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METHODS OF DEVELOPMENT NETWORK ANALYSIS AS A TOOL IMPROVING EFFICIENT ORGANIZATION MANAGEMENT

METODY ANALIZY SIECI ZALEŻNOŚCI JAKO INSTRUMENT EFEKTYWNEGO ZARZĄDZANIA ORGANIZACJĄ

Abstract

The analysis of the dependence network consists in the calculation of dates and time reserves of subsequent events, and then on the calculation of the time stocks during the execution of particular activities. In the dependency network, it is possible to calculate the earliest and the latest possible date of occurrence of each event and the possible reserve of time. Thanks to this, we will learn the stock of time related to individual activities. Those activities that do not have a stock of time (that is, the reserve is equal to zero) are called critical activities. All critical activities in the dependence network create a critical path. We will not have any stock of time on the entire critical path (from the event of the initial linking network to the final event). What's the conclusion? Activities that are on

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the critical path must be made at the scheduled time, because it will decide on keeping the deadline for the entire undertaking.

Keywords: *dependence networks, organization management, efficiency, the probabilistic model*

Streszczenie

Analiza sieci zależności polega na obliczeniu terminów i rezerw czasu kolejnych zdarzeń, a następnie na obliczeniu, jakie są zapasy czasu podczas wykonywania poszczególnych czynności. W sieci zależności można bowiem obliczyć najwcześniejszy i najpóźniejszy możliwy termin zaistnienia każdego zdarzenia oraz ewentualną rezerwę czasu. Dzięki temu poznamy zapasy czasu dotyczące poszczególnych czynności. Te czynności, które nie mają zapasu czasu (to znaczy, że zapas jest równy zeru) nazywane czynnościami krytycznymi. Wszystkie czynności krytyczne w sieci zależności tworzą drogę krytyczną. Na całej drodze krytycznej (od zdarzenia początkowego sieci powiązań, aż po zdarzenie końcowe) nie będziemy mieli żadnych zapasów czasu. Jaki z tego wniosek? Czynności znajdujące się na drodze krytycznej muszą być wykonane w zaplanowanym czasie, bo to właśnie będzie decydowało o dotrzymaniu terminu realizacji całego przedsięwzięcia.

Słowa kluczowe: *sieci zależności, zarządzanie organizacją, efektywność, model probabilistyczny*

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Statement of the problem in general outlook and its connection with important scientific and practical tasks.

In modern management and organization of work (production), various methods and techniques are used to ensure effective management of both the entire institution and its individual parts, ensuring that these parts form an organized system and work efficiently and effectively. In the face of the increasing complexity of contemporary work and production, the flow of information must not only allow the compilation of various, often complex indicators and drawing diagrams, but also to develop a view on the whole, especially production, its uniformity and rhythm, planning accuracy, etc. Good organization of work and production is a guarantee of success in all kinds of business. At the same time, with the modern requirements of the organization of work, production and management one can and must strive for economy under the four least - in terms of time, space, matter, energy - while using each of these resources to achieve a given result, making sure that to the extent of consumption of any of them, get the richest results possible. Rational resource management is used, among others, by methods of analysis of dependence networks, often referred to as network methods, as graphical methods of organization and management, especially planning and control. They cover the totality of ways of expressing thoughts and mapping reality with the help of images,

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symbols and signs, which have a conventional meaning and are most often depicted on a flat surface (Peter J. Carrington, J. Scott, S. Wasserman, 1994 & J. Scott, Peter J. Carrington, 2011). Nowadays, organizational and management processes are becoming more complex, which creates additional difficulties in their planning and control. The search for efficient methods (techniques) of organization and management is as important as searching for new structural or technological solutions. Old methods are ineffective, they do not guarantee efficient management of the problems of organization and management of modern institutions in the new conditions of management. Progress should be noted in the search for methods and techniques to improve the organization and management processes. The group of these methods includes, among other things, operational research, initiated in the years of World War II, when teams of scientists from various fields, working on allied staffs, worked on important military strategic and tactical problems. It should be remembered that operational research is a group of methods originating from various fields of science, which enable analysis of many variants of the plan of the operation under consideration and selection of the most advantageous variant. The essence of operational research and its effectiveness consist in the consistent adoption of the principle that the basis for making a decision can only be logical reasoning, always supported by detailed observation and subsequent methodical analysis. Today, operational research is inextricably linked with running a business, and their goal is, inter alia, to develop methods that allow making optimal economic decisions and choosing the best directions of action. As a group of methods covered by the name "operational research", network methods have been created (network schedules). The basics of network methods (methods of analysis of dependence networks) were developed in the USA - in two independently operating centers. At the turn of 1956 and 1957 the integrated engineering control group of the DuPont chemical concern was put in the task of applying better, than usual, methods of planning and controlling the order of renovation works of large chemical facilities. An employee of this branch M.R. Walker together with J.E. Kelley from Remington Rand has developed a method for graphically presenting a work plan in the form of a network of activities (dependencies). This method was called the Crimetic Path Method (CPM), while the scope of its analysis was called CPA (Critical Path Analysis), that is, critical path analysis (E. Otte, R. Rousseau, 2002 & S. Wasserman, K. Faust, 1994).

The use of network methods consists of two separate but closely interrelated phases:

- establishing an action program, that is, determining what, where and in what order it should be performed, and establishing a network of activities;
- setting deadlines for starting and completing individual activities and the time of completion of the entire program.

