities and small businesses. This research underscored the need to harmonise urbanisation processes with the requirements of local entrepreneurs and environmental sustainability. Thus, literature analysis confirms the interconnectedness of financial, organisational, and technological challenges faced by small tourism enterprises. At the same time, a research gap is evident regarding the systemic integration of regulatory barriers and the operational efficiency of tourism facilities.

The purpose of this article was to assess the impact of new regulatory requirements on the financial performance and occupancy rates of small tourism facilities in Croatia. To achieve this goal, the following tasks were set: to analyse contemporary regulatory changes in Croatia's tourism sector; to examine the dynamics of revenues and occupancy rates of small tourism facilities before and after the introduction of new regulations; to develop recommendations for improving regulatory policy to ensure the balanced development of small tourism businesses.

## ■ Materials and Methods

The study covers the period from 2015 to 2024 and is based on the analysis of Croatian legal acts, EU strategic documents, and empirical sources concerning the regulatory and technological transformation of the tourism sector. Two periods were identified: 2015-2019 as the baseline period prior to the introduction of new regulatory rules (reflecting the initial state and dynamics of small tourism business development), and 2020-2024, representing the combined impact of regulatory innovations and the COVID-19 pandemic on the functioning of small tourism facilities. At the national level, the following legislative acts were utilised: Law of the Republic of Croatia "On the Provision of Tourist Services" (2021), which comprehensively defines the conditions for organising and conducting tourism activities, determines the legal status of service providers, and outlines their obligations and responsibilities towards consumers. Law of the Republic of Croatia

“On Hospitality” (2024), which regulates the functioning of hotels, restaurants, guesthouses, apartments, and other accommodation and catering facilities; Law of the Republic of Croatia “On Tourist Associations and Promotion of Croatian Tourism” (2020), defining the competences of national and local tourism bodies responsible for strategic planning, marketing, and tourism promotion; Law of the Republic of Croatia “On Consumer Protection” (2023), governing contracts related to timeshare, long-term holiday products, and consumer information requirements; Law of the Republic of Croatia “On Obligations” (2023), regulating general contractual rules applicable where specific tourism law provisions are absent; Law of the Republic of Croatia “On Maritime Property and Seaports” (2023), establishing the legal framework for the use of maritime areas, coastal concessions, and port infrastructure operations. At the EU level, the research was grounded in the Small Business Act for Europe (2008), outlining strategic priorities for supporting small and medium-sized enterprises (SMEs), including the simplification of administrative procedures, promotion of innovation, and digitalisation. Additionally, statistical data and the eVisitor system enabled assessment of the engagement of small tourism enterprises in electronic reporting and online booking. Materials from Interreg Europe (2025) provided insight into practical approaches to interregional cooperation and knowledge exchange in tourism development and SME support. The Tourism Trends and Policies Report (OECD, 2022) offered an overview of contemporary trends in the tourism sector and regulatory initiatives in EU member states, while L. Kralj (2023) supplied data on digital skills, upskilling programmes, and technology adaptation needs among small enterprises.

The methodological framework employed a comprehensive approach ensuring analytical depth and multidimensionality. The formal-legal method was applied to reveal the internal logic and structure of Croatia’s and the EU’s tourism legislation, including Directive (EU) 2015/2302 of the European Parliament and of the Council (2015), Directive 2012/27/EU of the European Parliament and of the Council (2012), and World Bank (2020) guidelines on organised travel and related services. This enabled the identification of interrelations between national and EU regulatory requirements and their impact on small tourism enterprises. The comparative-legal method facilitated benchmarking Croatia’s approaches against the Small Business Act for Europe (2008), allowing assessment of the alignment between national regulation and European SME support and digitalisation standards. Statistical analysis of data from the Croatian Bureau of Statistics (n.d.) and eVisitor systems enabled identification of revenue and occupancy trends before and after the introduction of new rules governing licensing, categorisation, electronic reporting, and online booking. Reports such as Tourism in figures (2016–2024) and International Monetary Fund (2024) data were utilised to evaluate trends in small business development, digital tool adoption, and the effectiveness of regulatory reforms. This combination of

methods ensured a holistic analysis – assessing formal legal and institutional conditions while empirically confirming the impact of administrative and technological challenges on small tourism enterprises in Croatia. The findings provide a scientific basis for policy recommendations aimed at reducing administrative burdens and strengthening digital support for small businesses in the tourism sector.

The methodology employed for formulating recommendations was based on the integration of findings derived from formal-legal and empirical analyses. On this basis, a set of practical proposals was developed, aimed at supporting information and technological infrastructure, enhancing the digital competencies of small business owners, standardising digital interfaces, subsidising Internet access, and implementing shared technological solutions.

## ■ Results and Discussion

### Regulatory changes in Croatia’s tourism sector: Contemporary context

The Croatian tourism industry is governed by a comprehensive regulatory framework shaped by both national development imperatives and the country’s commitments to harmonising domestic legislation with European Union law. The cornerstone of the current legal architecture is the Law of the Republic of Croatia “On the Provision of Tourist Services” (2021), which establishes an integrated framework for the organisation and delivery of tourism activities. It defines the legal status of entities providing tourism services, delineates their obligations and responsibilities towards consumers, and ensures transparency through the establishment of the Central Register of Hospitality and Tourism Service Providers. This register operates electronically and facilitates oversight of entrepreneurial activities at both national and municipal levels. A notable innovation introduced by this law is the regulation of package travel and linked travel arrangements in alignment with Directive (EU) 2015/2302 of the European Parliament and of the Council (2015), which stipulates consumer protection standards and clarifies the obligations of travel organisers. Complementing this framework is the Law of the Republic of Croatia “On Hospitality” (2024), which prescribes operational standards for hotels, restaurants, guesthouses, apartments, and other accommodation and catering establishments. It establishes requirements for the categorisation and classification of tourism facilities, infrastructure standards, health and safety regulations, and the procedures for obtaining relevant permits and licences. This law is of particular significance to small tourism enterprises (STEs), as it defines the minimum standards applicable to private apartments and family-run homesteads, which form the backbone of Croatia’s small-scale tourism industry. Its practical application is especially pertinent in the context of Croatia’s integration into the single European tourism area, where harmonised safety and quality standards are essential.

The regulatory structure is further reinforced by the Law of the Republic of Croatia “On Tourist Associations

and Promotion of Croatian Tourism” (2020), which outlines the status, powers, and responsibilities of national and local tourism organisations tasked with strategic planning, marketing, and branding of Croatia’s tourism products. A defining feature of this law is its emphasis on a decentralised governance model, whereby substantial authority for tourism support and development is delegated to municipalities. For small businesses, this entails the necessity of engaging with both national regulators and local authorities, which frequently adopt supplementary legal acts reflecting regional development specificities. Additionally, the Croatian tourism legislation incorporates provisions from the Law of the Republic of Croatia “On Consumer Protection” (2023), which extends to the regulation of timeshare agreements, long-term holiday products, and information disclosure requirements concerning service conditions. Law of the Republic of Croatia “On Obligations” (2023) also plays a vital role, setting out the general principles of contract formation and serving as a reference framework in the absence of specialised tourism law provisions. Between 2022 and 2024, Croatia’s regulatory policy in the tourism sector acquired practical significance through a series of targeted reforms aimed at digitising tourist registration, strengthening licensing and quality

standards for accommodation facilities, revising tax and local fiscal regimes, and introducing more stringent environmental and spatial planning restrictions in coastal areas. Among the most impactful reforms was the implementation of a mandatory electronic registration and reporting system for accommodation providers – eVisitor (Unique in the..., 2022). The eVisitor system facilitates real-time data exchange among tourism market actors, local administrations, and tax authorities, standardises guest check-in and check-out procedures, and integrates with the tourist tax administration mechanism. Consequently, the digitisation of record-keeping has enhanced revenue transparency and improved the assessment of seasonal infrastructure loads, though it has simultaneously created additional administrative and technical barriers for small private hosts previously unfamiliar with such information systems.

The Small Business Act for Europe (2008) also plays a crucial role in shaping the regulatory environment, articulating principles of support for small and medium-sized enterprises, including the simplification of administrative procedures, facilitation of access to finance and technology, and promotion of digital transformation. Table 1 presents summarised data illustrating the impact of new regulatory requirements on the operations of Croatian STEs.

**Table 1.** Impact of new regulatory requirements on small tourism businesses

| Regulatory area                            | Specific changes, regulatory acts   | Primary objectives   | Potential impact on small tourism businesses  |
|--|---|--|---|
| Digital registration and accounting        | Mandatory registration in the eVisitor (n.d.) system, integration with tourist tax administration   | Enhancing market transparency, accurate accounting of tourist flows, control of revenue collection | Administrative burden on owners, need for digital skills, operational control of occupancy        |
| Licensing and categorisation               | Standardisation of apartments, private homes, family pensions; clarification of licensing and sanitary requirements (Law of the Republic of Croatia “On the Provision of Tourist Services”, 2021) | Improving service quality and safety, consumer protection  | Additional investment in modernisation, more complex licensing procedure                          |
| Tax and fiscal regulation                  | Establishment of local tourist tax rates; integration with eVisitor; tax amendments concerning short-term rentals   | Ensuring equitable tax burden, incentivising long-term rentals                                     | Potential decrease in profitability in the short-term rental segment, need for accounting support |
| Quality and infrastructure standardisation | Minimum technical, sanitary, and informational standards; accessibility requirements (Law of the Republic of Croatia “On the Provision of Tourist Services”, 2021)                                | Enhancing competitiveness and tourist trust  | Investment costs for modernisation, ensuring accessibility for all guest categories               |
| Environmental and spatial restrictions     | Restrictions on coastal area overcapacity, energy efficiency requirements, waste management (Law of the Republic of Croatia “On Tourist Associations and Promotion of Croatian Tourism”, 2020)    | Protecting ecosystems, sustainable territorial management, ensuring public access                  | Additional capital and operational expenditures, limitations on the exploitation of beach zones   |

**Source:** compiled by the author based on Law of the Republic of Croatia “On Tourist Associations and Promotion of Croatian Tourism” (2020), Law of the Republic of Croatia “On the Provision of Tourist Services” (2021)

Concurrently, legislative initiatives have sought to specify licensing and categorisation requirements for small accommodation facilities – including apartments, private homesteads, and family guesthouses. Amendments to sectoral laws and subordinate regulations in the hospitality domain have introduced mandatory minimum technical, sanitary, and informational standards, defined clear licensing procedures, and enhanced the role of local self-government in issuing and monitoring compliance with such permits. Although

these changes aim to improve service quality and consumer protection, they also impose additional operational costs on small-scale owners, who must either invest in compliance or risk legal vulnerability. Law of the Republic of Croatia “On Hospitality” (2024) and accompanying decrees issued by the Ministry of Tourism and Sport detail these requirements.

