Planning a Research Process in Security Sciences Through Methods of Operational Research

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Abstract. *This article presents fundamental issues related to the process of planning scientific research in security sciences based on methods belonging to operational research. Operational research is one of the areas that are intensively developed and implemented towards security and performance improvement in areas such as planning, organizing, implementing or controlling various types of projects. Therefore, issues related to operational research, its methodological foundations, and the use of network programming methods in the field of planning research process required a broader explanation in the context of security sciences. As a consequence, a reference to the decision model was made. It was stated that each decision related to security research increases the demand for methods of analysis and objective assessment. Each undertaking, in particular this related to security research, is associated with specific goals, the achievement of which requires possession of appropriate forces and resources. This study refers to the essence of project implementation time, which is very often limited and can be used in a variety of ways, which is determined by the specific conditions in which the technical, organizational or other activities are carried out. As a consequence of the above, it is stated that the research process is characterized by conducting a sequence of activities aimed at achieving research goal, solving research problem or verifying hypothesis within a specified time frame. It is also stated that each research process has a specific duration and one can be tempted to state that it is usually unique.*

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Introduction

Contemporary conditions of the world cause security to be regarded as the most important value for a 21st-century human. The comprehensive nature of security determines the fact that persistent maintenance thereof requires undertaking of numerous specific projects. These are, firstly, preventive projects against occurrence of hazards, secondly, preparatory ones in the event that hazards occur, furthermore, responsive ones after hazards have occurred, and finally, projects aimed at reconstruction. In the case of these enumerated kinds of projects, it is necessary to make decisions on the extent and manner of implementation thereof.

In view of the above, the subject matter of conducting research in security studies is characterized by quite an urgent need to improve the conceptual apparatus and to search for new, effective research methods, techniques and tools drawn from different disciplines as well as theoretical and practical approaches in the area of decision-making. Operations research is among the areas which enjoy sustained

interest and are extensively developed and implemented towards security and performance improvement in areas such as planning, organization, implementation, or project control. Taking the above into consideration, this study will present the scope of operations research and its methodological basis, as well as an original application of network programming methods in the area of planning a research process in security sciences.

The scope of operations research

As mentioned above, the scope of operations research is connected with a discipline concerned with the theory of decision-making, but simultaneously, it remains correlated with mathematical programming. As remarked by W. Sikora, it is hard to delineate clear boundaries between operations research, the theory of decision-making, and mathematical programming.[1] In order to explain the scopes of individual fields, their areas have been specified below. Thus, operations research is aimed at construction of models of different decision situations; the theory of decision-making is responsible for development of appropriate decision rules based on analysis of decision-making models while mathematical programming is connected with construction and analysis of properties of algorithms of resolution of specific optimization problems. It should also be emphasized that operations research is connected with economy and econometrics, i.e. fields of knowledge concerned with quantitative description of reality.

As a consequence of the above, it is stated that each decision connected with the subject matter of security research intensifies the demand for methods of analysis and objective assessment of decisions made in broadly understood planning. All projects, including, in particular, those related to security research, are connected with specific goals the achievement of which requires appropriate resources. Very often, these resources are limited and may be used in different ways, as determined by specific conditions under which the given project of technical, organizational or other nature is performed.

Decision models

A tool used by operations research specialists to determine an optimal decision is a decision model, also known as an optimization model. There are many kinds of decision models in operations research, depending on the results of decision-making and the kind of the decision problem. The models regarded by the author as the most useful for the purposes of security are:

- network models;
- decision trees;
- dynamic programming model;
- linear programming model;
- non-linear programming model;

[1] Sikora W (Ed.), Badania operacyjne. Warsaw, 2008, p. 10.

— simulation model (Monte Carlo).

From the viewpoint of practical application, the entire complex of optimization methods which could be implemented towards security may be divided into the following problem groups:

1. planning, organization and control of security-related projects;
2. decision-making under conditions of risk (decision theory, game theory);
3. decision-making under conditions of uncertainty.
4. optimization of security-related transport (transport issue);
5. control of resource reserves;

In the author's opinion, referencing the object of methodological reflection of security, network models and, in particular, methods used for planning, organization and control of implementation of projects may be transposed to the field of the subject matter of scientific research methodology in the area of planning, organization and control of implementation of the process of security-related scientific research on security sciences.