The basic concepts in network planning are activity and event. The network of activities (dependencies) presents a specific model of work progress, dependencies and limitations contained in the action program in the form of a graph. The principles of building a network of dependencies are described in the literature, but the ability to compile it is gained only in practice (Michael D. Greicius, B. Krasnow, Allan L. Reiss, V. Menon, 2003). When constructing a network of dependencies, it should be remembered that it concerns specific conditions of execution, with all the consequences of the adopted technical and technological as well

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as organizational and economic assumptions. Before building the network, it is advisable to prepare a written description of the planned undertaking to clearly specify your goals. The size of the network, the number of activities and the degree of difficulty of connections and dependencies should be adjusted to the size of work, technical and technological solutions and organizational solutions and the scope of network decisions on the program (plan) and implementation of the project and control. Concepts of building dependence networks are divided into events-oriented (single-point) and activities (two-point). Due to the possibilities of modeling the proposed solutions, the choice of the concept of network construction is of little importance, although in practice two-point models are more widespread. In network methods based on the network theory, two-point activities are presented in the form of directed edges of the graph limited by events. An event is an element determining the start or end of activities (activities). The event beginning the given activity is called the preceding event, whereas the event ending the given activity - the following event. The preceding event, to which no activity in the dependence network occurs, is called the initial event, and the event the following, from which no activity in the network leaves - the event of the end. An event is thus the moment of completing or starting one or several activities (activities). They are presented in the dependence scheme as a circle divided into four parts, the number placed in the upper part of the circle (quadrant) means the number of the event, the number in the left quarter - the earliest date of the event, number in the right - the latest, the number in the lower quadrant of the circle - the time needed to perform the action (action). An activity is an element that requires time and resources (resources). It is marked with an arrow (graph), and the duration of activity (action) is given on it. The number above the arrow indicates the set or predicted duration of the activity. The activity combines two consecutive events and the numbers of these events are identifiers of a given activity in the dependence network. An additional structural element of the dependence network are zero activities (apparent), which do not absorb time or resources, but only show the ongoing technological and organizational links; they are marked with a dashed arrow. In the dependency network scheme, it is assumed that an event following one action is simultaneously an event preceding the next activity, and thus the ending of all activities aimed at a given event allows to start activities coming out of this event.

The constructed dependence network should meet several formal requirements:

• every event in the network must have a different number;

• the graph showing the given dependence network must be acyclic;

• each event must be associated with at least two other events (exception are initial and final events);

• there may be only one start event and one end event in the network;

• the dependence network can not be a multigraph, that is, there can not be several different activities with the same numbers of preceding and subsequent events.

Events and activities (activities) create the right network of dependencies, which is a graphical representation of the network method. The correct construction of the dependence network, which is then subject to analysis (time and resources), is the most important and the most difficult element in the creation of network methods of planning and controlling work (network schedules). It should be primarily:

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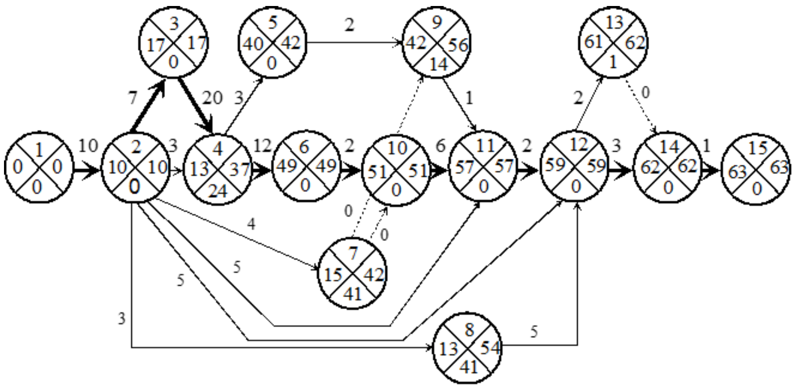
• compile a list of all activities necessary to implement the undertaking;
• determine the necessary sequence of actions and the possibility of their simultaneous implementation.

All activities occurring in the manufacturing process are placed
in the appropriate list (table), regardless of whether they are performed by man or not. At the same time, the following are determined:
• what action should be completely completed before the activity begins;
• what action can be carried out with the action being taken;
• what action can only start after the end of the action being considered.

When building a network of dependencies (activities), it should be carried out on individual activities, taking into account their interrelationships and dependencies. The network of activities should be performed exactly to reflect the real needs of coordination of activities on the one hand and not to be excessively developed on the other hand. Sometimes, firstly, a basic network containing only nodal actions (activities) is prepared, and then based on it, detailed dependence networks are developed, intended for contractors of different levels.

Fig. 1 illustrates a simple exemplary network of dependence of the bulb structure. The list of activities necessary to complete the sailboat and the necessary estimated time of their execution are presented in Tab. 1. The author assumes that the builders of the sailboat are to be members of the family consisting of the father, mother and son, and the construction itself will be done in a house manner. The constructed network model (network of dependencies) will help to find the answer to the question whether it is possible to build a sailboat at a given time or whether it will have to be moved.

Fig. 1. A network of sailboat construction operations with calculated calculations and a critical path (the bold arrow is assumed for the critical path).



Source: Żukowski P., Podstawy naukowej organizacji pracy z wybranymi problemami zarządzania, WSZiA, Opole 2008.

The graph presents a network of activities (simplified), taking into account the logical sequence, as well as the possibility of carrying out certain groups of activities (activities) at the same time. On the network, the individual dependencies between activities are marked with arrows. Each of them has starting and ending points. According to the direction of the arrow, it represents the limited events - preceding and following. The

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identifier of actions in this method are the numbers of the preceding and the following event. The numbering inside the circles (in the upper quadrant), denoting the events, determines the logical order of events, also shows the possibility of performing some of the works at the same time (eg painting, mast drying time and boom). Arrows with dashed lines indicate null (apparent) actions. They have a zero duration and present only organizational and technological links (a specific activity can only be started when the preceding activity is completed), for example painting and painting can only be started after the paints and varnishes have been imported. Measures 7-9, 7-10 and 13-14 in the dependence network (fig. 1) are zero activities, they do not involve the duration or dates of the start and end of activities, but only illustrate the technological and organizational links taking place.