Particular attention must also be paid to environmental and spatial restrictions, which have evolved in response to the need to protect coastal ecosystems and manage the

spread of mass tourism along the shoreline. The adoption and revision of the Law of the Republic of Croatia “On Maritime Property and Seaports” (2023) introduced enhanced planning and environmental standards for facilities located within coastal zones. In pursuit of ecological sustainability and harmonisation with the European legal framework, Croatia has implemented a range of regulatory measures promoting energy efficiency and waste management in tourism infrastructure. These measures include mandatory energy audits for small and medium-sized enterprises with significant energy consumption, as stipulated by Directive 2012/27/EU of the European Parliament and of the Council (2012). Under this directive, high energy-consuming enterprises are required to conduct energy audits to identify potential savings.

In this context, the role of municipalities as key actors in implementing new regulatory requirements in Croatia’s tourism sector is particularly noteworthy. In practice, local self-government bodies are responsible for licensing and supervising small accommodation units, including apartments, private homesteads, and family guesthouses, as specified by the Law of the Republic of Croatia “On Hospitality” (2024). Municipalities act not only as administrative authorities issuing permits but also as inspection bodies authorised to record violations and impose sanctions, including licence revocation in cases of systematic non-compliance. Moreover, municipalities have assumed responsibilities for administering tourist taxes through the eVisitor system, which enables transparent revenue accounting and facilitates local budget planning. This, in turn, provides opportunities to allocate funds towards infrastructure development, maintenance of public spaces, and enhancement of regional tourism attractiveness. The reinforcement of municipal roles in regulating spatial and environmental standards, as established by the Law of the Republic of Croatia “On Maritime Property and Seaports” (2023), further heightens local accountability for the balanced use of coastal zones and the prevention of overexploitation. Thus, Croatian municipalities ensure the practical implementation of legislative initiatives, oversee adherence to service quality, environmental, and sanitary standards, and simultaneously bear political responsibility to local communities for maintaining equilibrium between economic growth and environmental preservation. This underscores the strategic importance of the municipal level within the tourism governance system and highlights the necessity of strengthening its institutional and financial capacities.

Findings from the conducted analysis indicate that contemporary regulatory changes in Croatia’s tourism sector

produce a dual effect: on the one hand, they enhance transparency and competitiveness; on the other, they generate new challenges for small operators related to financial burdens and organisational adaptation. These conclusions align with the research of J. Đurkin Badurina & D. Soldić Frleta (2021), who emphasised that perceptions of local tourism governance vary significantly depending on the intensity of tourism activity. In municipalities heavily dependent on tourism, residents tend to assess regulatory practices more critically, confirming the growing importance of municipal capacity-building for the effective implementation of new policies.

The results also demonstrate that environmental and spatial restrictions – particularly those introduced via the Law of the Republic of Croatia “On Maritime Property and Seaports” (2023) – serve as crucial instruments for managing the sustainable development of coastal territories. A similar trend was identified by D. Mance *et al.* (2020), whose panel analysis of municipalities revealed a direct correlation between tourism intensity and waste generation. Their findings are consistent with this study’s conclusions, confirming that environmental regulations possess a sound empirical rationale and are directed at mitigating tourism’s adverse effects.

Conversely, the present findings partially diverge from the perspective of N. Stojčić *et al.* (2024), who highlighted the adverse social consequences of short-term rental expansion, including resident displacement and housing price inflation. Although the analysis corroborates an increased regulatory burden within the short-term rental segment, the primary focus herein was on the financial and administrative implications of new norms for small tourism enterprises. This suggests that future research should adopt a more comprehensive approach by integrating socio-economic dimensions, combining analyses of revenues and occupancy rates with examinations of housing market impacts and community well-being.

#### **Income dynamics and occupancy rates of small tourism establishments before and after the implementation of new regulatory requirements**

Between 2015 and 2019, indicators characterising the development of small tourism accommodation facilities in Croatia demonstrated consistent growth in their contribution to the national tourism industry, alongside structural shifts preceding the introduction of new regulatory reforms (Gregoric & Pajić, 2016). Aggregated data indicate a substantial increase in demand within the segment of private rooms, apartments, and family houses, while the tourist apartment segment exhibited relative stability and a moderate decline towards the end of the period (Table 2).

**Table 2.** Dynamics of revenues and occupancy of small tourism accommodation in Croatia, 2015-2019

| Year | Tourist apartments, thous. arrivals | Tourist apartments, thous. overnight stays | Average length of stay tourist apartments (days) | Private rooms, apartments, thous. arrivals | Private rooms, thous. overnight stays | Average length of stay in private rooms (days) | Total tourism receipts (\$ bn) |
|------|-------------------------------------|--|--|--|---------------------------------------|--|--------------------------------|
| 2015 | 207                                 | 1,317                                      | 6.36   | 4,934                                      | 26,708                                | 5.41   | 8.60                           |
| 2016 | 230                                 | 1,407                                      | 6.12   | 5,810                                      | 35,546                                | 6.12   | 9.20                           |

Table 2. Continued

| Year | Tourist apartments, thous. arrivals | Tourist apartments, thous. overnight stays | Average length of stay tourist apartments (days) | Private rooms, apartments, thous. arrivals | Private rooms, thous. overnight stays | Average length of stay in private rooms (days) | Total tourism receipts (\$ bn) |
|------|-------------------------------------|--|--|--|---------------------------------------|--|--------------------------------|
| 2017 | 220                                 | 1,315                                      | 5.98   | 6,984                                      | 40,851                                | 5.85   | 10.63                          |
| 2018 | 213                                 | 1,251                                      | 5.87   | 7,682                                      | 43,382                                | 5.65   | 11.35                          |
| 2019 | 198                                 | 1,133                                      | 5.72   | 8,135                                      | 44,530                                | 5.47   | 11.97                          |

**Source:** compiled by the author based on Tourism in figures (2016; 2017; 2018; 2019; 2020), International Monetary Fund (2024)

In 2015, private apartments and rooms accounted for approximately 4.9 million arrivals and over 26.7 million overnight stays, corresponding to an average stay of 5.4 nights. By 2019, arrivals in this segment had risen to 8.1 million and overnight stays to 44.5 million – an increase of nearly 1.7 times. Meanwhile, the average length of stay marginally decreased from 5.4 to 5.5 nights, reflecting an intensification of tourism flows characterised by a higher frequency of short-term trips, typical of domestic and regional tourism. The expansion of the private accommodation sector occurred alongside a general rise in tourism revenues, which grew from an estimated USD 8.6 billion in 2015 to nearly USD 12 billion in 2019, demonstrating a positive correlation between the proliferation of small-scale accommodation and overall industry performance. By contrast, tourist apartments exhibited a different trend. In 2015, they recorded over 207,000 arrivals and 1.3 million overnight stays, but by 2019, these figures declined to 198,000 and 1.1 million, respectively. The average stay decreased from 6.4 to 5.7 nights, signalling reduced attractiveness compared to private accommodation. This tendency may be attributed to intensified competition from the private sector, which actively integrated into digital booking platforms, as well as to heightened price sensitivity among tourists favouring more flexible lodging options.

Given the dynamics of the industry's overall revenues, it can be concluded that private apartments and family-run homesteads were the primary drivers of Croatian tourism growth in the pre-crisis period. Their increasing share within the market structure was associated with several factors: the growing popularity of economically accessible and authentic forms of leisure, a shift in consumer preferences towards more personalised experiences, and an expansion

of supply resulting from both the legalisation and partial informality of the private accommodation sector (Tourism in figures, 2016; 2017; 2018; 2019; 2020). At the same time, the gradual decline in average length of stay indicated the need for market adaptation to evolving patterns of tourist behaviour and a reorientation towards shorter yet more frequent trips. Thus, the analysis of data from 2015-2019 revealed two key development trajectories: first, the intensive growth of the private rooms and apartments segment, which became the main channel for attracting tourists; and second, the stagnation of the tourist apartment category, which was gradually losing its competitive advantages (Glowka & Zehrer, 2019). These trends created the prerequisites for regulatory revisions in the 2020s, aimed at standardisation, the regulation of tax revenues, and quality control within a dynamically developing segment that simultaneously generated risks of inequality and overloading of local infrastructure.

The analysis of revenue dynamics and occupancy rates of small tourist establishments in Croatia during 2020-2024 demonstrated a complex and ambiguous development pattern, shaped by both external challenges (primarily the COVID-19 pandemic) and internal regulatory changes in the tourism business (Table 3). While 2015-2019 were characterised by steady growth in arrivals and overnight stays in private apartments, rooms, and small hotels, 2020 saw a sharp decline in these indicators. According to Tourism in figures (2021), the number of arrivals in tourist apartments and private rooms decreased by nearly half compared with the pre-crisis period, whereas the average length of stay increased, reflecting a shift in demand towards longer holidays under conditions of restricted travel opportunities. In 2020, total tourism revenues amounted to only USD 6.0 billion, nearly halving compared with 2019.

