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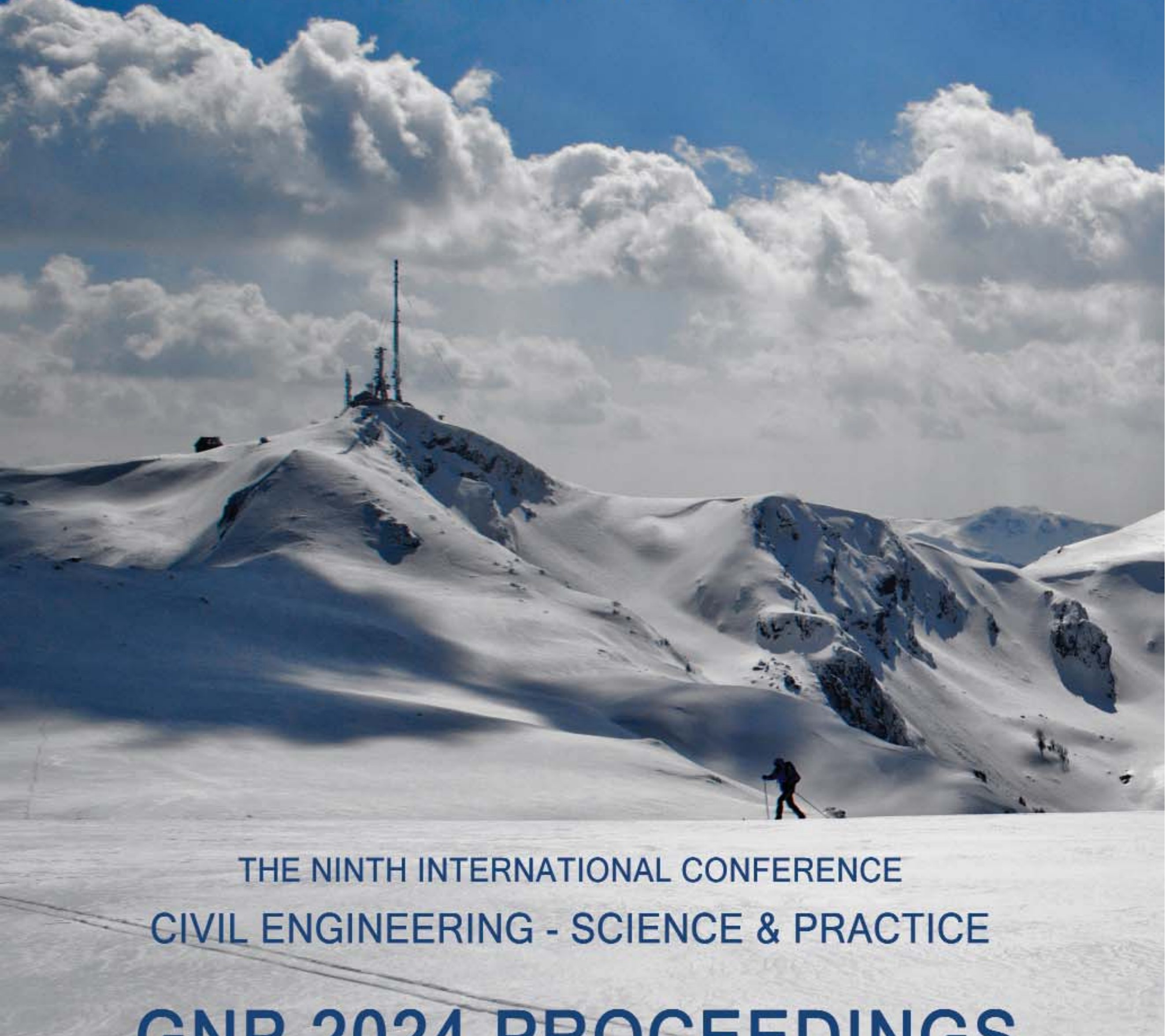

THE NINTH INTERNATIONAL CONFERENCE

CIVIL ENGINEERING - SCIENCE & PRACTICE

GNP 2024 PROCEEDINGS

Kolašin, March 2024

UNIVERSITY OF MONTENEGRO

FACULTY OF CIVIL ENGINEERING

THE NINTH INTERNATIONAL CONFERENCE

CIVIL ENGINEERING - SCIENCE & PRACTICE

GNP 2024 PROCEEDINGS

KOLAŠIN, 5-9 MARCH 2024

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"CIVIL ENGINEERING – SCIENCE AND PRACTICE"

GNP 2024 – Kolašin, Montenegro, 5-9 March 2024

Marijana lazarevska[1], Vasko Gacevski[2], Zlatko Zafirovski[3]

APPLICATION OF PRECEDENCE DIAGRAMMING FOR PLANNING OF A LOCAL ROAD RECONSTRUCTION

Abstract

Planning is essentially a way of mentally presenting projects in the future, and it is implemented through the creation of models (graphical, mathematical, etc.) through which the behaviour of the future real project is simulated in a changing environment. It implies the implementation of analyses with included risk and uncertainty for correct decision-making during the implementation of projects.