Tab.1. Groups of activities and duration of the ship's construction.

Activity	Order of events (activities)	Duration (5-hour working days)
Making plans	1 – 2	10
Order and check wood	2 – 3	7
Order and check glue and nails	2 – 4	3
Order and import of paints and varnishes	2 – 7	5
Order and import of canvas, thread and cables	2 – 8	3
Order and bringing fittings and nibs	2 – 11	4
Order and bringing interior fittings	2 – 12	5
Cutting the wood	3 – 4	20
Execution of the mast and boom	4 – 5	3
Construction of the hull	4 – 6	12
Painting and drying the mast and boom	5 – 9	2
Drying the hull	6 – 10	2
Zero action	7 – 9	0
Zero action	7 – 10	0
Cutting and sewing sails	8 – 12	5
Mast and boom painting	9 – 11	1
Sealing and painting the hull	10 – 12	6
Deck equipment	11 – 12	2
Interior fittings	12 – 13	2
Trimming sails	12 – 14	3
Zero action	13 – 14	0
Finishing and checking the ship	14 – 15	1

Source: own case study based on: Żukowski P., Podstawy naukowej organizacji pracy z wybranymi problemami zarządzania, WSZiA, Opole 2008.

The dependence network (Fig. 1) was prepared in accordance with the requirements described, i.e. it has only one starting event (No. 1), one final (No. 15), is coherent and acyclic and is not a multigraph. Each activity has its own name and expected duration, determined in working days. The necessary resources needed for its implementation should also be provided from the adopted technology and fixed time of completion. The system of activities and interrelations show the basic organizational assumptions. The plan of making a sailboat presented in this form is clear, easy to interpret and suitable for possible correction (corrections and changes). A network of technological preparation activities for the production of a new machine tool is presented in Fig. 2.

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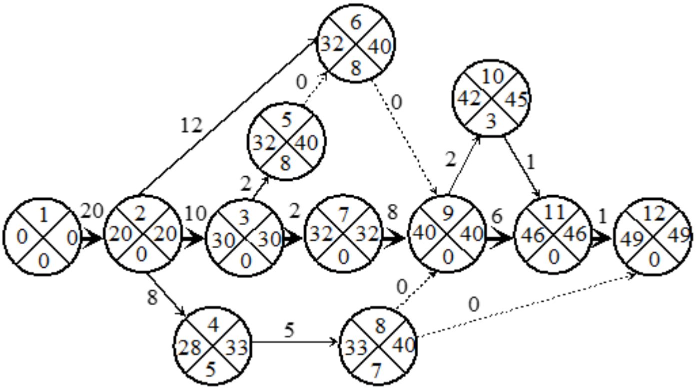
Fig. 2. A network of technical preparation activities for the production of a new machine tool with calculations and a critical path (bold arrow).



Source: Żukowski P., Podstawy naukowej organizacji pracy z wybranymi problemami zarządzania, WSZiA, Opole 2008.

It should be remembered that when constructing a network of dependencies of a planned undertaking (especially a complex one), its readability should be taken into consideration. Some Project Management systems are equipped with procedures that allow automatic creation of dependency network schemas after defining the list of activities and existing connections. It is purposeful when planning small objects (projects), because with a large number of activities, and especially with a complex structure of dependencies, the generated drawings are very often not very legible (Stephen P. Borgatti, A. Mehra, Daniel J. Brass, G. Labianca, 2009 & P. Stępka, K. Subda, 2009).

Aims of paper. Methods

Management sciences use typical methods encountered in the social sciences and humanities, i.e. study of analyzes, expert opinions, source data, etc., comparative methods (legal opinions, analyzes resulting from linguistic, grammatical and historical interpretations) and case studies. The result of cognitive research are new theorems or theories. On the other hand, the results of research for the needs of business practice determine whether and if the existing theorems and theories on the analysis of the dependency network are useful for solving specific economic and social problems that appear in the management of economic entities, both in the area of human resources and production control, inventory optimization, etc. In other words, they serve to refine and fragmentary verification of existing theorems and theories. Induction was used as the main research method. It consists in deriving general conclusions or establishing regularity based on the analysis of empirically identified phenomena and processes. This is a type of inference based on details about the general properties of the

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phenomenon or object. The use of this method requires the assumption that only facts can form the basis for scientific inference. These facts are real situations (economic and management). Inductive methods include various types of legal acts, analyzes, expert opinions and scientific documents used in social research. In addition, two general research methods have been used in the work, i.e. analytical and synthetic methods, characterized by a particular recognition of the reality study. The analysis treats reality as a collection of individual, special features and events (objects of taxation). Proceeding according to this test method consists in distributing the object of research into parts and on examining each of them separately or on detecting components of this object. The negative feature of the analytical method is excessive displaying of details, sometimes causing the entire subject of research to be lost from view. This makes it difficult to fully and objectively know reality, which is a collection of independent partial elements, but also a set of parts closely related to each other in a limited whole. The synthetic method treats reality as a group of features, its implementation consists in searching for common features of various phenomena and events, and then binding them into a unified whole. Thus, the synthetic method examines and determines the whole subject of the research. The aim of the article is to assess the role and importance of the dependence network in business management, from the perspective of quality and management and increasing the organization's effectiveness.