In view of the above, a general description of planning was provided in order to proceed to the description of the basics of network programming methods. Next, the Program Evaluation and Review Technique (PERT) method was characterized followed by the reference to Critical Path Methods (CPM) in order to present the planning schedule for the project related to the research process using the CPM method.

Planning description

Planning can be understood as 'defining goals and the best ways to achieve them'[2]. It is both a process of defining goals and ways to achieve them in an efficient and effective manner. In other words, planning is 'the purpose of the future action anticipated by the actor, a state of affairs in some respects that, as an actor in some way valuable, sets the direction and structure of his action to cause or maintain this state of affairs.'[3]

The process of defining goals takes place in the context of a specific environment and effective planning is not possible without thorough knowledge of it. Therefore, both internal conditions and external environment should be taken into account. Planning in each organization corresponds to its organizational structure, and fulfils two tasks at each level.[4]

The first of them sets goals for lower-level plans, while the second is an instrument for achieving the goals set in higher-level plans. Objectives can be divided into:

— operations;
— tactical;
— strategic;

The operational objectives are set at the lowest level and relate to short-term problems associated with the tactical objectives.

[2] Kuc B.R, Zarządzanie doskonałe. Warsaw, 2000, p. 104.

[3] Mikuła B, Pietruszka-Oryl A, Potocki A, Podstawy zarządzania przedsiębiorstwami w gospodarce opartej na wiedzy. Warsaw, 2007, p. 31.

[4] Zieleniewski J, Organizacja zespołów ludzkich, Wstęp do teorii organizacji i kierowania. Warsaw, 1978, p. 206.

Tactical objectives concentrate on the rationalization of the activities necessary to achieve strategic goals.

Strategic objectives are set at the highest level and focus on broad and general issues[5].

Due to the implementation time, we can distinguish the following types of planning:

— strategic (over 5 years) — a plan of the future, implemented on a one-term basis thanks to appropriate conduct and implementation of tasks aimed at this.
— long-term (from 2 to 5 years) — specific activities related to the implementation of the main objective.
— medium-term (from several months to a year) — this is part of the implementation of the long-term plan.
— short-term (up to three months) — specific tasks to be performed as part of the medium-term plan.
— ongoing — detailed activities carried out daily or on a weekly basis[6].

Access to information and the ability to process this information into decisions are important in the planning process, resulting in an action plan. For this reason, both the planning process and decision making are distinguished[7]. Deciding is choosing one action from a certain group of available actions. The choice of a particular type of decision depends on the nature of the problem. However, the decision should always follow the cycle of organized action consisting in setting the goal, examining the means and methods that are needed to achieve the set goal, and preparing the means and conditions deemed necessary[8].

Basics of network programming methods

Implementation of each decision of an entity should be connected with planning of specific projects set in a specific time and taking place at specific implementation costs. This planning of projects may take place using methods of planning of complex organizational projects, also known as network programming methods in the literature on the subject.

A project is understood here as 'an organized human activity aimed at achievement of a specific goal, contained within a finite time interval, with a determined beginning and completion, implemented by a finite number of pieces of information, people, technical and material resources, as well as financial resources.'[9]

Foundation for network programming methods is a definition of time relations between individual activities, i.e. strict determination of the sequence and durations thereof, which enables building a network of activities illustrating the course

[5] *More:* Gikiewicz M, Analiza porównawcza planów zarządzania kryzysowego na szczeblu wojewódzkim. *Zeszyty Naukowe SGSP*, 2013, Vol. 45, Issue 1, p. 27.

[6] Sienkiewicz-Małyjurek K, Krynojewski F.R, Zarządzanie kryzysowe w administracji publicznej. Warsaw, 2010, p. 104.

[7] *More:* Gikiewicz M, Analiza porównawcza …, *op. cit.,* p. 28–29.

[8] Czerminski A, Czapiewski M, Organizacja procesów decyzyjnych. Gdańsk, 1995, p. 39.

[9] Kukuła K (Ed.), Badania operacyjne w przykładach i zadaniach. Wydanie VII. Warsaw, 2016, p. 223.

of the entire given project under discussion. The activities network itself, presenting the sequence of all activities in a project, consists of the following components:

- An activity is a portion of the project, characterized by duration and consumption of resources for implementation thereof.[10]
- An event is a moment in time when a certain degree of progress in implementation of the project has been achieved.[11]
- A dummy activity not connected with lapse of time. It connects events between which no spending of resources is required but time sequence exists.[12] The graphic symbol is a dashed arrow;
- A critical path, meaning the longest sequence of activities necessary to be performed as a part of a project[13] and determining the shortest time for implementation of the project. It consists of critical activities the implementation of which does not allow any float.