In modern construction, the realization of any more serious project cannot be imagined without the application of quality planning and management methods. Network models are an example of the most commonly used methods for planning of the implementation of complex and long-term projects. The most commonly used network models in construction are: Critical Path Method (CPM) and the PERT method (Project Evaluation and Review Technique). They are used for analysis of the project time duration, cost and resources. Both methods use a graphical representation of the project through an appropriately oriented network model composed of basic elements such as: activities, events, durations, costs, resources etc.

This paper gives an example of the application of Precedence diagramming for planning of a local road reconstruction, as an easy approach for determination of the total time duration of the project that gives a clear overview of the technology of construction in accordance with the general and specific conditions of the project and its environment.

Keywords

Precedence diagramming, planning, time analysis, road, reconstruction, network plan, critical path, technology of construction, project activities.

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1. INTRODUCTION

Planning is one of the most complex, difficult, sensitive and important conscious human activities in any area of his activity. It includes vision and assessment of all possible events and situations, that is, prediction of all activities resulting from the occurrence of possible events in the future. It is a complex process that implies an accurate and precise direction of action and decision-making, based on knowledge, experience and correct assessments.

Although it is complex process that is often accompanied by a large number of risks and uncertainties, planning is the basis for efficient and successful work of any company, regardless of the activity, type, size and characteristics of its organizational structure. Correct project planning leads to successful realization of the project goals.

The modern concept of the organization of the building construction process implies timely planning of all project activities, in terms of time and costs, as well as in terms of continuous coordination and control of all parameters that are necessary for quality construction of the structures, in the optimal time frame. and with the most favourable economic conditions.

The main goal of construction project planning is the management of all project activities, ensuring coordination, monitoring and control of their implementation, in order to achieve the defined goals. Appropriate prediction and planning of the construction projects allows a better division of work tasks, more rational application of construction machines, better use of working time and resources, increase in productivity and economy, reduction of losses in production etc. For construction projects, various techniques and methods can be applied that enable planning of: time, costs, quality, resources and risks.

2. NETWORK PLANNING TECHNIQUE

The technique of network planning enables adaptive management of the project realization process. This positively affects the facilitation of the exchange of information between the participants in the implementation of the project, their accuracy and reliability, and is an effective means of increasing the responsibility of executors and managers at all levels.

Using this technique, people who manage complex projects can foresee the problems in the execution of the project and perceive the critical things (activities) that can affect the deadline for the execution of the task. On the basis of the data obtained from the network diagrams, the execution of the activities within the planned deadlines, the engagement of the participants in the realization of the project and the material resources can be optimized in advance.

The technique of network planning uses sufficiently strict algorithms with the help of which the optimal (or close to optimal) solution is determined, the probability of the realization of individual parts of the project and the whole is forecasted. This technique provides a significant improvement in the quality of planning by looking for logical connections between activities during the realization of the plan, which ensures its placement on a realistic basis. In particular, it should be emphasized that the methods of network planning and management allow a precise estimation of costs, with which project managers can pay attention to critical activities and find a way to realize their principle ideas with which the end result would be: cost reduction and shortening the project implementation period.

3. PRECEDENCE DIAGRAMMING FOR TIME ANALYSIS

For planning of the time for the realization of projects, especially in construction, in addition to the critical path method and the PERT method, the so-called priority method (Precedence diagramming) has significant importance. The development of this method is due to the need to overcome some of the shortcomings that arise during the use of the critical path method and the PERT method, which mainly relate to: complicated network plans and ways of marking of the events, as well as the impossibility for graphically displaying activities that have overlapping beginnings and/or endings.

The Precedence diagram uses a block network plan to graphically display the realization of projects. The rules for displaying the project activities and for constructing the network plan are slightly different compared to the classical planning methods. Namely, with this method, the activities are presented as circles (or rectangles), and the technological and logical dependence between the activities is represented with the help of arrow-shaped lines.

Time analysis implies solving the network plan model, that is, calculation of the earliest and latest beginnings or ends of activities, time reserves, as well as critical activities and the critical path in the network plan. In the Precedence diagram several terms for the time are being used.