Analysis of latest research where the solution of the problem was initiated.

Since the publication of the theoretical assumptions of the network of activities (dependencies) and two basic methods of their analysis (CPM and PERT), new names of methods and techniques are appearing more frequently in the journals, bulletins and prospectuses of service centers and computer manufacturers. Today, you can register dozens of them. Often the only feature that distinguishes these methods (techniques) from the methods already used is actually their name, because the creators of these methods, minor changes and improvements, raise new methods for commercial reasons. Regardless of this, it is possible to observe constant and sustainable development of already used methods and techniques of activity network analysis. It follows either the path of new original studies or by taking over elements of other methods, causing the boundaries between particular methods to become more and more blurred. Among the network methods, in our opinion one can distinguish:

• methods allowing analysis only in terms of time and dates using both deterministic and probabilistic (stochastic) models. These include CPA, PERT, PEP, PET, OPI, GUR, SPU;
• methods for analyzing time, dates and resources using deterministic models. Important methods in this group are: CPM, LESS, CPPS, CPT, CPA;
• methods for analyzing time, dates and resources using probabilistic models. These include, among others: PERT - COST, PERT CO, SUPER PERT CO, PAR;
• methods for analyzing the time, dates and resources of many projects implemented simultaneously. These are among others the methods: RAMPS, RPSM, SCANS, APPRAISE, SPRAT, IMPACT, SPERT;
• methods for analyzing models with alternative solutions. The most important is the generalized PERT method and so called

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programming and planning based on decision points (V. Alee, 2003).
The CPM and PERT methods with appropriate modifications are still mentioned as the main types of methods of analysis of the dependence network.
In January 1958, during the development of a technique that was to ensure operative control of the Polaris program, the PERT method was established, ie the method (technique) for the evaluation and control of the program. The results of its application proved to be so good that the PERT method, and not the CPM method, which was one year older than it, contributed to the dissemination of such methods in the world. The PERT method is particularly effective during the analysis of one-off projects, especially those of a prototype nature. These projects, in addition to repetitive activities, contain new activities whose execution time can be determined with a greater or lesser probability. Thus, a need arises to develop a probabilistic model of the network analysis of the undertaking being implemented, defining the probability distribution of each activity during a certain time interval. The assumption underlying this assumption lies in the uncertainty of the assessment of the duration of individual activities depending on the amount of information available. According to the arrangements adopted in the classic PERT method, the time required to perform particular activities is a random variable with a beta distribution. In order to make it practical, three times are given: optimistic, most probable and pessimistic. Optimistic assessment and determines the minimum time needed to perform the activity in the absence of any difficulties or disturbances. It is assumed then that there is a very small chance that the activity will be carried out at this time (probability close to zero). The pessimistic assessment b determines the time of performing activities longer than the actual, assuming unfavorable circumstances (probability also close to zero). The most probable assessment is the most appropriate assessment in the case of determining only one duration of activity. These three times of performance assessment, determined in specific time units (hours, weeks, months), must meet the following condition: $a \leq m \leq b$
The PERT method assumes that random variables describing the duration of activities are not dependent on each other and that the interaction between these activities is not taken into account. On the basis of the above mentioned three times, the so-called expected time is calculated, which is the basis for calculations as a function of time. The values of 1.4 and 1 are taken as means of individual time assessments. Therefore, the expected duration of activity t0 is calculated according to the formula:

$$t_0 = \frac{a + 4m + b}{6}$$

The greater the spread of ratings between the optimistic and the pessimistic times, the greater is the uncertainty associated with the execution time of a given activity. The measure of this uncertainty is the variance σ:

$$\sigma^2 = \left(\frac{b-a}{6}\right)^2$$

The calculated duration of activity t0 and uncertainty connected with it σ are the basis for the analysis of the time of the dependence network (activities). The CPM method (the critical path method), described further on, is considered to be the basic network method of planning and controlling work - in addition to the PERT method. The PERT method already known, with all its advantages, is however a poor

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method. In addition to many important features and parameters, this method reflects quantitatively only one aspect, namely time. However, the first development of the CPM network method was aimed at capturing, in addition to time, the costly side of the venture. An integral part of the original CPM method (critical path method) is the optimization of the system: the duration of the project - the total costs of its implementation. According to the CPM assumptions, the duration of the undertaking, calculated by means of the network analysis, resulting from the duration of individual activities, from the so-called critical path, is taken as the "normal" time, based on the so-called normal assessment of the duration of activities. It is assumed that the performance of activities (activities) in the normal time is associated with the lowest direct costs (P. Anklam 2007 & J. Scott, Peter J. Carrington, 20011 & Peter J. Carrington, J. Scott, S. Wasserman, 1994). Referring to the example of the construction of a sailboat and the course of the production process presented by the network of activities in Fig. 1, we can determine the duration of individual activities. In this case, a 5-hour working day was accepted per unit of time; the duration of individual activities is shown in tab. 1. In order to calculate the duration of the entire undertaking, it is necessary to go along the arrows to set a sequence of activities whose sum of execution time is the largest, so the longest path in the network of activities should be determined. This is the critical path (path) and critical activities are critical activities. It is assumed that the duration of the critical path (in Fig. 1 marked with a bolded arrow) is the shortest possible time of the entire undertaking. Activities not lying on the critical path, that is, noncritical activities, have a certain reserve (so-called reserve) of time for their execution. The time available for performing any activity indicates how many time units can be postponed until the completion of the entire project has been completed. In the example of building a sailboat, for example, activities 2-8 have a stock of 41-hour long working hours, which means that starting this construction only on the 54th day will not delay the end of the project; also starting work on the 13th day will not speed up the date of completion of boat construction. Activities with little time for their execution are considered to be subcritical activities and are classified as critical, because even with small delays of deadlines they become critical activities. The importance of the critical path is already revealed during the planning of a given undertaking. It allows to isolate from the complex of activities those that have a decisive impact on the successful completion of the undertaking on a date determined in a logical and justified manner in terms of technical and economic terms. The management of a given undertaking, wishing to manage it efficiently and rationally, must pay special attention to actions. Knowledge of the road and the critical zone also allows the management to rationally prepare adequate reserves, in the form of qualified personnel, as well as standby machines and equipment, spare parts stocks, materials, semi-finished products, etc. The importance of the critical path also manifests itself in the course of controlling the implementation of the undertaking. The network of activities allows, with a minimum of workload, to receive an ongoing picture of the implementation of the plan of the entire project and update it, maintaining always well-thought-out, thoroughly analyzed and approved its organization. In principle, updating an activity network involves entering information about the real time of the course of individual activities (activities) during the implementation of a given undertaking. If