**Table 3.** Dynamics of revenues and occupancy of small tourism accommodation in Croatia, 2020-2024

| Year | Tourist apartments, thous. arrivals | Tourist apartments, thous. overnight stays | Average length of stay in tourist apartments (days) | Private rooms, apartments – arrivals, thous. | Private rooms, thous. overnight stays | Average length of stay in private rooms (days) | Total tourism receipts (\$ bn) |
|------|-------------------------------------|--|---|--|---------------------------------------|--|--------------------------------|
| 2020 | 44                                  | 310  | 6.2   | 2,993  | 24,181                                | 6.6  | 6.0                            |
| 2021 | 91                                  | 560  | 6.2   | 5,825  | 36,059                                | 6.2  | 11.9                           |
| 2022 | 188                                 | 1,039                                      | 5.7   | 7,540  | 44,182                                | 5.9  | 14.3                           |
| 2023 | 175                                 | 980  | 5.6   | 8,100  | 46,000                                | 5.7  | 15.9                           |
| 2024 | 170                                 | 950  | 5,6   | 8,300  | 47,500                                | 5.7  | 16.4                           |

**Source:** compiled by the author based on Tourism in figures (2021; 2022; 2023; 2024), International Monetary Fund (2024)

Recovery began as early as 2021-2022: the number of arrivals and overnight stays in small accommodation facilities demonstrated steady growth, while the average length of stay remained relatively high. This can be explained by the fact that private apartments and guesthouses became the most sought-after accommodation form in the post-pandemic period, offering greater privacy, distancing, and flexibility compared with large hotels. Moreover, during this period, regulatory changes came into effect, enhancing control over the legality of operations of small establishments. Municipal registers also recorded an increase in the number of registered apartments, as owners sought compliance to gain access to official support programmes. This contributed to greater business transparency and, consequently, higher tourism revenues, which in 2022 exceeded USD 14.3 billion, surpassing the pre-crisis level. In 2023, growth slowed. Although the number of arrivals in rooms and apartments continued to rise, the growth rate was lower than in previous years. The average length of stay declined, indicating a return of tourists to shorter but more frequent trips. Tourism revenues reached approximately USD 15.9 billion; however, part of this increase can be attributed to inflationary factors and higher average accommodation prices following the introduction of stricter regulatory requirements. In 2024, the situation in the small accommodation sector showed signs of stabilisation. The number of arrivals in private rooms and apartments reached 8.3 million people, 200,000 more than in 2023, while overnight stays increased to 47.5 million, up by almost 1.5 million. This indicates sustained demand for small-scale tourism enterprises despite the deceleration in growth. Meanwhile, the tourist apartment segment experienced a slight decline – arrivals fell from 175,000 in 2023 to 170,000 in 2024, and overnight stays from 980,000 to 950,000. The average length of stay remained stable at 5.6-5.7 days, confirming the trend towards shorter but regular trips. Aggregate tourism revenues rose to USD 16.4 billion, setting a new record high, although the increase compared with 2023 was moderate (+USD 0.5 billion). Overall, the 2020-2024 data revealed several key trends. First, the pandemic caused a short-term downturn; however, small accommodation establishments quickly regained their positions and became the foundation of post-pandemic growth (Camilleri & Valeri, 2022). Second, regulatory changes led to a structural transformation of the market: official registration increased, tax compliance improved, and income transparency was enhanced. Third, tighter controls and higher compliance costs imposed additional burdens on owners, which were partly reflected in rising prices and a reduction in average stay duration. Fourth, tourism revenues grew steadily in 2021-2023, yet this growth combined both real increases in tourist numbers and price effects.

The research findings indicating income volatility and heightened risks for small tourism enterprises during crisis periods are partly consistent with the conclusions of M. Cita *et al.* (2022), who, in their analysis of liquidity management in Croatian small and medium-sized construction

enterprises, emphasised the vulnerability of this business segment. The researchers found that under crisis conditions, small enterprises face limited capacity to maintain financial stability due to insufficient reserve funds and restricted access to financial instruments. This aligns with trends in the tourism sector, where similar dependence on seasonality and external shocks leads to revenue and occupancy declines, confirming cross-sectoral similarities in vulnerability mechanisms.

At the same time, the results of this study partly correlate with the conclusions of V. Kovsca *et al.* (2024), who examined contemporary financing mechanisms for small and medium-sized enterprises in Croatia. The authors highlighted that access to new financial instruments, including digital platforms and alternative lending schemes, allows small firms to adapt more flexibly to market changes. Comparable processes can also be observed among small tourism businesses: the adoption of innovative revenue management approaches and software-based support tools, introduced alongside new regulatory frameworks, partly offsets the negative effects of seasonal fluctuations. However, a key distinction lies in the tourism sector's limited responsiveness to financial flexibility without concurrent demand stimulation, underscoring the sector's specificity. The efficiency of business processes in small tourism enterprises is not only determined by regulatory adaptation but also by the internal organisation of operations. As Yu. Myronov & M. Myronova (2020) emphasised, evaluating business process efficiency in tourism requires a comprehensive methodological framework that integrates financial, operational, and customer-oriented indicators. This perspective supports the findings of our study, where financial constraints and limited managerial resources have been identified as key barriers to effective adaptation of small-scale accommodation providers.

Conversely, the observed results align to some extent with the findings of B. Morić Milovanović (2022), who explored the relationship between components of entrepreneurial orientation and performance among small and medium-sized enterprises. The author found that innovativeness, proactiveness, and risk-taking positively affect firms' competitiveness. For small tourism enterprises, similar characteristics manifest in their ability to swiftly adapt to new regulations and employ digital tools for booking and marketing, directly influencing occupancy rates and revenues. Nevertheless, this study's results show that not all enterprises managed to capitalise on these opportunities, which partially contradicts the author's conclusions regarding the universality of entrepreneurial orientation effects, as in tourism this influence largely depends on external demand and the regulatory environment. A general comparison suggests that the obtained results are not unique to tourism but reflect broader patterns in the functioning of small enterprises under crisis conditions. However, tourism's specificity lies in its stronger dependence on demand and regulatory changes, which explains partial discrepancies with some existing scholarly conclusions.

### Challenges of adapting small tourism enterprises to regulatory requirements

Following the introduction of new regulatory norms in Croatia's tourism sector, owners of small hotels, apartments, and private rooms faced a range of challenges concerning not only organisational but also financial aspects of operations. The most significant issue was financial constraints related to working capital shortages and the need to attract investment to meet new requirements for service quality and infrastructure modernisation. Research by the Croatian Tourism Association (HTA) (Tourism in figures, 2022; 2023) revealed that in 2022, 38% of small private accommodation establishments reported insufficient financial resources to bring their facilities into compliance with new standards on sanitation, energy efficiency, and digital reporting. These financial limitations not only slowed the pace of regulatory implementation but also heightened competitiveness risks for small enterprises compared with large hotel chains possessing more stable financing sources.

One potential solution is the creation of state and municipal support funds providing grant or subsidy programmes to cover modernisation costs, particularly in the areas of energy efficiency and waste management. In this context, the experience of Slovenia is instructive, where small hotels receive grants covering up to 50% of total project costs, facilitating faster adaptation to regulatory standards and reducing financial pressure on entrepreneurs (Interreg Europe, 2025). The development of municipal co-financing programmes may also serve as an effective tool for local support. Local authorities could partially subsidise the implementation of environmental and infrastructure standards, as stable and sustainable tourism development directly influences regional economic and social progress. In addition to financial constraints, administrative burdens constitute another significant factor complicating the adaptation of Croatian small tourism enterprises to new regulatory standards. Complex licensing, certification, and reporting procedures create substantial barriers, particularly for businesses with limited human resources unable to maintain dedicated compliance departments. According to World Bank data, in Croatia's tourism and related service sectors, over 300 professions are subject to state regulation, significantly exceeding the European Union average of around 200 (World Bank, 2020). This means that entrepreneurs must ensure their employees meet numerous qualification criteria and regularly confirm compliance through certification, demanding considerable time and financial resources. Tourism Trends and Policies (OECD, 2022) also confirmed that complex and fragmented regulatory procedures remain one of the main barriers to the development of small and medium-sized enterprises in the tourism sector, as administrative costs typically amount to 4-6% of total operating expenses, thereby constraining competitiveness and the overall quality enhancement of local tourism products.

Similar conclusions are presented in the study by I. Čapeta *et al.* (2023), who determined that for Croatian

small enterprises operating in the tourism sector, financial vulnerability and the absence of a long-term development strategy constitute the key factors undermining their resilience to changes in the regulatory environment. A comparative analysis of findings revealed that both studies emphasise the necessity of state support and the development of mechanisms facilitating access to credit resources, which aligns with the observations presented in this paper. However, the current research places greater emphasis on technological adaptation, whereas the work of I. Čapeta *et al.* prioritises sustainable development strategies. To alleviate administrative pressure on small tourism enterprises, it is advisable to implement a comprehensive set of measures aimed at simplifying and digitalising regulatory procedures. Mechanisms for regular assessment of regulatory efficiency should be introduced to identify outdated or redundant provisions, with a view to their subsequent abolition or modernisation. This would help reduce excessive regulatory burdens and enhance the flexibility of the system. An important complementary measure involves the establishment of advisory support centres for small businesses, providing informational and methodological assistance in complying with administrative requirements. Such support would facilitate timely licensing and minimise the risk of procedural errors. A convergence of findings is also observed with the research conducted by I. Raguž *et al.* (2025), who identified low levels of digitalisation and underdeveloped internet infrastructure in remote areas as the principal challenges for rural and regional tourism. The data confirm that inadequate network connectivity and high costs of information technologies significantly constrain enterprises' capacity to integrate into electronic booking and reporting systems. However, unlike the aforementioned study, which focuses on the strategic development prospects of rural tourism, the results presented herein primarily highlight the urgent issues of short-term adaptation to current regulatory requirements.

The transition towards digital technologies in the tourism sector has been marked not only by a growing number of online bookings but also by an increase in reporting obligations via electronic platforms, data management and accounting systems. Owners of small tourist establishments have been compelled to invest in IT infrastructure (such as online booking systems, channel managers, and digital accounting via eVisitor) and in enhancing the digital competencies of their staff to meet regulatory standards. The Croatian Ministry of Tourism and Sports reported that during the first nine months of 2023, 56.6% of all overnight stays in short-term rental accommodation were booked through online platforms (e.g., Airbnb, Booking, Expedia, Tripadvisor) – a 13.4% increase compared to the third quarter of 2022 (Republic of Croatia. Ministry of Tourism and Sports, 2024). This demonstrates a significant dependence of enterprises on digital sales channels, necessitating appropriate technical equipment and stable internet connectivity. Furthermore, according to L. Kralj (2023), as of 2023 approximately 59% of Croatia's population possessed

basic digital skills, exceeding the EU average (55.6%), yet still falling short of the 2030 targets set within the Digital Decade framework. This suggests that, while human capital is available, there remains substantial potential for capacity building, particularly among those employed in small-scale tourism businesses.

A particularly illustrative comparison can be made with the findings of O. Vlahović *et al.* (2024), who highlighted the pivotal role of electronic booking systems in transforming the business models of small tourism enterprises. Their research emphasises that the implementation of e-booking contributes to greater transparency, cost optimisation, and enhanced customer trust. The results of this study corroborate this trend, identifying the adoption of contemporary digital platforms as one of the key determinants of enterprises' compliance with new regulatory standards. Nevertheless, it was also established that, for the majority of small operators, high implementation costs and a shortage of qualified personnel remain major barriers – issues not examined in depth by O. Vlahović *et al.* A crucial component of overcoming these barriers involves the organisation of digital skills enhancement programmes for owners and employees of small tourism establishments. Training courses and workshops focusing on online booking management, digital reporting, data management, and cybersecurity can significantly lower the obstacles to technological adaptation. An additional challenge concerns limited access to reliable internet connectivity in remote coastal and island regions. Therefore, subsidising internet access and local IT services by the state and municipalities could serve as a necessary precondition for ensuring equitable access to digital services. Equally important is the unification and standardisation of digital interfaces and reporting frameworks. The development of a national data integration standard (API) between booking platforms, the eVisitor system, and other public registers would reduce technical complexity and administrative burdens for small businesses.