The earliest time when the activity "i" can start is called the Earliest Start Time and is marked with ES_i. When the activity "i" starts at the earliest start, it will be able to finish at the earliest possible moment, which is called the Earliest Finish Time and is denoted by EF_i. The moment in time when the activity "i" is finished at the end of the available time is called the Latest Finish Time and is marked with LF_i. When the activity ends at the latest, it means that it started late, and that moment in time is called the Latest Start Time and is marked with LS_i.

The code of the activity, which is defined in the first stage of the network planning technique (in the list of activities) is written in the upper quarter of the circle. The duration of the activity, expressed in appropriate time units, is written in the lower quarter of the circle. The earliest start and finish time of the activities are calculated according to the "forward method", from the first to the last activity in the network plan. The values of these time terms are entered in the left quarter of the circle. The latest start and finish time of the activities are calculated according to the "backward method", from the last to the first activity in the network plan. The values of these time terms are entered in the right quarter of the circle (Figure 1).

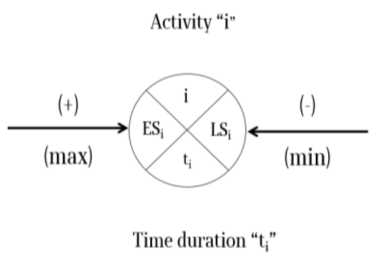

Figure 1. Graphical representation of a project activity in Precedence diagram

Activities that have equal values of earliest and latest finish time are called critical activities. The critical activities that connect the first to the last activity give the critical path of the network plan. The critical path determines the total duration for the realization of the project.

4. APPLICATION OF PRECEDENCE DIAGRAMMING FOR PLANNING OF THE LOCAL ROAD RECONSTRUCTION

This paper gives an example of the application of Precedence diagramming for planning of a local road reconstruction, as an easy approach for determination of the total time duration of the project that gives a clear overview of the technology of construction in accordance with the general and specific conditions of the project and its environment.

The process of planning the reconstruction of roads is very complex task, having in mind the many different activities that have to be taken into account, specific environmental conditios and requirements that have to be addressed, complex design requirements that have to be followed, the complexity of the type of works that have to finished, the complexity of the technology of construction and the specific technical rules and requirements that cannot be ignored.

Although there are many tasks that should be finished when planning the reconstruction of roads, as a complex construction project, the example shown in this paper addresses some of them: the preparatory works (such as: organization of the construction site, setting up the laboratories on the site, geodetic marking of the route), main works related to the demolition of the existing asphalt layer of the road, curbs, gutters, protection fences and traffic signs), main civil engineering works relatind to the reconstruction of the road (subgrade, tampon layer, asphalt layer, concrete curbs, asphalt gutters, berms) and additional works related to slope protection, installation of traffic signs and protection fences. The works related to the installations located under the road surface are not part of the analysis, because the example was made according to the realistic design that did not include reconstruction of the installations.

All data that are used as inputs in the analysis for modelling of the Precedence plan are given in the Table 1: description of project activities, code, time duration of each activity expressed in days, and the technological and logical interconnection between activities.

Table 1. List of project activities for reconstruction of an existing local road

Description of activity	Code	Duration of activity	Previous activity
		t_i	
Site organization	1	3	/
Provision of a laboratory with the necessary equipment and conditions for field ongoing and control geotechnical, asphalt and concrete investigations	2	2	1
Traffic time regime	3	3	1
Geodetic marking, securing and staking the route	4	2	2, 3
Cross cutting of existing asphalt	5	1	4
Demolition of existing asphalt, with loading and transport of the material to a landfill	6	5	5
Demolition of existing concrete curbs by loading and transporting the material to a landfill	7	3	5

Demolition of existing gutters by loading and transporting the material to the landfill	8	3	5
Dismantling of the existing protective fence and traffic signs	9	2	6, 7, 8
Excavation of sub-base and earth material with loading and transport to a landfill	10	7	9
Demolition of existing shoulders from sub-base material	11	3	9
Construction of subsoil (under improved subgrade)	12	4	10, 11
Procurement, transport and execution of an improved subgrade the entire width of the substructure of the road with a thickness of 30 cm	13	7	12
Construction of subgrade	14	2	13
Procurement, transport and execution of subbase course from stone material 0-63mm	15	7	14
Procurement, transport and execution of concrete curbs	16	2	15
Preparation of asphalt base with spraying of cationic stabilized emulsion for connection of subbase with BNS	17	2	16
Procurement, transport and execution of bituminous bearing layer BNS 32 sA PmB 25-55/55 d=7cm	18	5	17
Construction of asphalt gutters	19	3	17
Preparation of asphalt base with spraying of cationic unstable emulsion for connection of AB with BNS	20	2	18, 19
Procurement, transport and execution of asphalt concrete AB – 16s PmB 45-80/65 d=5cm	21	5	20
Construction of shoulders with subbase material with thickness d=7cm with mechanical stabilizations	22	2	21
Construction of berms	23	2	22
Slope protections	24	2	22
Procurement, transport and installation of traffic signals and equipment	25	3	22
Installation on a protective barrier fence	26	5	23, 24, 25
Demobilization of the site	27	2	26