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certain time inventories are exceeded, due to disturbances in the course of non-critical activities, a new critical path may be created in the network. In practice, such a situation results not only in changing the date of completion of the entire undertaking, but also in the need to shift reserves or increase inventories, for example increasing the number of work measures related to a given measure, the number of contractors and other resources. The method of critical path analysis enables management bodies to quickly assess the impact of each change that occurs during the performance of a given organizational and technical project (object) on its final result. At the same time, it allows you to take the optimal decision in a given situation. The critical path method (CPM) is thus an efficient management tool, which also proves its great practical importance. After getting acquainted with the methods of analyzing the network of activities (dependencies), it is easy to form an opinion on the possibilities of their application. They are used in the planning and control of particularly difficult and complicated technical and organizational projects. The creators of the CPM method for the first time used it to plan and control the order of renovation works carried out by large chemical objects of the chemical concern Du Pont. The PERT method, in turn, was used for the first time to plan and control a prototype project of a one-off nature, which was the Polaris program (rocket construction). Despite the wide range of broad application of network methods in the literature, several areas are mentioned where their use is particularly beneficial. It is mainly about:

• preparing and conducting complicated and long-lasting research and implementation works;

• preparation and launch of production of prototype devices:

– preparation of project-estimate, contract and construction documentation,
– development of technological and workshop documentation,
– coordination of supplies of materials and devices,
– construction of the device,
– acceptance tests,
– commissioning and commissioning;

• planning of unit production;

– planning and coordination of some sections of works,
– planning all projects carried out simultaneously,
– investments and repairs,
– investment programming,
– planning general assumptions for plant development and modernization,
– construction of large investment facilities,
– export of complete investment objects,
– major repairs, plant modernization;

• organizing activities:

– changing the range of production,
– preparing and implementing organizational changes (plant reorganisations, changes in pay systems, planning methods),
– introduction of integrated information processing systems,
– preparing conferences, conventions, large celebrations (Michael D. Greicius, B. Krasnow, Allan L. Reiss, and V. Menon & K. Ara, N. Kanehira, D. Olguín, B. N. Waber, T. Kim, A. Mohan, P. Gloor, R. Laubacher, D. Oster, A. (Sandy) Pentland, K. Yano, 2008).

Due to the quite significant differences distinguishing certain network methods, attention should be paid to the most purposeful application of them:

• the CPA method is used for operative planning, management and control of the

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course of project implementation, in which most elements are already known;

• the CPM method is used where there is a need to closely match the duration of activities with the cost of the project and determine the most favorable implementation cycle;

• the PERT method is mainly used to plan and control new, yet unknown projects, including elements of uncertainty, impossibility of deterministic assessment of time;

• generalized PERT method is used during planning of studies characterized by a multi-variant course of the implementation process;

• The RAMPS method is used for complex, complex, intentional purposes from a few or a dozen different projects, when it is necessary to set proper priorities for them, an even distribution of resources (J.S. Brown, P. Duguid, 2000 & R.S. Burt, 2001).

When applying the method of activity network analysis in a given undertaking, it should be remembered that it should have a clearly defined start date. It is desirable that it should be a date in the near future, however, many benefits may also give the use of the discussed methods to projects already started, being in progress, which is to continue for a long time. In its simple form, network methods can be used for projects presented using small and medium-sized networks, without the help of electronic calculating machines. More developed methods of analysis of dependence networks generally require cooperation with computing centers that have computers with large internal memory and appropriate data processing programs or those that can develop and implement such programs. The scope of application of network methods covers all investment works (construction of metallurgical plant, construction of a highway), unit production (construction of a turbine), renovation and construction works (renovation of a blast furnace). The non-technical applications of the discussed methods include: organization of large sports events (eg olympics), scientific conferences, conventions, etc. This range of applications of network methods results mainly from the relatively simple principles of their construction and high efficiency.

Network analysis in case of probabilistic model in production management. In order to ensure the production continuity, the reserves of different kinds of based material are generated and maintained. In the furniture industry, wide range and community of decisions, as well as, economic influence of wrong decisions concerning material reserves are of such importance, that they prove a need of overworking an optimal strategy of based material reserves management on the basis of the probabilistic model with an application of computer techniques (S.J Farlow, G. M.. Haggard, 1987 & F.S. Hilier, G.J. Lieberman, G.J., 1998).