## ■ Conclusions

The regulatory and legal framework governing Croatia's tourism sector is characterised by its complexity, multi-layered structure, and dynamic nature. Its core comprises specific legislative acts defining the conditions for conducting tourism-related activities, supplemented by provisions of general commercial and contract law, as well as consumer protection regulations. A notable feature is the active role of municipalities in implementing and specifying regulatory requirements, which introduces a degree of regional variation in rules. At the same time, there is a clear trend towards strengthening control over the operations of small tourism establishments, mandating their registration, standardisation, and integration into digital accounting systems. This evolution of legal regulation aims to enhance the quality and transparency of tourism services; however, it simultaneously imposes additional financial and administrative burdens on small entrepreneurs,

necessitating further examination of these changes' impact on their economic resilience.

The analysis of income dynamics and occupancy rates of small tourism establishments in Croatia confirms a substantial transformation of the sector under the impact of regulatory reforms. Between 2015 and 2019, the segment of private rooms and apartments expanded significantly, with arrivals increasing from 4.9 million to 8.1 million and overnight stays from 26.7 million to 44.5 million. Tourism receipts also rose from USD 8.6 billion to nearly USD 12 billion. By contrast, the tourist apartment category gradually lost competitiveness, showing a decline both in arrivals and in the average length of stay. Following the introduction of new regulations and the outbreak of the COVID-19 pandemic in 2020, performance indicators fell sharply: private accommodation arrivals almost halved and overall revenues declined to USD 6 billion. At the same time, small establishments proved to be the most adaptive and became the driving force of recovery. By 2022, total receipts had already exceeded pre-crisis levels (USD 14.3 billion), and in 2024 they reached USD 16.4 billion, with private rooms and apartments recording 8.3 million arrivals and 47.5 million overnight stays.

The findings indicate that legalisation and digitalisation measures – particularly the eVisitor system and the spread of online booking – contributed to an increase in registered establishments and to greater income transparency. However, small accommodation providers continue to face significant barriers. The most pressing of these are financial constraints, with 38% of owners reporting insufficient resources for modernisation; complex and fragmented administrative procedures; and the need for improved digital competences, especially in remote regions with unstable internet connections. Addressing these challenges requires not only the internal efforts of enterprises but also active engagement from the state, municipalities, and European institutions, providing targeted financial support, regulatory simplification, and enhanced digital tools.

The study's limitations lie in its reliance on official statistics and international reports, which may not fully capture the informal practices of small businesses. Moreover, the temporal scope of the analysis restricts the ability to trace the long-term effects of regulatory changes. Future research directions should include a deeper examination of regional disparities in the impact of new regulations, as well as an exploration of the role of digital platforms and government support in shaping the resilience of small tourism enterprises in the post-crisis period.

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## Розвиток малого туристичного бізнесу в умовах регіональних регуляцій у Хорватії

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■ **Анотація.** Метою статті було дослідження впливу регуляторних вимог на економічні показники та завантаженість малих туристичних підприємств у Хорватії. Методологія дослідження ґрунтувалася на поєднанні правового аналізу нормативних актів та статистичного опрацювання даних eVisitor, Croatian Bureau of Statistics і міжнародних джерел, що дало змогу оцінити вплив регуляцій на діяльність малих туристичних підприємств. У 2015-2019 рр. розвиток малого туристичного бізнесу в Хорватії характеризувався стійким зростанням сегменту приватних кімнат та апартаментів: кількість приїздів збільшилася з 4934 тис. у 2015 р. до 8135 тис. у 2019 р. Водночас туристичні апартаменти після короткочасного зростання у 2016 р. продемонстрували поступове скорочення: приїзди зменшилися з 207 тис. у 2015 р. до 198 тис. у 2019 р. (після піку 230 тис. у 2016 р.), а середня тривалість перебування скоротилася з 6,36 до 5,72 доби. Подальший період 2020-2024 рр. позначився різким падінням показників унаслідок пандемії COVID-19, однак приватні апартаменти та сімейні садиби швидко відновили свої позиції та стали базисом постпандемічного відновлення. У 2024 р. кількість приїздів у приватні кімнати й апартаменти сягнула 8,3 млн осіб, а сукупні туристичні доходи – 16,4 млрд дол. США, що перевищило докризові показники. Водночас туристичні апартаменти зберегли тенденцію до стагнації, що вказує на поступову втрату їх конкурентних переваг. Результати дослідження вказують на потребу комплексного підходу до підтримки малого туристичного бізнесу, який передбачає спрощення регуляторних процедур, зниження адміністративних витрат та сприяння цифровізації процесів через інвестиції та навчання персоналу. Отримані результати можуть бути використані державними та муніципальними органами влади для розробки політики підтримки малих туристичних підприємств шляхом вдосконалення інформаційно-технологічної інфраструктури, навчання цифрових навичок, субсидування доступу до інтернету та впровадження стандартизованих цифрових рішень

■ **Ключові слова:** фінансові результати; електронна звітність; онлайн-бронювання; інформаційно-технологічна інфраструктура; регуляторні виклики; конкурентоспроможність

## Innovations in the field of urban transport on the example of electric bus programmes in France and the Netherlands

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■ **Abstract.** The purpose of the study was to find out the economic and environmental feasibility of implementing electric bus programmes in France and the Netherlands considering their impact on municipal budgets, environmental indicators, and social development. The analysis of financial indicators, the cost structure of total cost of ownership, and socio-environmental effects found that the payback period for investments averaged 8-10 years in France and 6-8 years in the Netherlands due to different levels of regulatory requirements and the development of charging infrastructure. The cost structure showed that the share of purchases of electric buses was 45% versus 30% for diesel buses, while energy and maintenance costs were lower (35% vs. 55%, respectively). In France, energy costs for electric buses were 0.18-0.22 EUR/km versus 0.35-0.40 EUR/km for diesel buses, and maintenance costs were 0.12-0.15 EUR/km versus 0.18-0.22 EUR/km; in the Netherlands, the difference was smaller, but remained in favour of electric buses. The environmental impact was determined by reducing carbon dioxide emissions by 900-1,100 tonnes per year per 100 buses in France and 800-1,000 tonnes in the Netherlands. Social results included an 8-12% increase in passenger traffic in French agglomerations and 6-10% in Dutch medium and small cities, the creation of 5-7 thousand jobs in France and 3-5 thousand in the Netherlands, and the development of innovative sectors – battery technologies in France and digital services in the Netherlands. It has been proven that a centralised financing model in France provides stability, while a decentralised concession system in the Netherlands promotes faster adaptation and competition between carriers. The practical significance of the study was to determine the conditions of economic feasibility and socio-environmental benefits of electric bus programmes, the results of which can be used by authorities, municipalities, and transport operators to improve sustainable transport strategies and investment planning

■ **Keywords:** municipal budgets; total cost of ownership; energy; maintenance; depreciation; payback period; regulatory requirements

### ■ Introduction

The need to study the electrification of urban transport has emerged as a result of a combination of environmental, economic, and social challenges, including high levels of greenhouse gas and toxic compound emissions from diesel buses, rising fossil fuel costs, limited municipal budgets, and the need to meet climate commitments under the European Union and the Paris Agreement. The challenge lies in finding balanced solutions that combine reducing environmental impact with the economic sustainability of transport systems, ensuring the effective use of

investments, developing innovative sectors and creating additional social benefits for urban communities.

A literature review has shown that there is a strong empirical base on urban transport electrification and related policies in Europe. As part of the comparison of innovative energy technologies in road transport, J. Kraciuk *et al.* (2022) examined the dynamics of electric mobility adoption in the European Union countries and the impact of regulatory incentives on market performance. It was found that the increased use of support tools accelerated

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the diffusion of electric vehicle (EV) in public fleets and reduced the energy intensity of transportation in the medium term. European review by R. Ruggieri *et al.* (2021) focused on integrating electric mobility into the smart city paradigm, with an emphasis on infrastructure and digital services. The researchers showed that the complexity of urban solutions (charging infrastructure, tariff models, mobility data) correlated with higher acceptance rates for users and an increase in the share of public transport trips. N. Pohuda *et al.* (2024) conducted a comprehensive analysis of the functioning of the passenger transportation market across airlines, road transport, and railways, providing methodological approaches aimed at improving market efficiency and sustainability.

In comparative study on Mediterranean public transport systems, S.M. Miraftebzadeh *et al.* (2024) analysed the sustainability of electrification, considering the energy profile of the region and Urban operating conditions. It was shown that with predictable electricity tariffs and optimised charging schedules, there was a noticeable reduction in CO<sub>2</sub> emissions and stabilisation of operating costs. F. Pollák *et al.* (2021) considered interregional cooperation as a factor in accelerating electric mobility in the “catching-up” regions of Europe. The results showed that policy synchronisation and access to EU structural funds increased the effectiveness of pilot electric bus programmes and strengthened the institutional capacity of local authorities.

Focusing on the institutional dimension, a report by the European Commission’s Joint Research Centre, M. Stepniak *et al.* (2022), summarised the landscape of research and innovation (R&I) in public transport. It was found that the presence of common taxonomies and data standards made it easier to compare the results of electric bus tests and accelerated the scaling of technical solutions. In the study of local innovations in the field of sustainable mobility, S. Minami (2021) analysed municipal governance practices and policy tools. It was confirmed that the ability of local governments to innovate and coordinate stakeholders was associated with a higher rate of adoption of electric mobility and better operational results.

M. Połom (2021) provided a critical overview of the development of electric urban transport in Poland, taking into consideration historical institutional conditions. The study found that the heterogeneity of implementation was explained by differences in access to funding, local capacity, and consistency of national and urban strategies. H. Kryshal *et al.* (2024) analysed the ecological and innovative transformation of the urban infrastructure of Ukraine in the context of post-war reconstruction. The results showed that the environmental benefits of electrification were combined with economic effects in the context of institutional coordination, the availability of grant tools and the development of local competencies. K. Vakulenko *et al.* (2024) examined the inclusiveness of passenger services and the environmental impact in Ukrainian cities. It was found that the introduction of electric rolling stock was accompanied by an increase in the availability of transportation for certain groups of users and a reduction in local air pollution.