The network of events implemented in a project concerning a research process is presented as a set of activities, indicating a preceding and following activity for each of them. The methodology of building project networks consists of the following stages: development of a precise listing of activities; next determination of events initiating the beginning and completion of the project; then determination of the sequence of performance of activities, including preceding, parallel and following ones; afterwards determination of durations of individual activities; and finally graphic presentation of the network of activities planned in the project[14].

These presented stages enable detailed planning of projects performance. Nevertheless, when developing a network of activities, one should take account of the basic rules of creation thereof. In the network model of a project, it is required that the initial activity have no preceding activities, the final activity have no following activities, and that all activity-initiating events, excluding the initial one and the final one, be an end and a beginning of at least one activity. The list of rules is supplemented by the one stating that two consecutive events may only be linked by one activity and that the arrows representing activities should not cross.

Due to the limitations of editorial nature, the further part of the article focuses on presentation of a general characterization of the methods, taking account of the criterion of optimality concerning the minimization of the duration of a project.

Description of Program Evaluation and Review Technique method

The Program Evaluation and Review Technique is a network programming method. The most crucial issue in network methods is determination of durations of given activities, due to which, error in estimation of durations is a quite a common

[10] Majchrzak E (Ed.) Badania operacyjne teoria i zastosowanie. Gliwice, 2007, p. 232.

[11] *Ibid.*

[12] Kukuła K (Ed.), Badania operacyjne…, *op. cit.*, p. 224.

[13] Kołodziński E (Ed.), Modelowanie w inżynierii bezpieczeństwa. Warsaw, 2015, p. 177.

[14] *More:* Gikiewicz M, Badania operacyjne bezpieczeństwa, [in:] Czupryński A, Wiśniewski B, Zboina J, Nauki o bezpieczeństwie. Wybrane problemy badań. Józefów, 2017, p. 104.

problem. Therefore, one of the main goals of planning is risk minimization. The risk connected with duration of a project is assessed using the PERT, developed just after the CPM, in 1958. It is a stochastic method of planning and control of implementation of projects. 'Stochastic models assume that durations of activities may only be determined with a certain probability.'[15] The PERT is mainly used for projects of prototypical nature, with no possibility to determine the duration of an activity by comparison with other model projects. The goal of the PERT is to identify the parts of the process and to determine time segments with the greatest effect on implementation of the project. In this method, the duration of each activity is estimated. Durations of activities are assumed to be random variables in normal distribution N (*m*,δ), whereas:

- *m — the average value of duration of an activity;*
- δ — *standard deviation from the average value of duration of an activity.*

Such an approach to duration of activities comprising a project enables application of probabilistic methods to determine the probability and risk of completion thereof within the desired time limit.[16] The probability distribution parameters of the expected completion date of the task are determined on the basis of values of estimations of three time variables:

— optimistic,
— actual,
— pessimistic.

Assuming the following designations: t_o — optimistic time of performance of the activity, i.e. the shortest possible duration of the activity; t_r — actual time of performance of the activity, i.e. the most probable duration of the activity; t_p — pessimistic time, i.e. the longest expected duration of the activity, the formula for the value of expected time (t_{ocz}) assumes the following form[17]:

$$t_{ocz} = \frac{t_o + 4t_r + t_p}{6}$$

The experience suggests that this method assumes that probability distributions of duration of individual activities are *beta* distributions. In network methods, it is assumed that the variance of duration of an activity is expressed by the formula:[18]

$$\sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2$$

Variance is an assumed measure of uncertainty of duration of individual activities. Probabilist terms also enable calculation of performance of the entire project within a specific time, as well as stating the time for project performance with a given probability.

[15] Kołodziński E, Lachowicz T, Tomczyk Ł, Zapert P, Modelowanie w inżynierii bezpieczeństwa. Warsaw, 2015, p. 188.

[16] *Ibid.*, p. 190.

[17] Cegiełka K, Matematyczne wspomaganie decyzji. Warsaw, 2012, pp. 98–99.

[18] *Ibid.*, pp. 98–99.