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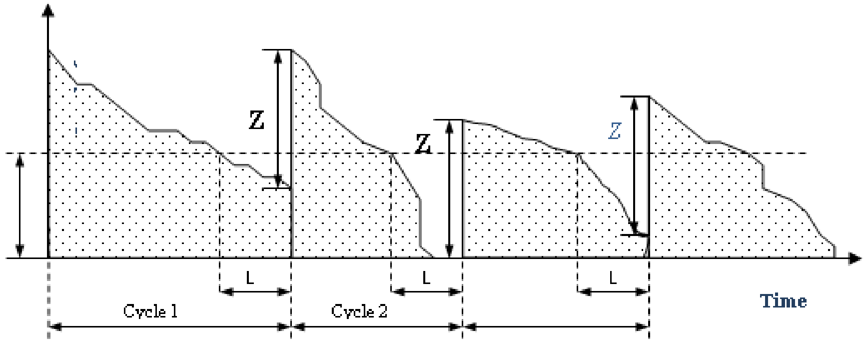
Fig. 3. Change in the level of material reserves in a store: Z – value of order of special kind of material, R – value of safety reserve, L – period of delivery.



Source: own elaboration.

The level of wood material reserves in a store of furniture industry's differs during time, depending on input and output of these materials. Input of these materials depends on the amount of supplied material and time between deliveries, whereas output depends on the level of production consumption (Fig. 3). A period of time between subsequent material deliveries (delivery cycle) fluctuates, as well as production consumption of different kinds of materials. The problem of based material management could be a source of opposite tendencies in a factory. There are groups of different factors (technical, organizational, economical, financial etc.) which influence high or low levels of material reserves. High levels of material reserves are concerned with the great costs of storage, but low levels influence costs as well, because of the lack of production consumption ensuing (the continuity not ensured). The level of based material reserves is maintained on certain rigidly determined levels. Keeping of high or low levels of materials in a store is a source of additional costs. The main objective of reserves management optimization should focus on analysis of costs of these materials, while criterion of optimization should be the minimization of value of expected medium costs of buying, storing and lack of production consumption ensuring of based materials. As a result of main (criterion) function optimization there is to ensure the levels of based materials needed for the regular production program realization, with the lowest level of cost.

In order to construct the probabilistic model of reserves management such symbols are introduced:

D – mean production consumption for special kind of material in certain time (e.g. medium years consumption),

Z – value of order of special kind of material,

D/Z – mean number of orders of special kind of material in certain time (e.g. during one year),

R – value of safety reserve (for special kind of material),

K – constant costs of orders,

h – single cost of storing,

p – single cost in case of lack of needed level of reserve for special kind of material in a store,

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L – period (time) of delivery (time for order realisation),
v – production consumption for special kind of material in period of delivery,
E(v) – wanted value of production consumption for special kind of material in period of delivery,
g(v) – probability distribution of production consumption for special kind of material in period of delivery (function, of random variable density probability),
b – mean level of lacking stores in period of delivery,
B – mean level of lacking stores for special material in certain investigation time,
E(B) – expected value of mean level of lacking stores for special material in certain time,
A – uniform distribution - upper limit of function,
E – operator of expected value,
F(Z,R) – main function of model with decisive variables Z and R.

It should be noted, that by the end of delivery cycle expected level of reserve of certain based material in a store is R–E(v) but when a particular order is completed (on the beginning of cycle) such level is Z+R–E(v). Expected medium level of reserves for certain kind material in the cycle (if $v \leq R$) is equal to:

$$\frac{\left(Z+R-E(v)\right)+\left(R-E(v)\right)}{2}=\left(\frac{Z}{2}+R-E(v)\right) \qquad (1)$$

If, $v > R$, then medium level of lacking reserve of certain based material

$$b=\int_{R}^{\infty}(v-R)\,g(v)\,dv \qquad (2)$$

(b) in a store is calculated:

Expected in a certain time (e.g. during one year) medium level of lacking stocks special based material (B) in a store is obtained by the equation:

$$E(B)=b\cdot\frac{D}{Z} \qquad (3)$$

riate costs, multiplicating appropriate single costs h and p by the expressions (1) and (3). Thus, the main function of optimisation in the probabilistic model of material reserve management at a certain time can be expressed by the formula:

$$E\left[F(Z,R)\right]=K\frac{D}{Z}+h\left[\frac{Z}{2}+R-E(v)\right]+p\frac{D}{Z}b\rightarrow \min \qquad (4)$$

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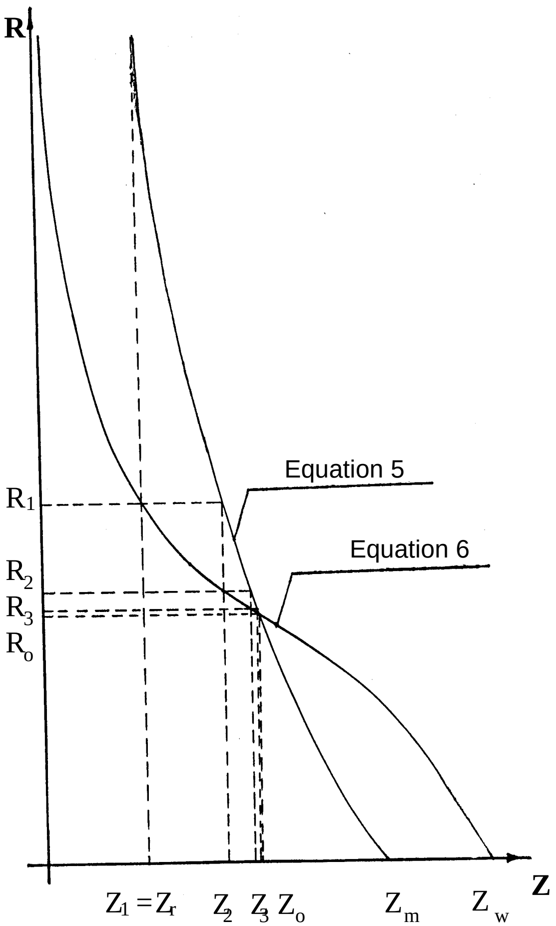
The first component of sum represents mean cost of constants, the second one is mean cost of storing reserves, whereas the third component means cost in case of lack kind of certain reserve. Changes in the level of quantities of basic values (Z and R) in the main function will be minimal when Z and R are optimal (Anatoly V. Kondratenko, 2015). Then, the dependencies should determined from which optimal values Zo and Ro could be calculated. It is necessary, that for optimal values of the pair (R,Z).