T. Borysova *et al.* (2021) focused on the priorities of marketing, competitiveness, and innovative development of transport operators in the context of a sustainable city. The study showed that the focus on service quality and partnerships with manufacturers contributed to faster commercialisation of electric bus solutions and formed sustainable demand models. The conference article by G.P. Kostenko *et al.* (2023) evaluated the potential of vehicle-to-grid (V2G) for the sustainability of the energy system in Ukraine. The results showed that two-way transport-network interaction provided additional system benefits, subject to appropriate tariff policies, technical standards, and battery system protection. Taken together, the sources analysed provided a consistent picture of the results regarding the environmental and economic consequences of electrification, the institutional conditions for scaling, and the technological prerequisites for integrating electric buses into urban networks. However, the need for standardised operational performance metrics, cross-country panel estimates of Total Cost of Ownership (TCO) based on real municipal budgets, causal and long-term estimates of social effects with confounder control, and a comparative analysis of the impact of concession and public-private mechanisms on the financial stability of urban carriers remained open; these aspects were key gaps for further targeted research.

The purpose of the study was to find out the economic and environmental feasibility of urban transport electrification considering their impact on municipal budgets, environmental indicators, and social development. To achieve this goal, the following tasks were set: to trace the evolution of state and municipal policies of urban transport electrification in France and the Netherlands; to conduct a comparative analysis of the total cost of ownership (TCO) and the economic efficiency of implementing electric bus programmes; to assess the environmental and social results of implementing electric buses in the context of sustainable urban development.

## ■ Materials and Methods

The study was analytical and comparative in nature and was conducted in 2024, based on retrospective data from 2009, when the first regulations of the European Union in the field of clean transport development were adopted. This approach helped to trace the evolution of state and municipal strategies in long-term dynamics and to identify key stages in the development of programmes. France and the Netherlands were chosen as the subjects of analysis because of their representativeness in the European transport space and the difference in electrification models: in France, the emphasis was on centralised state regulation and large-scale investment, while in the Netherlands – on decentralised governance mechanisms and partnerships with the private sector. This combination allowed comparing two different approaches and evaluating their effectiveness within the framework of common decarbonisation goals.

To achieve this goal, the method of comparative analysis was applied, which was used to investigate differences in financial and organisational models for implementing electric bus programmes. The source of this method was the regulations of the European Union, in particular, Directive 2009/33/EC of the European Parliament and of the Council (2009), Directive 2014/94/EU of the European Parliament and of the Council (2014) and the European Commission (2019). The new EU rules on zero-emission buses (European Commission, 2023), which defined the conditions for switching to zero-emission vehicles, were considered separately.

In part of the French national legislation, Law of France No. 2015-992 (2015), Law of France No. 2019-1428 (2019) and the electric vehicles quota system in corporate fleets (French Republic, 2024) were analysed. Of particular importance were the provisions (Law of France No. 2021-1104, 2021) and the requirement to equip buildings with charging stations (French Republic, 2025) that established the institutional basis for the development of electric mobility. For the Netherlands, the study was based on the Ministry of Infrastructure and Water Management (2016), a regional policy for implementing zero-emission zones (Dutch Municipalities Association, n.d) and the draft law on the implementation of Renewable Energy Directive III (RED III) (Government of the Netherlands, n.d). A comparative analysis of these documents revealed the strengths and weaknesses of the centralised French model and the decentralised Dutch approach.

The content analysis method was used to systematise texts of official documents, municipal reports, and programme materials. In France, the key source was the programme (Île-de-France Mobilités, 2025), which defined mechanisms for financing and coordinating transport policy in the capital region. Reports from municipal associations (Dutch Municipalities Association, n.d) documenting the implementation of zero-emission zones were particularly important for the Netherlands. The content analysis identified strategic guidelines, determined regulatory requirements for the purchase and operation of electric buses, and systematised state and local incentive tools for transport operators.

The economic analysis method was used to estimate the total cost of ownership of TCO of electric buses and diesel buses. As part of this method, procurement, energy, maintenance, and depreciation costs were compared. The source basis was data (International Energy Agency, 2025), which contained indicators of the cost of energy carriers and the dynamics of energy markets. Additionally, the study used materials from the European Environment

Agency (EEA), in particular (European Environment Agency, 2025a) and (European Environment Agency, 2025b), which allowed comprehensively assessing the environmental consequences of transport operation. The financial component of the analysis was provided by reports (European Investment Bank, 2025a) and (European Investment Bank, 2025b), which reflected lending and subsidy instruments in the field of sustainable transport. This method determined the long-term economic efficiency of electric buses and the level of financial burden on municipal budgets.

The interpretation of the results was based on a combination of quantitative and qualitative approaches. The quantitative indicators obtained based on data from the International Energy Agency (2025) and the European Environment Agency (2025a; 2025b) were compared with qualitative factors reflected in the legislative acts and municipal programmes of France and the Netherlands. This generalisation of different types of sources ensured the complexity of the analysis without excessive duplication of data and helped to form a holistic assessment of the economic, environmental and social effectiveness of electric bus programmes. The combination of normative, financial and statistical materials improved the validity of the results and provided a multidimensional assessment of the impact on transport systems.

## ■ Results and Discussion

### Evolution of urban transport electrification policies in France and the Netherlands

Regulatory support for transport electrification processes in the European Union countries is a key factor for creating stable conditions for the development of the electric bus market. European documents set out a single regulatory framework within which national governments specify requirements and develop their own mechanisms for their implementation. In France and the Netherlands, these acts reflect the strategic goals of decarbonisation and simultaneously form the financial and institutional prerequisites for the practical implementation of innovative solutions in urban transport. The established system of regulatory guidelines helped to compare the approaches of the two countries and assess the level of integration of their policies into European climate priorities. A summary of the documents adopted at the EU, France and the Netherlands showed their importance in forming the framework conditions for the transition to zero-emission transport. Table 1 shows the key legislative acts and defines their content, which directly affected the pace of implementation of electric bus programmes in these countries.

**Table 1.** Current regulatory documents of the EU, France, and the Netherlands in the field of transport electrification

| Level | Year of adoption | Name of the document / act  | Main provisions relevant to transport electrification  |
|-------|------------------|---|--|
| EU    | 2009             | Directive 2009/33/EC “On the Promotion of Clean and Energy-Efficient Road Transport Vehicles” | Sets requirements for the consideration of environmental criteria in public procurement of buses and heavy transport.    |
|       | 2014             | Directive 2014/94/EU “On the Deployment of Alternative Fuels Infrastructure”                  | Defines the framework requirements for the development of the infrastructure of charging stations for electric vehicles. |

Table 1. Continued

| Level       | Year of adoption | Name of the document / act  | Main provisions relevant to transport electrification   |
|-------------|------------------|---|---|
| EU          | 2019             | European Green Deal   | Establishes the EU's long-term strategy to achieve climate neutrality by 2050, including the transport sector.  |
|             | 2023             | New EU rules on zero-emission buses                               | Provide for a mandatory transition to zero-emission city buses from 2035.   |
| France      | 2015             | Loi relative à la transition énergétique pour la croissance verte | Defines national guidelines for reducing the use of fossil fuels, encourages the renewal of fleets through subsidies and tax incentives.  |
|             | 2019             | Loi d'orientation des mobilités (LOM)                             | Introduces requirements for the development of charging infrastructure, in particular for buildings with more than 20 parking spaces; the regulations have been applied since 2025. |
|             | 2019             | Quotas for electric vehicles' share in corporate fleets           | Companies with more than 100 vehicles are required to provide an EV share of at least 20% from 2025 and gradually increase to 70% in 2030.  |
|             | 2021             | Loi Climat et Résilience  | Specifies measures to decarbonise transport, obliges municipalities to consider electric buses in purchases and expand zones à faibles émissions.                                   |
|             | 2025             | Obligation to equip non-resident buildings with charging stations | Obliges owners of buildings with more than 20 parking spaces to install at least one charging point and equip 5% of EV seats.   |
| Netherlands | 2016             | Voluntary Agreement on Zero Emission Bus Transport                | Assumes that all new buses from 2025 should be zero-emission, and the entire public transport fleet should be electric by 2030.   |
|             | 2025             | Introduction of zero-emission zones in cities                     | As of 2025, 15 cities have implemented zero-emission zones, and another 14 municipalities are planning until 2030.  |
|             | 2024             | Draft law on the implementation of RED III                        | Provides for the integration of updated requirements for the use of renewable energy in the transport sector; published in June 2025.   |

**Note:** EV – electric vehicle; RED III – Renewable Energy Directive III; zones à faibles émissions – low-emission zones introduced in French cities

**Source:** developed by the author based on data from the Directive 2009/33/EC of the European Parliament and of the Council (2009), Directive 2014/94/EU of the European Parliament and of the Council (2014), Law of France No. 2015-992 (2015), Ministry of Infrastructure and Water Management (2016), Law of France No. 2019-1428 (2019), European Commission (2019; 2023), Law of France No. 2021-1104 (2021), French Republic (2024; 2025), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

The analysis of Table 1 showed that EU policy forms the framework conditions within which France and the Netherlands implement their own transport electrification programmes. France focused on the legislative consolidation of long-term benchmarks and the introduction of mandatory quotas, which ensured stability in planning municipal purchases. The Netherlands, in turn, has adopted a more flexible model based on voluntary agreements with transport operators and the phased introduction of zero-emission zones. The European level of policy determined the final goals, while the national level set the pace and mechanisms for their implementation. A comparison of approaches showed that France focused on centralised regulation, while the Netherlands focused on partnership between the state and business, which

together increased the effectiveness of integrating the European framework into practice.

The implementation of public transport electrification programmes in the two countries had excellent organisational and financial priorities, which were reflected in the scale of investment, private sector participation, incentive system, and transition time horizons. To ensure a reasonable comparison of policies, these parameters were summarised, because they determine the effectiveness of the introduction of electric buses in urban transport systems. To this end, Table 2 presents a systematisation of the key characteristics of the national approaches of France and the Netherlands, which helped to identify the specifics of each model and their impact on the rate of transition to zero-emission transport.