Description of a Critical Path Method

The Critical Path Method is a method of analysis of project duration. It enables graphic presentation of the planned activities within a given project, indicating their estimated duration. The network parameter is the duration of individual activities, attached to the edges of the graph as a weight. All activities presented in the structure of a project must be implemented; unambiguous determination of duration thereof has to be possible as well. This method may be applied when durations of individual activities are known and determined, i.e. when time is expressed in a single number, e.g. in minutes, days, weeks, etc. In most cases, the CPM is applied for projects with a certain degree of repeatability, enabling determination of durations of individual activities by analogy. This enables time management as a part of implementation of a project. As a part of analysis of time conditioning of project implementation, the following steps of activities may be identified:

- presenting the project structure as a network chart;
- determination of times of occurrence of individual events;
- determination of beginning and completion times of individual activities comprising the entire project;
- determination of the completion date of the entire project;
- calculation of floats;
- determination of a critical path conditioning timely implementation of the project;
- control of implementation of the critical path activities and of the sub-critical activities[19].

As shown above, the hitherto described method is characterized by determined duration of individual activities. However, the experience shows that the duration of individual activities may fluctuate over a wide range. Therefore, an useful extension of the CPM is to include probability to determine the duration of an activity. This is also the essential difference between the CPM and the PERT method characterized below.

Case study

For example, Table 1 below shows a research process expressed using the CPM, being, as pointed out by the literature on the subject, 'a multi-stage process comprised by a set of research activities aimed at relatively full and objective learning and explanation of the phenomena of interest for the researcher.'[20] A similar approach to the definition of a research process is proposed by M. Cieślarczyk and B. Wiśniewski.[21]

[19] *More:* Gikiewicz M, Badania operacyjne…, *op. cit.,* p. 105.

[20] Kuc B.R, Ścibiorek Z, Podstawy metodologiczne nauk o bezpieczeństwie. Warsaw, 2013, p. 122.

[21] Wiśniewski B (Ed.), Bezpieczeństwo w teorii i badaniach naukowych. Wydanie II. Szczytno, 2018, p. 15.

Nevertheless, the literature on the subject of research methodology includes different suggestions and proposals concerning the manners of conducting the research, as well as stages of research procedure. These disagreements result from difference in understanding research goals, research subjects, the undertaken subject matter of research, or the research methods, techniques and tools themselves. However, a research process should always be planned in such a way to enable implementation of the assumed goals. It is stated that the activities identified in the research process should be put in a sequence of consecutive activities which affect each other and jointly determine the value of the collected research material. As pointed out by A. W. Maszke, 'the sequence of activities in a research process is sometimes subject to change or modification,'[22] however, it is important not to disregard any of them, since conclusions from one stage of research usually constitute a beginning of the following one.

In view of the above, a research process is characterized by carrying out a sequence of activities aimed at achievement of the research goal, resolution of a research problem, or verification of a hypothesis within a specific time frame.

It is also stated that each research process has a specific duration and one may risk a statement that it is usually unique. Management of such a research process may be defined as planning (what should be done), organizing (how it should be done), implementation (performance of the planned activities) and control (maintenance of the set direction of research).

The above provides a basis to regard a research process as a *sui generis* project, understood by the author as a 'unique task the effect of which is a single product. It has a specific moment of beginning and completion, and all works within this time interval have to be coordinated.'[23] Following this concept, it allows us to regard a research process as a project and to manage it in accordance with methodical project management.

Table 1. Listing of data for a model research project

Research activity	Description of the research activity	Preceding activities	Duration *t* [days]
A	Determination of undertaking of the subject matter of research	—	1
B	Determination of the research goal, research problem, research hypothesis[24]	A	1
C	Critical analysis of the literature on the subject	A	7
D	Selection of research methods, techniques and tools	B	2
E	Research area determination	C	2

[22] Maszke A.W, Metody i techniki badań pedagogicznych. Rzeszów, 2013, p. 85.

[23] Waters D, Zarządzanie operacyjne towary i usługi. Warsaw, 2001, p. 483.

F	Survey questionnaire development (if an empirical method is selected)	C, D	4
G	Research material collection	F	14
H	Research results elaboration	G	2
I	Research results analysis	H	5
J	Substantiation of the hypothesis, summary of the research, drawing conclusions	I	2

Source: Author's own study[25].

