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# Development of Computer-Based Network Planning Technology

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***Abstract.*** *The article aims to explore the development of network graph parameter calculation methodology. Computer programmes are analysed to serve the identification process of the above-mentioned parameters. A particular example is examined in order to show the additional preferences of implemented methodology. Major additional preferences of the proposed methodology are the following: calculation of time instants to start and finish concrete events, activities and the entire project, determination of time resources associated with particular event and activity, identification of critical activities, visibility of reserves distribution prospect, which enable the optimisation of an arranged plan by redistributing the time available and the material reserves and invoking external sources of these reserves, where necessary. It is very important that any changes in the network plan schedule, after entering them into the investigated computer programme, are reflected without additional logic changes calculated in the parameters table. This is particularly valuable during the project implementation process, because deviations from the plan allow updating parameter settings and thus enable the manager to manage the project implementation process specifically and purposefully.*

**Key words:** *network planning, parameters, reserves, computer programme.*

**Raktažodžiai:** *tinklinis planavimas, parametrai, rezervai, kompiuterinė programa*

## Introduction

Network planning is a well-known planning approach. It has obvious advantages, compared to text planning methods, and even many advantages over the Gantt Chart. Its main advantages are: establishing links between activities, getting to know when to start a particular activity and when to complete it, the activities that raise issues, how to allocate human and other resources, how to monitor the progress of work, when to start the project in order to complete it within the assessed point of time. These and other advantages make the planning and plan implementation process more transparent and efficient. Network planning is widely used in project management, but often all opportunities of the method are not fully exploited.

**The purpose of the article** is to propose a network plan calculation methodology, which is based on the developed computer programmes that allow the calculation of all the possible parameters, the most important of which is the reserves of activities and events. It is based on the assumptions they make to the optimal allocation of various existing and additional resources.

## Formulation of the Problem

Network planning can be divided into the following phases: formation, analysis, optimisation and application. This article focuses on the analysis of an already developed plan through investigated computer programmes, assuming that plan formation does not pose serious problems, while it significantly expands the opportunities for optimisation, however, these are not analysed in more detail.

Network planning is based on the list of activities or precedence relationship chart (see Table 1), which is reflected in all the elementary activities, activity index, completion time of activities, and immediate predecessor. The analysis is performed by means of a specific example, but contains the necessary formulas and calculation examples, applicable for a general case.

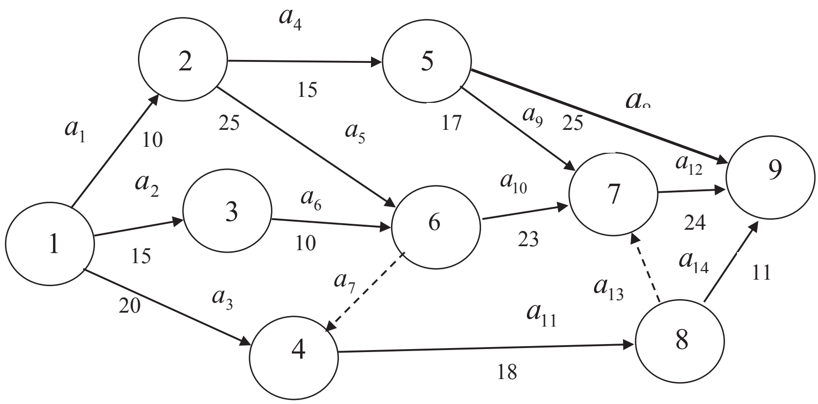
## Some Examples

Suppose we have the following list of activities with precedence relationships (see Table 1).

*Table 1.* **Precedence relationship chart**

| Activity | Activity index | Estimated completion time, days | Immediate predecessor |
|---|---|---|---|
| a1 | 1;2 | 10 | none |
| a2 | 1;3 | 15 | none |
| a3 | 1;4 | 20 | none |
| a4 | 2;5 | 15 | a1 |
| a5 | 2;6 | 25 | a1 |
| a6 | 3;6 | 10 | a2 |
| a7 | 6;4 | 0 | a5;a6 |
| a8 | 5;9 | 25 | a4 |
| a9 | 5;7 | 17 | a4 |
| a10 | 6;7 | 23 | a5;a6 |
| a11 | 4;8 | 18 | a3;a7 |
| a12 | 7;9 | 24 | a9;a10;a13 |
| a13 | 8;7 | 0 | a11 |
| a14 | 8;9 | 11 | a11 |
| **ai** | aik | tik | Activities before |

Under the given list of activities we compose a network diagram (see Picture 1).