**Table 2.** Comparison of the main parameters of implementation of electric bus programmes in France and the Netherlands

| Country | Scope of investment   | Share of private sector                                    | Main incentives (subsidies / benefits / funding)   | Transition time horizons  |
|---------|---|--|--|---|
| France  | Île-de-France Mobilités programme: approximately EUR 5.7 billion for fleet renewal and infrastructure | Limited, mainly due to tenders for the operation of routes | Subsidies for the purchase of electric buses, tax incentives, government grants for infrastructure | Partial transition of the fleet in 2025-2029, with gradual coverage of large agglomerations |

Table 2. Continued

| Country     | Scope of investment  | Share of private sector  | Main incentives (subsidies / benefits / funding)  | Transition time horizons   |
|-------------|--|--|---|--|
| Netherlands | Investment in charging infrastructure; USD 57 million for commercial charging stations | High, due to concession agreements with transport companies WW | SEBA scheme (subsidies up to USD 5,000 for zero-emission transport), financing of charging infrastructure | From 2025, all new buses are emission-free; by 2030, the fleet will be fully electrified |

**Note:** SEBA – subsidy scheme for zero emission commercial vehicles; zero-emission – zero emission transport; Île-de-France Mobilités – regional agency that coordinates transport policy in the French capital region

**Source:** developed by the author based on data from the Ministry of Infrastructure and Water Management (2016), Île-de-France Mobilités (2025), International Energy Agency (2025), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

An analysis of Table 2 showed that France focused on centralised public investment, while the Netherlands relied heavily on private carriers under the concession model. The French incentives were aimed at supporting municipalities and implementing large-scale regional programmes, which allowed for a systematic upgrade of the bus fleet and infrastructure. In the Netherlands, financial support was mainly provided to businesses and the development of charging infrastructure, which stimulated the active involvement of the private sector. Time differences were also established: France envisioned a gradual transition over several years, while the Netherlands fixed more stringent and clearly defined implementation deadlines. As a result, the French model was centralised and gradual, while the Dutch model was characterised by decentralisation and a focus on partnership between the state and business.

Results of the study by M. Aldenius *et al.* (2022) confirmed that in the UK and Sweden, the main barriers to the development of electric bus transport remained high capital intensity of infrastructure and weak coordination between central and local authorities. The researchers showed that the effectiveness of programmes depended on the consistency of management decisions at different levels of government. These findings correlate with the results obtained: in France, centralised financing and state control provided stability, while in the Netherlands, the emphasis was placed on integrating municipalities and private operators into the implementation of transport policies. D.A. Hensher (2021) emphasised that the transition to green bus fleet required the application of negotiated contracts between authorities and transport companies. It was proved that this tool reduced financial risks and contributed to the development of trust between the participants in the process. This concept was consistent with the Dutch concession model, under which the private sector received expanded powers while meeting state climate goals.

The comparison of strategies established that France relied on centralised support and large-scale national investment, while the Netherlands developed a decentralised model with the leading role of regional authorities and private businesses. Both approaches were integrated into the common climate priorities of the European Union, but differences in management mechanisms led to different speed and nature of programme implementation. This differentiation helped to adapt the electrification process to the specific economic and social conditions of each country.

The evolution of electrification policies in France and the Netherlands has shown that the effectiveness of the transition is determined by the ability to combine government incentives, municipal strategies, and private investment. It was this combination that formed the gradual prerequisites for the introduction of a new technological basis for public transport. The obtained conclusions created the basis for further analysis of financial and operational characteristics that determine the economic feasibility and practical effectiveness of electric bus programmes.

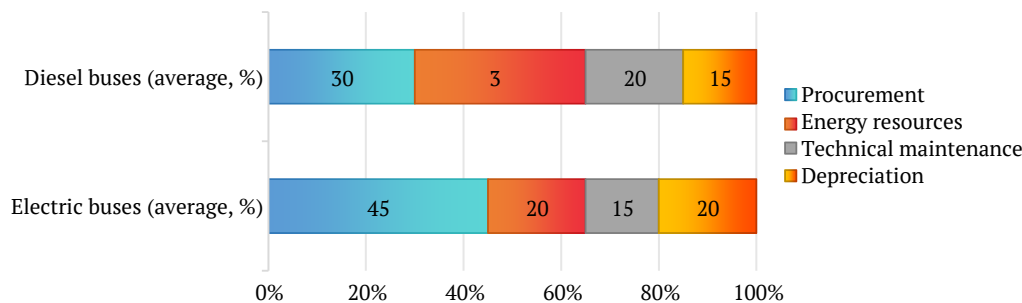
#### Comparative analysis of the cost of ownership of electric buses and diesel buses

The cost structure of TCO served as a basic indicator for assessing the economic efficiency of urban transport. In the case of electric buses and diesel buses in France and the Netherlands, it was formed in several key categories: vehicle purchases, energy costs, maintenance and depreciation charges. Generalisation of these parameters within the framework of the analysis identified the main patterns and demonstrated the presence of differences in the financial burden between different modes of transport, which were determined by both technical characteristics and features of energy markets.

Analysis of the cost structure showed that electric buses had higher initial purchase costs and a higher share of depreciation charges in TCO. Instead, diesel buses showed increased energy and maintenance costs, reflecting their reliance on fossil fuels and traditional technology solutions. The identified features confirmed different approaches to the development of financial strategies in France and the Netherlands, and determined the specifics of the long-term economic consequences of operating both types of transport. To detail these results, Figure 1 shows a systematisation of average cost values in TCO. Analysis of Figure 1 showed that electric buses were characterised by higher initial purchase costs – an average of 45% in the TCO structure, but had lower energy costs (20%) and maintenance (15%). Diesel buses, on the other hand, required less initial investment (30%), but their maintenance during the life cycle was more expensive due to the high share of energy costs (35%) and the higher frequency of repairs (20%). The ratio of depreciation costs also differed: for electric buses, this component was about 20%, while for diesel buses – only 15%. The difference confirmed that in the long run, electric buses have a better potential to reduce the total

cost of ownership. The generalised results highlighted the need to consider national characteristics of energy markets

and tax support instruments when assessing the economic feasibility of electric bus programmes.



**Figure 1.** Cost structure in TCO for electric buses and diesel buses on average by country (France and the Netherlands)

**Note:** TCO – total cost of ownership, which includes all costs associated with the purchase and use of a vehicle during the life cycle

**Source:** developed by the author based on data from Île-de-France Mobilités (2025), International Energy Agency (2025), European Environment Agency (2025a), European Environment Agency (2025b), European Investment Bank (2025a)

A detailed comparison of energy costs and maintenance helped to clearly identify the economic differences between electric buses and diesel buses in France and the Netherlands. These categories of expenses were crucial in the composition of TCO, as they formed the main financial risks and simultaneously identified potential benefits for

municipal budgets and transport operators. Generalisation of average indicators in terms of one kilometre travelled helped to objectively assess the long-term advantages of using electric buses, which confirms the relevance of their integration into urban transport strategies. For clarity, these parameters are shown in Table 3.

**Table 3.** Comparison of average energy costs and maintenance of electric buses and diesel buses in France and the Netherlands

| Country     | Type of transport | Average energy costs, EUR/km | Average maintenance costs, EUR/km | Share in TCO, % |
|-------------|-------------------|------------------------------|-----------------------------------|-----------------|
| France      | Electric buses    | 0.18-0.22                    | 0.12-0.15                         | 35              |
|             | Diesel engines    | 0.35-0.40                    | 0.18-0.22                         | 55              |
| Netherlands | Electric buses    | 0.20-0.24                    | 0.13-0.16                         | 38              |
|             | Diesel engines    | 0.37-0.42                    | 0.19-0.23                         | 57              |

**Note:** the table shows the average cost values per kilometre travelled

**Source:** developed by the author based on data from Île-de-France Mobilités (2025), International Energy Agency (2025), European Environment Agency (2025a), European Environment Agency (2025b), European Investment Bank (2025a)

Analysis of Table 3 showed that electric buses provided significant savings in both energy and maintenance costs compared to diesel buses. In France, the average energy costs for electric buses were only 0.18-0.22 EUR/km versus 0.35-0.40 EUR/km for diesel buses, which indicates a reduction in fuel costs by almost 50%. Maintenance costs were also lower – 0.12-0.15 EUR/km versus 0.18-0.22 EUR/km, which reduced the overall financial burden on municipal budgets. In the Netherlands, a similar trend was observed, although the difference between the cost of electric buses and diesel analogues was smaller (0.20-0.24 EUR/km versus 0.37-0.42 EUR/km), which was explained by the specifics of tariff formation for electricity and fuel. In general, electric buses showed consistently lower operating costs, which confirmed their superiority in terms of the life cycle and economic efficiency of transport systems.

The influence of incentive programmes on the economic attractiveness of electric mobility was confirmed in the paper by E. Macioszek (2021), who noted that tax

breaks and government subsidies formed key conditions for reducing the financial gap between traditional and electric transport. Similar results were confirmed in the analysis of French and Dutch practices: the first country focused on grants and preferential conditions for municipalities, while the second focused on compensation mechanisms for transport operators. This showed the universality of the impact of financial incentives on the development of electric bus programmes in various institutional environments. G.A. Ogunkunbi *et al.* (2021) found that the most effective model for the development of the electric transport market was formed under the condition of a combination of incentive and regulatory measures. It was shown that the simultaneous application of subsidies and regulatory requirements allowed reducing the financial risks of transport operators and increasing the competitiveness of electric buses in comparison with diesel vehicles. This result coincides with the practice of the Netherlands, where mandatory zero-emission

requirements were combined with support programmes for transport companies, creating favourable conditions for accelerated adoption of new technologies.

The structure of energy markets determined not only the cost parameters, but also the environmental characteristics of the implemented programmes. The French model was based on nuclear generation, which ensured tariff stability and low emissions for municipal operators. In the Netherlands, the focus was on gradually increasing the share of renewable energy sources, which helped to reduce the cost of electricity and increased the competitiveness of electric buses in the future. Thus, economic feasibility was combined with environmental benefits, creating the basis for long-term sustainable development of transport systems.

Similar dependencies were recorded in the study by P.A. Brehm & Y. Zhang (2021), where the example of the functioning of the Texas energy market showed that the organisation of the electricity market directly affected the efficiency of resource use and the level of environmental consequences. Comparing these results with the data obtained during the study in France and the Netherlands showed that regulatory mechanisms and the structure of the energy balance determined not only the cost of electricity for transport operators, but also the economic feasibility of switching to electric buses in the long term. The study by E.A.D. Galatoire *et al.* (2024) proved that the design of the electricity market in the Iberian region contributed to the development of a sustainable pricing system and created prerequisites for the large-scale introduction of renewable energy sources. The relationships identified between market organisation and the efficiency of

electrified transport development correlated with the results obtained in France and the Netherlands, where the long-term economic benefits of electric bus programmes were ensured by the stability of energy markets and support for state policies. This confirmed that the level of integration of the electricity market and transport policy determined not only cost indicators, but also the pace of transition to zero-emission transport.

#### Economic efficiency of electric bus programmes for municipalities

Financial models for the implementation of electric bus programmes determine opportunities and limitations for the development of urban transport, since the sustainability of investments and the speed of infrastructure modernisation depend on the financing structure. In France and the Netherlands, different approaches to managing financial flows have emerged, reflecting both the specifics of national budget systems and the level of private sector involvement. The study of these models allowed evaluating the effectiveness of centralised and decentralised mechanisms and determining their impact on the economic results of municipalities.