The project activities are defined in accordance to the optimal technology for reconstruction of a local road, located in the Republic of North Macedonia, with a total length of 3.00 km. For each project activity the previous activity has been defind, according to the adopted technology and organization of construction. The fact that some of the project activities can be realized at the same time, even though they are different type, gives the opportunity to achive shorter time of construction. This approach should be followed whenever it is possible, because the statistics of already built roads in Republic of North Macedonia show that none of the major projects were finished as planned, netither on time, neither within the planned budget (taken from the official reports written by the Public Enterprise of State Roads). It is very important to plan the realization of different activities at the same time, in order to stay within the projected deadlines and to have some time reserves that can be used if some unplanned or unforeseen situations happen during the construction.

The time duration (t_{ij}) of each project activity (expressed in working days) is determined based on recorded historical data for the actual time required for their execution. In other words, the time of the activities is calculated by applying the construction norms and standards that are based on elementary engineering assessments and experiences on the way and time of the realization of activities in normal working conditions and environment. The normal execution time of the activities implies the application of standard work technology and an open work front, work in one (or more) shifts, with the most favorable work methods, and the optimal selection of construction tools and methods.

By following the logical and technological dependence between the defined project activities, a network plan has been constructed, the total time needed for the reconstruction of the local road was calculated and the critical activities and the critical path were obtained. The constructed technological model of the network diagram is shown on Figure 2. The project activities are graphically presented by their codes written in the circles, and the dependence between the activities is expressed by arrowed lines.

With the "forward" method, the earliest finish time of the activities were calculated, starting from the first to the last activity included in the network plan. The latest finish time of the activities were calculated by the “backward” method and these values are shown in Figure 3.

According to the calculation of the earliest and latest finish time of previously defined project activities it is obtained that the total time required for the reconstruction of the existing local road is 67 days. The critical activities and the critical path are also determinate and they are shown on Figure 3. The total time duration of construction projects has direct and multiple effects on the total investment costs. That is why the precise and proper planning is of significant importance for achieving the project goals and meet the project requirements. Furthermore, regular monitoring and control of the construction plans gives the possibility for taking adequate measures to maintain the planned dynamics, and that can significantly affect the cost for construction, increase the saving of financial resources during the construction, and increase the return on investment in the exploitation phase.