*Picture 1.* **Network diagram**

### Parameters to be Calculated

After the composition of a network diagram, its parameters should be calculated: the early completion time of the events (Tak), the latest completion time of the events (Tvk), the reserves of the events (Rk), the reserves of the activities (Rti), critical path and critical activities.

The main goals of the analysis are: to find the critical path and reserves of all activities and events. Activities on the critical path are called critical activities. These are the most important activities because the end of the entire complex of activities depends on them. Critical activities should be started immediately once the previous dependent activities are over. In other words, critical activities cannot be delayed or overdue, whereas other activities may have time reserve. Therefore, critical activities should be precisely monitored and timely managed to ensure the elimination of delay or overdue risks. Consequently, critical path is considered as the most vulnerable part of the plan.

The answers to these and other planning issues are related to the relatively intensive analysis requiring, though simple, but large-scale calculations. This analysis becomes easy and even enjoyable if is carried out by means of a computer.

However, it is necessary to develop an appropriate programme under the methodology explained in this article.

The model of the network plan analysis should be developed.

### The Algorithm to Calculate the Parameters

The algorithm of the model consists of six stages: data preparation, estimation of the early and the latest completion time of the events, determination of the reserves of events, the reserves of activities, identification of critical activities and critical path.

Data preparation stage is implemented as follows:

- Activate the Excel programme and select the order of data allocation (see Table 2).
- Fill in column A with activity indexes.
- Fill in column B with activity indexes by relating them to events.
- Fill in column C with duration of particular activities.
- Fill in column D with symbols of immediate predecessors, i.e. activities which should start earlier.
- Fill in column E with numbers of events.
- Fill in column I repeatedly with activity indexes; this makes it easier to understand the dependency of parameters.

## Formulas Developed

*The early completion time* of the event is estimated on the basis of the following formula:

$$T_{Ak} = \max_i (t_{ik} + T_{Ai}), k = 2,3,\dots n, T_{A1} = 0, \qquad (1)$$

Where $T_{Ak}$ – an early completion time of the event with number *k*;
*i* – values of previous events and activities directly related to the event *k*;
*n* – total number of events.

*Table 2.* **Network plan parameter values calculated by computer**

| A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|
| a1 | 1;2 | 10 | none | 1 | 0 | 0 | 0 | a1 | 0 | a1 |
| a2 | 1;3 | 15 | none | 2 | 10 | 10 | 0 | a2 | 10 | |
| a3 | 1;4 | 20 | none | 3 | 15 | 25 | 10 | a3 | 20 | |
| a4 | 2;5 | 15 | a1 | 4 | 35 | 40 | 5 | a4 | 16 | |
| a5 | 2;6 | 25 | a1 | 5 | 25 | 41 | 16 | a5 | 0 | a5 |
| a6 | 3;6 | 10 | a2 | 6 | 35 | 35 | 0 | a6 | 10 | |
| a7 | 6;4 | 0 | a5;a6 | 7 | 58 | 58 | 0 | a7 | 5 | |
| a8 | 5;9 | 25 | a4 | 8 | 53 | 58 | 5 | a8 | 32 | |
| a9 | 5;7 | 17 | a4 | 9 | 82 | 82 | 0 | a9 | 16 | |
| a10 | 6;7 | 23 | a5;a6 | | | | | a10 | 0 | a10 |
| a11 | 4;8 | 18 | a3;a7 | | | | | a11 | 5 | |
| a12 | 7;9 | 24 | a9;a10;a13 | | | | | a12 | 0 | a12 |
| a13 | 8;7 | 0 | a11 | | | | | a13 | 5 | |
| a14 | 8;9 | 11 | a11 | | | | | a14 | 18 | |
| **ai** | **aik** | **Completion time** | **Activities before** | **Events** | **Tak** | **Tvk** | **Rak** | **ai** | **Rtij** | **akr** |

Fill in column F with the corresponding formulas obtained by linking the formula (1) indexes with concrete activities and events. We enter zero in the first line, as stated in the formula.

In the second row of column F, we enter the formula $T_{A2} = t_{1,2} + T_{A1}$, =SUM(F1;C1). Number 10 appears.

Perform similar actions in cells F3, F5 and F8. We do not look for the maximum in these cells, as these events depend only on one activity.

In cell F4 enter the formula =MAX(SUM(F1;C3);SUM(F6;C7)), in cell F6=max(sum(F2;C5);sum(F3;C6)), etc.

*The latest completion time* of the event is calculated by using the following formula:

$$T_{vk} = \min_j (T_{vj} - t_{kj}),\ j = n, n-1,...,2;\ k = n, n-1,...,1, \tag{2}$$

Where *j* – values of subsequent events and activities directly related to the event *k*.