A comparison of financial models shows that in France, centralised investment and active participation of municipal programmes predominate, while in the Netherlands, concession agreements with private carriers play a key role. Both countries use international loans and grants, which reduces the burden on local budgets and ensures investment stability. Table 4 shows a systematic reflection of these financial models.

**Table 4.** Comparison of financial models for implementing electric bus programmes in France and the Netherlands

| Financial model                | France  | Netherlands   |
|--------------------------------|---|---|
| Centralised investments        | Significant government investments through national programmes and budget subsidies for the purchase of electric buses and the development of charging infrastructure | Limited application; the central government sets framework goals and provides co-financing for individual projects  |
| Municipal programmes           | Leading role of regional agencies (Île-de-France Mobilités) in financing procurement and coordinating transport strategies  | Municipalities participate in route planning, but the main funding is provided by private operators                 |
| Concession agreements          | Used in large cities, but the main focus is on state and regional funding   | Main financing mechanism: private operators invest in the fleet and infrastructure as part of long-term concessions |
| International loans and grants | Active attraction of funds from the European Investment Bank and EU funds for the modernisation of urban transport systems  | Used to support infrastructure projects, mainly in combination with private investment                              |

**Note:** Île-de-France Mobilités – regional agency that coordinates transport policy in the French capital region

**Source:** developed by the author based on data from the Ministry of Infrastructure and Water Management (2016), Île-de-France Mobilités (2025), European Investment Bank (2025a), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

Analysis of Table 4 showed that the French financial model was characterised by a high level of centralisation and significant participation of municipal programmes, which ensured stability in the implementation of long-term investment projects. In the Netherlands, the model was more decentralised and was based on the activities of private operators who made key investments through the concession system. International loans and grants played a supporting role in both countries, compensating for local

resource shortages and contributing to the expansion of infrastructure projects. A comparison of these approaches confirmed that the centralised model of France provided a controlled and uniform implementation of transport innovations, while the Dutch strategy created conditions for faster adaptation and stimulated competition between carriers. Thus, differences in financial mechanisms reflect a balance between government obligations and market instruments in the field of urban transport.

The results of the analysis are consistent with the conclusions of S. Alotaibi *et al.* (2022), which proved that transport investment and the development of railway and urban transport infrastructure directly affected regional economic growth. It was confirmed that the centralised investments typical of France contributed not only to the renewal of transport systems, but also created a multiplicative effect for the local economy. A similar dependence was observed in the Netherlands, where financial decentralisation provided faster investment turnover and increased economic performance in the medium term. The paper by V. Foster *et al.* (2023) emphasised that the quality and scale of infrastructure investments determine the final socio-economic results. The researchers showed that projects supported by international credit institutions reduced risks for local budgets and provided better conditions for their payback in the long term. These findings highlight those found in France and the Netherlands, where the resources of the European Investment Bank have played a supporting but important role in stabilising funding for transport programmes.

C. Wang *et al.* (2021) showed that global financial crises and associated market shocks significantly affected the investment attractiveness of the transport sector. The researchers proved that adaptation through flexible economic and regulatory strategies has reduced the risks of long-term infrastructure projects. This is consistent with

the experience of France and the Netherlands, where government support combined with international financial instruments reduced the vulnerability of transport programmes to external economic fluctuations. L. Haywood & M. Jakob (2023) highlighted the role of Emissions Trading Scheme 2 mechanisms in the process of decarbonising the European Union's transport sector. The researchers proved that strict regulatory mechanisms created prerequisites for reducing the payback period for investments in clean transport due to market incentives and reallocation of costs between market participants. This result highlights the differences found: in France, regulatory rigidity provided stability in planning, while in the Netherlands, preference was given to market instruments that accelerated the adaptation of transport operators.

The assessment of the return on investment in electric bus programmes helped to determine under what conditions high initial costs were transformed into long-term economic benefits for municipalities. In France and the Netherlands, these parameters differed significantly depending on the level of government support, the rigidity of regulatory requirements, and the degree of infrastructure development. Generalisation of indicators helped to identify specifics in terms of payback and cost dynamics during the transport life cycle. To systematise these data, Table 5 shows the key conditions that determined the economic efficiency of investments in electric buses in France and the Netherlands.

**Table 5.** Key conditions for the return on investment in electric buses in France and the Netherlands

| Parameter   | France   | Netherlands  |
|---|--|--|
| Payback period                                    | 8-10 years (depending on the level of subsidies and electricity tariffs)                             | 6-8 years (subject to compliance with the requirements for zero-emission transport)                          |
| Support level                                     | High: state subsidies, municipal grants, soft loans  | Average: compensation for operators, purchase benefits, concession agreements                                |
| Average reduction in operating costs over 5 years | 25-30%   | 30-35%   |
| Cost dynamics over the life cycle                 | High initial purchase costs ( $\approx 45\%$ TCO); gradual reduction in maintenance and energy costs | High initial costs ( $\approx 40\%$ TCO); rapid reduction of operating costs due to developed infrastructure |

**Note:** Zero-emission – zero-emission vehicle that meets EU environmental standards

**Source:** developed by the author based on data from the Ministry of Infrastructure and Water Management (2016), Île-de-France Mobilités (2025), International Energy Agency (2025), European Investment Bank (2025a), Dutch Municipalities Association (n.d.), Government of the Netherlands (n.d.)

Analysis of Table 5 showed that in France, the payback period for investment in electric buses was longer and averaged 8-10 years. This dynamic was attributed to high initial costs, which were gradually offset by reduced maintenance and energy costs during the transport life cycle. In the Netherlands, the payback period was shorter and amounted to about 6-8 years, which was ensured by strict regulatory requirements and a high level of development of the charging infrastructure. The French model was based on active government support, while in the Netherlands market mechanisms and a system of concession agreements with private operators played a key role. In both cases, a steady reduction in fuel and maintenance costs was a determining factor in economic feasibility.

N.T. Hosseinkhani (2025) proved that tariff policies played a crucial role in ensuring the economic stability of

transport systems. The researcher showed that changes in tariffs directly affected the payback period of infrastructure projects. This correlates with the patterns found in France and the Netherlands, where the stability or dynamism of tariff formation determined the speed of financial returns. The findings by D. Chattopadhyay & V. Foster *et al.* (2025) stressed that the regulatory challenges that accompanied the introduction of new energy and transport technologies required a balance between government control and market incentives. The researchers proved that the effectiveness of the policy depended on the ability to combine these elements. A comparison with the findings showed that centralised control prevailed in France, while the Netherlands used market instruments that reduced payback periods. D.T. Utomo & C. Dianita (2025) substantiated the use of a scenario approach to assess the economic

feasibility of infrastructure projects. The researchers noted that this method allowed considering the risks and variability of payback periods. This logic was consistent with the results of the analysis of France and the Netherlands, where adaptability to changes in financing and infrastructure development became an important factor in efficiency.

A summary of the results of the study confirmed that the implementation of electric bus programmes in France and the Netherlands created long-term economic benefits for municipalities. They were aimed not only at reducing operating costs, but also at creating new jobs, stimulating the innovation sector, and integrating advanced technologies into the transport infrastructure. The growing economic returns from electric buses formed a comprehensive framework for improving the sustainability of urban transport systems. Such dynamics opened up prospects for further assessment of broader socio-economic and environmental effects, which necessitated in depth analysis.

**Environmental and social benefits of urban transport electrification**

Reducing emissions of harmful substances is considered as one of the defining environmental effects that accompany the introduction of electric buses in urban transport. The transition from diesel buses to electric buses helps to reduce the amount of greenhouse gases and toxic compounds that previously had a significant impact on the environment and the health of the urban population. Similar trends were found for France and the Netherlands, but the level of reduction achieved depends on the structure of the energy balance and the specifics of each country’s transport systems.

To substantiate the results of the analysis, data on reducing CO<sub>2</sub>, NO<sub>x</sub> and particulate matter (PM<sub>2.5</sub>) emissions,

which are key indicators of the environmental impact of transport, were systematised. Generalised indicators allowed assessing the extent to which electric bus programmes in France and the Netherlands reduce the environmental burden in large urban agglomerations. Table 6 shows the average emission reductions per 100 electric buses, which allows directly comparing the environmental performance of the two countries. Analysis of Table 6 showed that electric buses in France provide a higher level of reduction in CO<sub>2</sub> emissions compared to the Netherlands, which is explained by the low-carbon structure of French energy focused on nuclear generation. In France, the average reduction in CO<sub>2</sub> emissions was approximately 900-1,100 tonnes/year per 100 buses, while in the Netherlands – 800-1,000 tonnes/year, that is, the difference reached about 100 tonnes/year in favour of French programmes. In the Netherlands, the reduction in emissions was also significant, due to a gradual increase in the share of renewable energy sources in the total energy balance. Nitrogen oxide (NO<sub>x</sub>) emissions in France decreased by 12-15 tonnes/year per 100 buses, while in the Netherlands – by 10-13 tonnes/year, which indicates a difference of about 2 tonnes/year between the implementation models of electric bus programmes. The decrease in particulate matter (PM<sub>2.5</sub>) was also noticeable: in France – 0.5-0.7 t/year, in the Netherlands – 0.4-0.6 t/year, which in both cases means a significant improvement in air quality in urban agglomerations. Thus, quantitative data confirm that electric buses are capable of annually reducing up to 1,100 tonnes of CO<sub>2</sub>, up to 15 tonnes of NO<sub>x</sub>, and up to 0.7 tonnes of PM<sub>2.5</sub> per 100 transport units, providing a significant reduction in the environmental burden and increasing the sustainability of urban transport systems (European Environment Agency, 2025a; 2025b).

**Table 6.** Reduction of emissions from the introduction of electric bus programmes in France and the Netherlands

| Indicator                                  | France (average values)          | Netherlands (average values)     |
|--|----------------------------------|----------------------------------|
| Reduction of CO <sub>2</sub>               | ≈ 900-1,100 t/year per 100 buses | ≈ 800-1,000 t/year per 100 buses |
| NO <sub>x</sub> abbreviation               | ≈ 12-15 t/year per 100 buses     | ≈ 10-13 t/year per 100 buses     |
| Particulate reduction (PM <sub>2.5</sub> ) | ≈ 0.5-0.7 t/year per 100 buses   | ≈ 0.4-0.6 t/year per 100 buses   |

**Note:** CO<sub>2</sub> – carbon dioxide; NO<sub>x</sub> – nitrogen oxides; PM<sub>2.5</sub> – particulate matter up to 2.5 micrometres in diameter  
**Source:** developed by the author based on data from the Law of France No. 2015-992 (2015), Law of France No. 2021-1104 (2021), Ministry of Infrastructure and Water Management (2016), International Energy Agency (2025), European Environment Agency (2025a), European Environment Agency (2025b), Dutch Municipalities Association (n.d.)