Fig. 4. Scheme of iteration researches Z_0 and R_0.



Source: own elaboration.

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the first partial derivatives of the function (1) in a comparison with Z and R values will be zero. Optimal values of order and store level R expressions could be found:

$$Z_0 = \sqrt{\frac{2D(K + pb)}{h}} \tag{5}$$

$$\int_{Ro}^{\infty} g(v)dv = \frac{hZ_0}{pD} \tag{6}$$

Should be underlined that the expressions (5) and (6) can not be used for direct calculating of optimal values (Z_0, R_0). (Fig. 4.). Thus, an iterative method (process) of seeking Z_0 and R_0 values in the finite number of steps was elaborated [2]. The conditions of required convergence of the iterative method (existence of the solution of problem) satisfies the inequality as follows:

$$\frac{pD}{h} > \sqrt{\frac{2D[K + pE(v)]}{h}} \tag{7}$$

i. e. $Z_w > Z_m$ (Fig. 4).

Algorithm of setting the optimal values. Beginning the iterative process with the first probable meaning of Z value equals $\sqrt{2DK/h}$, with the increase of iteration numbers the value of Z_i increases, when R_i value decreases. Hence, the iterative process is quickly convergent. It is recommended to use computer techniques to calculate the R_0 and Z_0 $(R_0 = \lim_{i \to \infty} R_i)$. For this purpose the computer software of operative scheme of R_0 and Z_0 was written. This program does calculations until the difference $R_{i+1} - R_i$ values is adequately low (e.g. 0,00001). It means, that two calculated values are similar. For the optimal value R_0 we use then R_{i+1} value, because $R_0 \cong R_{i+1}$. The optimal value of Z_0 were estimated on the basis of $R_0(R_{i+1})$ (Fig. 3, Fig. 4). It should be noted, that in case when there is even distribution of probability of production consumption of bases materials, the expressions (5) and (6) should be solved directly, i. e. optimal values of R_0 and Z_0 could be presented as follows:

$$R_0 = A\left[1 - p^{-1}\sqrt{\frac{2Kh}{D - Ah}}\right] \tag{8}$$

(8)

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$$Z_0 = D\sqrt{\frac{2K}{h(D - Ah)}} \qquad (9)$$

The formulas (8), (9) are based on case of even probability of production consumption of materials:

$$g(v) = \begin{cases} 0, & if \quad v \notin]0, A[\\ \frac{1}{A}, & if \quad v \in]0, A[\end{cases} \qquad (10)$$

The integral in the expression (6) can be presented by using elementary functions. In general case, the presented simplification is not possible and iterative process of estimation R0 and Z0 should be then employed (D. Farmer, M. Shubik, and Eric Smith, 2005 & Jean-Philippe Bouchaud, 2008).

Exposition of main material of research with complete substantiation of obtained scientific results. Discussion.

Methods for preparing and analyzing a network of activities for planning and work control, play an important role in improving business operations, especially in production, renovation and investment. They enable optimization of this activity (through appropriate analysis of time and resources), and thus better management of resources. Network methods are only a tool for effective management, enabling better results from the given inputs or achieving a given result with minimal consumption of resources (resources). Analyzing the development of research on the improvement of planning and control methods, based on network models (network schedules), one can notice more and more mature attempts to include random elements. The first developed method for analyzing network schedules as a function of time (CPM) captures the execution time of each activity (groups of activities) as a deterministic value, while all subsequent extensions of this method (techniques) allow entering data that maps the probabilistic (stochastic) nature of the planning process. The PERT method allowed to declare three assessments of the execution time of individual activities, which in turn allows to calculate the probability of keeping deadlines for the implementation of individual activities and the entire technical and organizational project. This is a progress in relation to the CPM method, but the assumption of stochastic independence of individual activities and their individual strings greatly simplifies the way of calculations and reduces the reliability of the obtained results. Therefore, attempts have been made to determine the time distribution of the event in which more than one activity coincides and introduce it to the calculations. The calculation method proposed by Clark solved this problem, however, due to great difficulties in calculations, it has not been adopted in practice. Another attempt to increase the reliability of network planning is the proposal to calculate the reliability of the network schedule.. In the classic PERT method, the critical path is taken as the most important