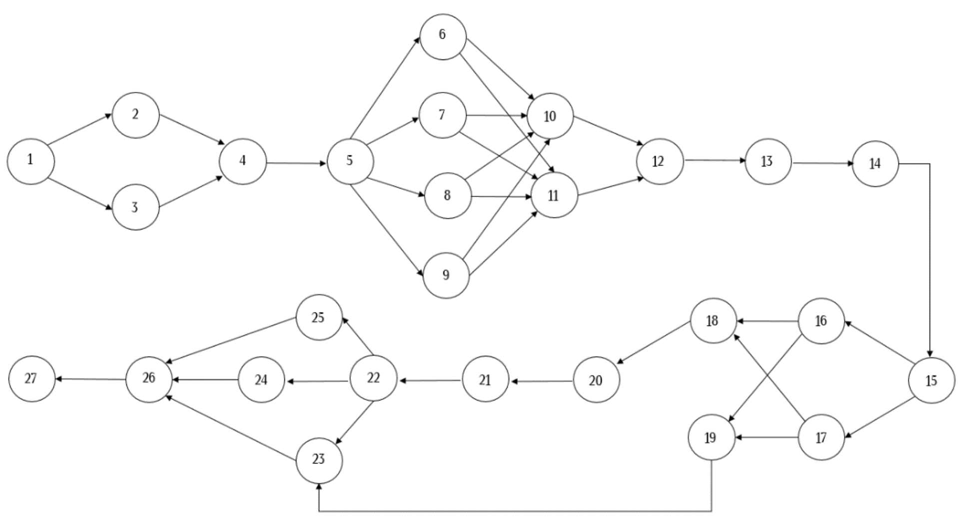

Figure 2. Model of network plan for reconstruction of an existing local road

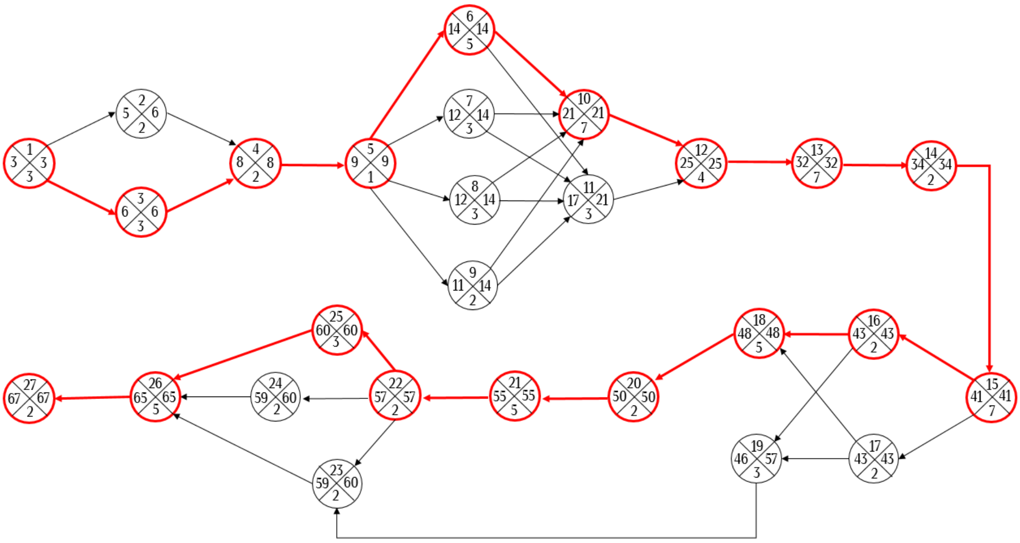

Figure 3. Graphical representation of the critical activities and the critical path in the network plan

5. CONCLUSIONS

This paper gives one example of application of network technique for planning of a reconstruction of a local road. It is possible to use a time-distance method for planning of road's construction, however, this method of planning does not offer the possibility of showing the connections and dependencies between project activities, and has poor transparency if the realization of a large number of activities needs to be planned. The precedence diagram, on the other hand, allows quick and easy change of the duration of activities and their dependence, whenever is needed. That why, the plan can be easily adapted to the real site conditions and all risks that might occur in every phase of the road life cycle.

The precedence plan, shown in this paper, takes into consideration the realization of major project activities that have to be precisely planned, monitored and coordinated in order to achieve the project deadline and budget. The possibility of occurrence of unforseen events and situation during construction can lead to longer time of completion of the road project, and this can significantly increase the project costs. That is why several different plans should be analysed, all in accordance with the adopted technology and organization of construction, so that the plan that takes into consideration the parallel realization of works and gives the optimal time of completion, can be selected. All works should be continuously monitored and controlled, during the construction phase.

Planning of the realization of road projects is an extremely complex process, taking into account all the specifics and characteristics of the project, such as: the vast number of project activities that have to be carried out, the large amount of works that need to be completed, the duration of the life cycle of the projects, the multiplicity and diversity of the participants who are involved in their implementation, the need for constant coordination of project tasks, the necessity of achieving previously set goals and strict requirements, etc.

It is known that road construction process, in general, is relatively poorly organized, which is most often a consequence of inadequate and/or insufficient preparations that precede the construction phase. In addition, practice shows that the technical and economic criteria for choosing the optimal solution, which are a basic prerequisite for achieving positive financial results, are not fully respected.

In order to ensure an efficient and effective construction of complex structures, such as roads and other infrastructural objects, it is necessary that the plans are ready before the start of the construction phase, so that any problems or difficulties which could cause a temporary stoppage of the construction and adversely affect the completion of the project can be predicted in advance. Given the fact that during the life cycle of road projects, numerous changes in the environment occur, and the projects themselves are subject to changes of different scope and character, it is necessary to include the changing nature of construction in the planning process. This means that planning must be treated as a continuous process that allows an easy adjustment of predictions to actual conditions, and that provides the opportunity for simple and continuous adjustment and modification of plans, where necessary. In addition, construction plans should be clear and allow a quick and easy review of all the data and information they contain, be realistic and made using accurate and unambiguous data, be precise and unambiguous in terms of showing time goals and the phases of construction, but also to be comprehensive, that is, the plan should cover all participants in the project and all contents and project activities.

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