

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.

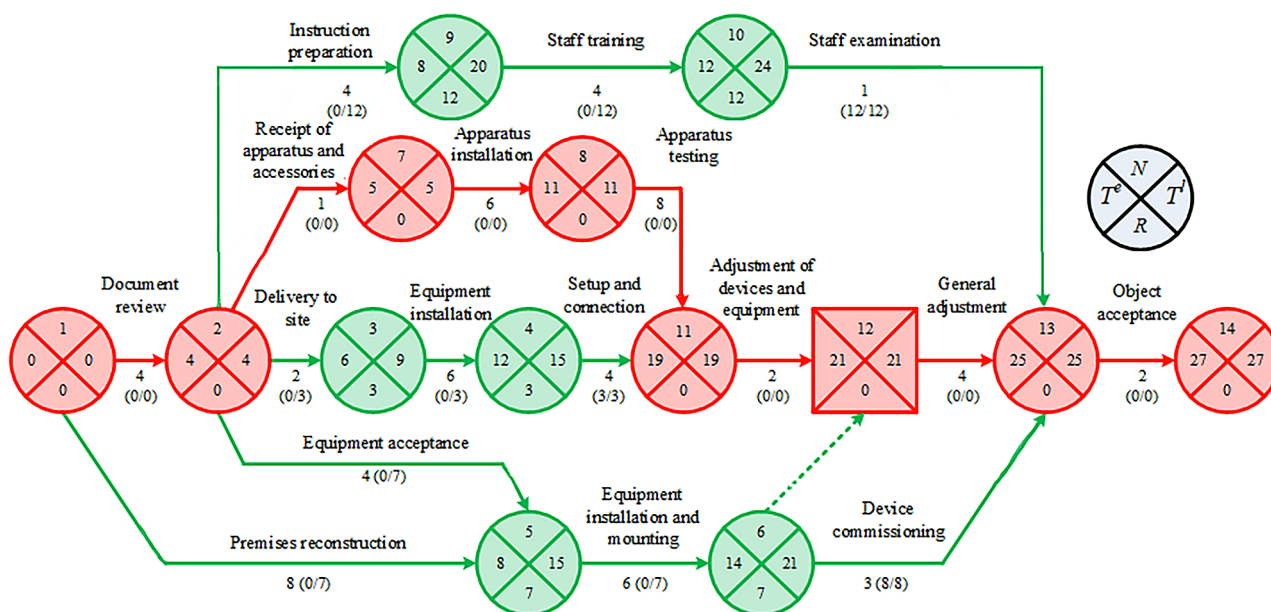


Figure 1. Network diagram of the production unit reconstruction project

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.

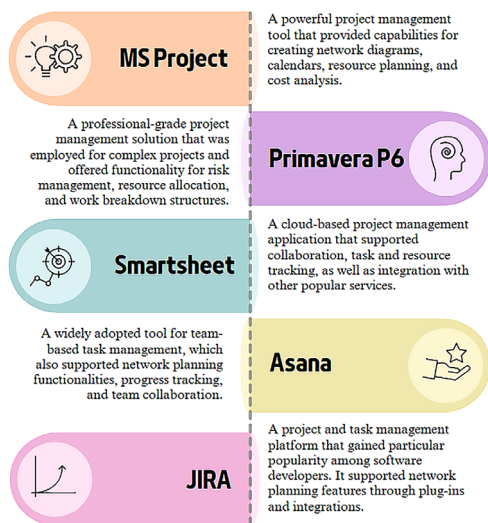


Figure 2. Most popular software products for project management

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

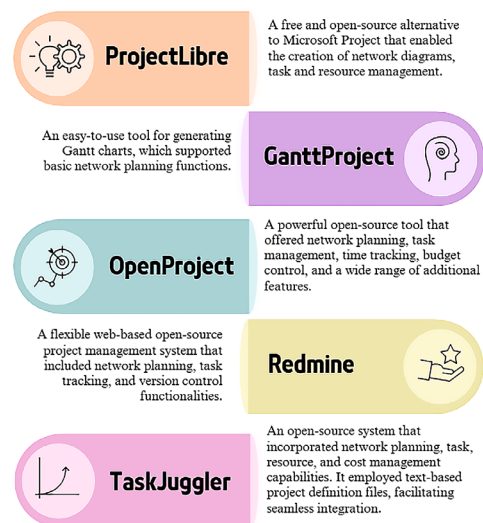


Figure 3. Most popular open-source software products for project management

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.

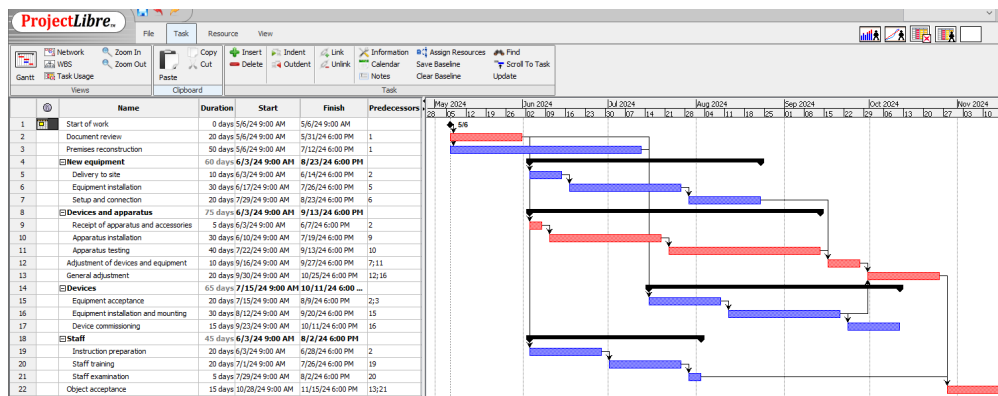


Figure 4. Gantt chart of the production unit reconstruction project

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

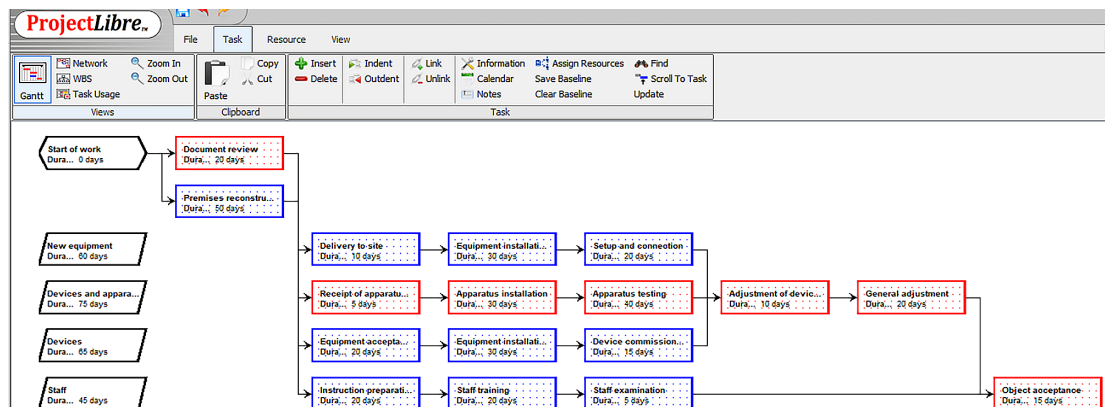


Figure 5. Network diagram of the production unit reconstruction project

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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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