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set of actions (group of activities), however, the certainty of performing neither specific activities nor the entire network program within the set deadlines is considered. By defining the concept of reliability of network programs, it became possible to determine the sequence of activities determining the deadline in the dependence network and calculating the most favorable (optimal) construction cycle from the point of view of reliability. Because the reliable object completion cycle is longer than the period calculated in the traditional time analysis, a time reserve separation algorithm was built in order to increase the reliability of keeping the construction cycle due date. Factors that increase or decrease the certainty of meeting planned dates, such as the size of the planned project, the availability of production resources or the method of organizing the construction, were also analyzed. One of the more common objections regarding the classical PERT method is the way of determining the duration of activities. An interesting method of defining this time is a method based on fuzzy set theory, which allows gradation of truth and falseness. In binary logic, the logical variables take the values 0 or 1, while the logical functions "or", "and" and "not" return 0 values as a result of their operations or 1. In fuzzy logic, variables and logic functions assume values in the interval [0 ... 1]. In the proposed method, the time model of the activity implementation is defined as the "fuzzy" relation in a set of possible terms. The share of a given element in a set of fuzzy values is defined by the so-called participation (membership) function. In this case, the time limit for completing activities is not strictly related to any specific time point, but falls within a certain range. The blurring is the greater, the less precise are the estimates of the duration of individual activities (activities). In the light of the conducted research on applications in engineering the theory of fuzzy sets to describe and study phenomena in which another mathematical model would have to be very extensive, it seems that this approach may in the future be widely used in network planning, especially in the analysis resources (resources), while maintaining the imposed restrictions in their availability. Regardless of the ways of estimating the time of performing the activities, significant progress was also made in the techniques of constructing the dependence network. Newer systems, based on single-point networks, allow for the definition of alternative connections between the activities under consideration. In addition, in these systems it is possible to determine overlap times or required intervals between their execution. It should be noted that such a method of establishing connections between activities increases the flexibility of the constructed network, but often complicates and stiffens the analysis of funds and causes difficulties in the interpretation of the obtained calculation results. By operating only a SF (start to finish) connection and using zero actions, you can model any coupling system between activities, but the analysis results are not difficult to interpret. The only disadvantage of this solution is the possible increase in the number of activities in the dependence network. Further research into the structure of the dependence network led to a significant extension of the definition of the event. In the GERT method, in which the described solutions were most fully implemented, an additional definition of the duration of activities based on a dozen or so probability distributions was introduced. Such a flexible way of object modeling - a technical and organizational undertaking - eliminated many draw-

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backs of the original PERT method and significantly increased the reliability of calculations based on it. However, it has extremely complicated the process of data collection, the design of the dependency network, and above all multiplied the requirements for programs and equipment that can be used to calculate. It appears that in engineering and organizing practice, such advanced methods will not find widespread use. However, it should be remembered that the first implementations of the PERT method also concerned very extensive military projects, but with time the progress in the field of operational research, electronics and computer technology allowed them to be adapted to planning and controlling the implementation of small and medium-sized technical, technological and organizational projects. What is important, the analysis aimed at searching for information brokers allows the organization to minimize the dependence of knowledge and information flow processes on individual people. It is particularly important in the case of enterprises characterized by high turnover of employees and companies in which key experts enter the pre-retirement age. The awareness of threats related to the addiction of the organization's intellectual capital from a few key information brokers should lead the management to take steps to retain key knowledge resources, thus enriching the so-called organizational memory 29. The activity often undertaken in this case includes the main information brokers in the work of task forces as well as in the mentoring and internal training system.

Conclusions.

The possibilities of various applications of the methods of analysis of the dependence network (network methods), as well as the fact that all their results are unknown, undoubtedly hinders their analysis and evaluation. However, in the literature on the subject, which uses national and international experience, there are numerous attempts to make such an assessment. We can states that it allows:

• unambiguous, clear and easy record of the project implementation plan for any level of management (management) with a specific accuracy;

• precise determination of coordination links between the contractor.

Assessment is more beneficial if a different planning and control method is used to analyze the activity network. It can then be concluded that the methods used:

• they are simple and do not require special preparation from users;

• they do not require the collection of additional information or statistical data, other than those that are collected in every normally operating enterprise;

• they force you to real planning;

• they help to precisely specify the tasks of particular levels of management and production and to assess their burden;

• facilitate the prior specification of tasks for any control cell;

• give the management precise information of a preventive nature, enabling decisions to be taken to ensure the correct course of implementation;

• enable defining the advance of deliveries of materials (semi-finished products) as part of the cooperation, which results in a significant reduction in the freezing of current assets;

• they enable the most effective use of resources (resources) related to the implementation of the undertaking;

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• facilitate the updating of production plans and enable delivery of precise network schedules for all levels of management;
• allow you to focus only on activities or a critical zone.
It is also worth mentioning the effects of using network methods in practice in accordance with their intended use. They create the possibility
characteristics:
• implementation of projects according to the most economical options with regard to assumed or forced situations;
• reducing the freezing of current assets;
• shortening of production cycles;
• better use of additional resources (eg overtime);
• detection of production reserves;
• increasing the production rhythmicity.
It is difficult to list all the advantages and sources of effects from the use of network methods, because these methods have a multidirectional impact on many technical and organizational issues. As usual, in addition to many advantages, network methods also have disadvantages. We calls them rather problems and difficulties appearing in the implementation of network methods to practice. Here are some of them:
• as a method, new network analysis requires more management attention, which must understand that it is only a means to the goal, and evaluate the suitability of the method to its specific conclusions;
• analysis of the activity network is not an automatic system and does not replace the management decision. Its task is to prepare and provide information to help you make the right decision.
This method interferes with established traditional organization and management schemes. It treats the implemented project as an integrated system, thus it moves away from the traditional vertical structure and stimulates horizontal cooperation and coordination at lower management levels. The management staff responds to the dynamic nature of planning and work control rather passively or even negatively. We also emphasizes other disadvantages of network methods. It claims, inter alia, that:
• methods of network analysis of activities do not solve all problems related to planning, management and control;
• these methods can not be used to control continuous processes, planning and large-scale production as well as mass production;
• analysis of large networks (eg for large projects) must be carried out using high-powered computers, which creates some limitations.
However, the aforementioned advantages of network methods are so important that they indicate their practical usefulness and high efficiency of application in practice.

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