The early and late completion of the events coincides, i.e. the following formula is true:

$$T_{vn} = T_{An}. \tag{3}$$

We enter the corresponding formulas in the column G, derived by linking indexes of formulas (1) and (3) to concrete activities and events.

Calculations need to start from the final event, because formula (3) enables simple calculation of the late completion of the final event; afterwards, we usually go downward the numbers of events.

In a given example, we enter the formula = F9 in cell G10.

We also complete other cells with the corresponding formulas, derived from formula (2), e.g. in cell G6 we enter the formula: =MIN(SUM(G9;-C14);SUM(G7;-C13)).

*The reserves of events* are calculated by using the following formula:

$$R_k = T_{vk} - T_{Ak}. \tag{4}$$

We enter the corresponding formulas in column H, obtained by linking the indexes of formula (4) to concrete events.

*The reserves of activities* are calculated by using the following formulas:

$$R_{aij} = T_{Vj} - T_{Ai} - t_{ij}. \tag{5}$$

We enter the corresponding formulas in column J, obtained by linking the indexes of formula (5) to concrete events. E.g., the reserve of activity a1 is calculated by entering the formula =G2-F1-C1) in the first row of column J. Similar actions are performed in all other cells of column J.

*Critical activities and events* are very easy to detect – their reserves should be equal to zero.

*Critical events* (see values in column H): 1; 2; 6; 7; 9, *critical activities* (see values in column J): 1; 5; 10; 12.

*The critical path* connects all the events and activities, the reserves of which are equal to zero.

Estimation procedure of the network plan parameters is especially required for the distribution of various resources, including human resources, for examining possible ways of particular activity organisation, for identifying the start and completion dates of particular projects, also in case of unforeseen circumstances and in other cases. Consequently, the proposed computer-based technique for estimating these parameters is immediately vital in achieving effective management of any project or complex of activities. It has another special advantage – once a computer model is developed, there is no need to implement all of the described actions repeatedly; once the changes in duration of the activity values are entered, we obtain all of the new plan parameters.

This technique is particularly necessary for the optimisation of various types of plans. In view of the limited scope of the article, further analysis of network planning optimisation technique is not given. The author invites the parties concerned to familiarize with the seminal work by S. Puškorius [7, p.63-67].

The same reasons were the basis to avoid the analysis related to the network plan transformation into a Gantt chart format, as it significantly simplified the practical application of the network plan [9, p.90-94]. Network planning issues related to activity duration as a random variable are analysed in another publication by S. Puškorius [8].

## Conclusions

This paper presents the methodology of computer-based calculation of the network graph parameters. The special algorithm and the necessary formulas are developed and the example of their application is proposed.

2. Major preferences of the proposed methodology are the following: calculation of time instants to start and finish concrete events, activities and the entire project, determination of time resources associated with a particular event and activity, identification of critical activities, visibility of reserves distribution prospect, which enables the optimisation of the arranged plan by redistributing the time available and the material reserves and invoking external sources of these reserves, where necessary.

3. It is shown that, if any changes occur in the network plan schedule during the implementation of the plan, the corresponding parameters may be calculated very easily by using the developed programme.

4. In general, the developed programme enables a manager of the project to manage the project implementation process specifically and purposefully.

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Stasys Puškorius

**Tinklinio planavimo technologijos plėtra panaudojant kompiuterį**

Anotacija

Straipsnyje plėtojama tinklinio grafiko parametrų apskaičiavimo metodika. Sukurtos kompiuterinės programos, leidžiančios tuos parametrus identifikuoti. Pateiktas konkretus pavyzdys. Parodoma, kokios papildomos galimybės atsiveria įdiegus šią metodiką.

Pagrindiniai sukurtos metodikos pranašumai yra tokie: apskaičiuojami laiko momentai, kada turi prasidėti ir užsibaigti konkretūs įvykiai, darbai ir visas projektas, nustatomi laiko ištekliai, susiję su kiekvienu įvykiu ir darbu, identifikuojami kritiniai darbai, matoma rezervų pasiskirstymo panorama, leidžianti optimizuoti parengtą planą, perskirstant turimus laiko ir materialinius išteklius ir pasitelkiant, esant poreikiui, tokių rezervų išorinius šaltinius.

Labai svarbu, kad bet kokie atlikti pokyčiai tinkliniame grafike, suvedus juos į sukurtą programą, atsispindi be papildomų loginių programos pokyčių, apskaičiuojamų parametrų lentelėje.

Tai itin vertinga vykdant projektą, nes atsiradę nukrypimai nuo plano leidžia atnaujinti parametrų reikšmes ir, vadinasi, įgalina vadovą tikslingai ir kryptingai valdyti projekto įgyvendinimo procesą.

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