The social benefits of the development of electric bus programmes extend beyond the transport sector and cover broader socio-economic processes. They are manifested in increasing the attractiveness of public transport, creating additional jobs, stimulating innovative sectors, and creating a positive image of municipalities.

A comparative analysis of France and the Netherlands revealed both common features and differences in social effects that reflect different priorities of national strategies. Table 7 shows systematic indicators of social benefits from the implementation of electric bus programmes in the two countries.

**Table 7.** Social benefits of electric bus programmes in France and the Netherlands

| Indicator                   | France   | Netherlands  |
|-----------------------------|--|--|
| Increased passenger traffic | +8-12% in large urban agglomerations due to improved air quality and reduced noise   | +6-10% in medium and small cities due to increased transportation comfort and development of zero-emission zones |
| Job creation                | 5-7 thousand new jobs in the service, battery production, and infrastructure sectors | 3-5 thousand jobs, in particular in the field of digital services and charging network management                |

Table 7. Continued

| Indicator                                  | France  | Netherlands  |
|--|---|--|
| Development of innovation sectors          | Activation of production of battery systems, development of training programmes for technical specialists | Promotion of smart mobility and integration of smart grid into urban transport                                     |
| Improvement of the image of municipalities | Strengthening positions within the EU's national decarbonisation programmes and climate initiatives       | Creation of a positive image through the introduction of zero-emission zones and partnership with private carriers |

**Note:** zero-emission zones – zero-emission zones that limit the use of fossil fuel vehicles; smart grid – intelligent energy networks; smart mobility – digital solutions for optimising transport systems

**Source:** developed by the author based on data from Law of France No. 2015-992 (2015), Ministry of Infrastructure and Water Management (2016), Law of France No. 2019-1428 (2019), Law of France No. 2019-1428 (2019), Île-de-France Mobilités (2025), European Environment Agency (2025b), European Investment Bank (2025a), European Investment Bank (2025b), Dutch Municipalities Association (n.d.)

An analysis of Table 7 showed that in France, social benefits were mainly focused on job creation, capacity development, and educational programmes focused on training personnel for innovation sectors. In the Netherlands, the main focus was on digitalisation of the transport system and the introduction of smart mobility solutions, which reflected the priority of technological innovation in urban policy. In both countries, there was an increase in passenger traffic, but in France it was more pronounced in large agglomerations, while in the Netherlands this trend prevailed in medium and small cities. The development of a positive image of municipalities occurred in both cases, although the mechanisms for ensuring it were different: France integrated electric bus programmes into national climate strategies, while the Netherlands relied on local zero-emission zones. The overall results confirmed that electric bus programmes were not only a transport, but also a socio-economic tool for the development of urban areas.

The results of the analysis are consistent with conclusions of A.R. Patel *et al.* (2022), who proved that socio-economic factors of users determine the readiness to use electric vehicles in future smart cities. The researchers noted that the combination of availability of services and an increase in the level of environmental awareness affected the dynamics of demand. This finding was consistent with trends found in France and the Netherlands, where the increase in passenger traffic was attributed to increased transport comfort and improved quality of the urban environment. The study by J. Adamczyk *et al.* (2024) proved that the development of electric mobility depended on the interaction of economic and environmental factors. The researchers noted that financial support in the form of subsidies and tax incentives created conditions for the spread of electric transport, while environmental effects shaped the public legitimacy of programmes. This is consistent with the analysis of France, where large-scale government support was combined with climate priorities, and the Netherlands, where considerable attention was paid to the combination of economic feasibility and environmental benefits.

Electric mobility in the study was considered as a factor in the development of an innovative and sustainable economy, since institutional support, together with the promotion of private investment, created conditions for the integration of new technologies into the transport

sector, which was confirmed by the conclusions of U. Motowidlak & A. Bukowska-Piędzyńska (2024). The consistency of these prerequisites with national approaches was manifested in the Netherlands through digitalisation and partnership between the state and business, while in France centralised regulation played a key role. The multidimensional effect of electrification – from the economy to energy and infrastructure – was explained by the ability to combine price incentives, grid development, and renewable integration, which is consistent with the findings of S. Mopidevi *et al.* (2022). Comparison with the results showed that in France, the stability of tariffs was ensured by low-carbon generation, while in the Netherlands, the growth of the share of renewable energy increased the long-term competitiveness of electric buses.

Strengthening climate responsibility and integrating transport projects into national strategies were interpreted as an additional channel for attracting investment and expanding international cooperation. As noted by P. Bastos *et al.* (2024), Latin American experience showed that partnerships between governments, financial institutions, and private companies have accelerated the introduction of electric buses, which was consistent with European practices of concessions and multi-level policy coordination. Based on the conclusions of R.A. Alarrouqi *et al.* (2024), technological operating conditions define additional reliability requirements: in hot climates, battery efficiency decreases by 10-15%, which requires adapted technical solutions and emphasises the versatility of engineering barriers. As noted by A.H. Yáñez *et al.* (2024), the development of charging infrastructure is a crucial factor in the stability of transportation, because its shortage creates risks for the regularity of transport operations. This can be traced in various regional models, from public investment to private network deployment.

A comparison of the results of France and the Netherlands confirmed that the social and environmental benefits of transport electrification combined common features and specific differences. Emission reductions and noise load reductions were common, while differences were driven by the energy structure and institutional regulatory policy mechanisms. This confirmed that the integration of social and environmental priorities into transport strategies created conditions for improving the sustainability

of urban systems and strengthening their capacity for sustainable development. Generalisation of the analysis proved that electric bus programmes formed long-term advantages that went beyond the transport sector. They combined environmental impacts with the creation of social benefits, increased confidence in municipal strategies, and provided a framework for assessing impacts in a broader economic and socio-environmental context. This complexity of effects made electric bus projects a key element in the transformation of urban systems in the direction of innovation and sustainability.

## ■ Conclusions

The study identified original approaches to the comparative analysis of electric bus programmes in France and the Netherlands, focusing on a comprehensive assessment of economic feasibility, environmental effects, and social benefits. It was determined that the return on investment in France averaged 8-10 years, while in the Netherlands it was shorter and reached 6-8 years due to a combination of strict regulatory requirements and a developed charging infrastructure. Analysis of the cost structure as part of the total cost of ownership showed that electric buses were characterised by a higher share of purchase costs (45% vs. 30% for diesel buses), but had lower energy and maintenance costs (together 35% vs. 55% for diesel analogues).

The results obtained confirmed the economic advantages of electric buses in comparison with diesel analogues. In France, energy costs for electric buses were 0.18-0.22 EUR/km versus 0.35-0.40 EUR/km for diesel buses, and maintenance costs were 0.12-0.15 EUR/km versus 0.18-0.22 EUR/km. In the Netherlands, the corresponding figures were slightly higher (0.20-0.24 EUR/km and 0.13-0.16 EUR/km for electric buses versus 0.37-0.42 EUR/km and 0.19-0.23 EUR/km for diesel ones), but the economic

advantage of electric transport remained. This confirmed the constancy of the trend regarding the lower cost of operating electric buses, regardless of the specifics of national energy markets.

Environmental and social results also demonstrated significant effects of transport electrification. In France, the reduction in carbon dioxide emissions was about 900-1,100 tonnes per year per 100 electric buses, in the Netherlands – 800-1,000 tonnes. Social benefits included an increase in passenger traffic by 8-12% in French agglomerations and by 6-10% in Dutch medium and small cities, the creation of 5-7 thousand new jobs in France and 3-5 thousand in the Netherlands. In addition, the development of innovative sectors was identified: the production of battery systems in France and digital services in the Netherlands. This confirmed that electric bus programmes performed not only a transport, but also a socio-economic function integrated into national sustainable development strategies.

The study had certain limitations related to the availability of statistical data, differences in cost accounting methods, and the impact of different tariff models on final results. Further research should focus on assessing the long-term effects of renewable energy integration, analysing the impact of climatic conditions on the operation of electric buses, and exploring the possibilities of scaling programmes in various regional contexts.

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## ■ Conflict of Interest

None.

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## Інновації у сфері міського транспорту на прикладі електробусних програм у Франції та Нідерландах

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■ **Анотація.** Метою статті було з'ясувати економічну та екологічну доцільність впровадження електробусних програм у Франції та Нідерландах з урахуванням їхнього впливу на муніципальні бюджети, екологічні показники та соціальний розвиток. У результаті проведеного аналізу фінансових показників, структури витрат у складі повної вартості володіння та соціально-екологічних ефектів було встановлено, що строк окупності інвестицій становив у середньому 8-10 років у Франції та 6-8 років у Нідерландах завдяки різному рівню регуляторних вимог і розвитку зарядної інфраструктури. Структура витрат засвідчила, що частка закупівлі електробусів становила 45 % проти 30 % у дизельних, тоді як витрати на енергоносії та технічне обслуговування були нижчими (35 % проти 55 % відповідно). У Франції витрати на енергоносії для електробусів становили 0,18-0,22 €/км проти 0,35-0,40 €/км для дизельних, а на технічне обслуговування – 0,12-0,15 €/км проти 0,18-0,22 €/км; у Нідерландах різниця була меншою, але зберігалася на користь електробусів. Екологічний ефект визначався скороченням викидів вуглекислого газу на 900-1100 тонн на рік на 100 автобусів у Франції та 800-1000 тонн у Нідерландах. Соціальні результати включали зростання пасажиропотоку на 8-12 % у французьких агломераціях та на 6-10 % у нідерландських середніх і малих містах, створення 5-7 тисяч робочих місць у Франції та 3-5 тисяч у Нідерландах, а також розвиток інноваційних секторів – акумуляторних технологій у Франції та цифрових сервісів у Нідерландах. Було доведено, що централізована модель фінансування у Франції забезпечувала стабільність, тоді як децентралізована система концесій у Нідерландах сприяла швидкій адаптації та конкуренції між перевізниками. Практичне значення дослідження полягало у визначенні умов економічної доцільності та соціально-екологічних переваг електробусних програм, результати якого можуть бути використані органами влади, муніципалітетами й транспортними операторами для вдосконалення стратегій сталого транспорту та планування інвестицій

■ **Ключові слова:** муніципальні бюджети; повна вартість володіння; енергоносії; технічне обслуговування; амортизація; строк окупності; регуляторні вимоги

# **МЕНЕДЖМЕНТ І БІЗНЕС**

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