In this project, it was crucial to prepare a precise listing of activities comprising the research project. The list of activities comprising a research process according to J. Gnitecki was used in this case; the next stage was to determine the events initiating the beginning and completion of the project; subsequently, the precise sequence of performance of activities, including the preceding and following ones, was determined; furthermore, from the viewpoint of the criterion of time, it became important to indicate the duration of an individual activity. Due to the fact that the CPM is used for projects with a certain degree of repeatability, the durations of individual activities in this example were determined on the basis of work of 18 research teams implementing scientific tasks in the area of security. Consequently, the durations of individual activities correspond to those given in Table 1. The final part of building a network of activities was a graphic presentation of the project[26].

In order to determine the shortest time of project implementation, ES — the earliest moment of a given activity start, and EF — the earliest moment of a given activity finish were determined for all activities at the first stage.[27] The arbitrary starting moment of the research process was 0. Subsequently, at the second stage, LS — the latest moment of a given activity start,[28] and LF — the latest moment of a given activity finish were determined. The final third stage involved determination of the float,[29] i.e. the time by which the implementation of a given activity may be delayed without delaying the implementation of the entire project. If the float of an activity is equal to 0 after these calculations, this means it is a critical activity. Critical activities comprise a so-called critical path in the network of activities, marked in red. This study has not presented a graphic form of results. For this purpose I refer to the publication [30].

[24] Gnitecki J, Zarys metodologii badań w pedagogice empirycznej. Zielona Góra, 1993, p. 129.

[25] The summary of data for the model research project was based on independent research carried out in a group of 19 research teams.

[26] *More:* Gikiewicz M, Badania operacyjne …, *op. cit.*, p. 108.

[27] Calculation formula EF = ES+ t, where t means the duration.

[28] Calculation formula LS = LF- t, where t means the duration.

[29] Calculation formula R = LS-ES=LF-EF.

[30] Gikiewicz M, Badania operacyjne …, *op. cit.*, pp. 108–109.

Table 2. Table of durations for a model research project

Research activity	Duration *t* [days]	ES	EF	LS	LF	Float
A	1	0	1	0	1	0
B	1	1	2	5	6	4
C	7	1	8	1	8	0
D	2	2	4	6	8	4
E	2	8	10	31	33	23
F	4	8	12	8	12	0
G	14	12	26	12	26	0
H	2	26	28	26	28	0
I	5	28	33	28	33	0
J	2	33	35	33	35	0

Source: Author's own study.

Conclusion

The literature on the subject includes many methods to determine critical paths and the project implementation time. Nevertheless, having performed a critical analysis thereof, the author suggests to use the critical path method (CPM) and the planning and control method known as PERT for the subject matter of research methodology, including the research process. Examples of dilution of both these methods are time and cost analyses (CPM-COST and PERT-COST), if the project organizer is interested not just in the duration but in the expenditures necessary for implementation.

The literature on the subject of research methodology points out different approaches to the research process. However, the differences rather seem to apply to the specificity of their presentation. Despite these differences, the essence of scientific research remains common and, for scientific works of theoretical and empirical nature, it lies within the three essential phases which support each other in parallel:

— Research implementation;
— Conceptualization;
— Finalization.[31]

An analysis of a research project, carried out using the critical path method, has enabled formulation of the following conclusions:

— The total time of implementation of the research project will be 35 days.[32]

[31] Cieślarczyk M, Chojnacki Z, Techniki i narzędzia badawcze stosowane w pracach magisterskich i doktorskich, [in:] Wawrzusiszyn A, Praca dyplomowa z bezpieczeństwa. Wprowadzenie do badań. Warsaw, 2016, p. 35.

[32] This time applies to the assumptions made.

- Such activities as: determination of undertaking of the subject matter of research (A); critical analysis of the literature on the subject (C); survey questionnaire development (F); research material collecting (G); research results elaboration (H); research results analysis (I); as well as substantiation of the hypothesis along with summary and drawing conclusions (J), cannot be delayed, as it would result in delay of implementation of the entire project.
- There are time floats for three activities connected with: determination of the research goal, research problem, and research hypothesis (B); selection of research methods, techniques and tools (D); research area determination (E). This means they may start later without affecting the duration of the entire project; however, of course, their float must not be exceeded.

I would like to summarize the most important points once more. There is a need for continuous search for manners of planning as well as identification and limitation of uncertainties and minimization of the risk accompanying the decisions being made in the research process. Network programming methods will enable shortening duration of the entire project. It will be possible to use floats rationally. Facilitation of actual planning and determination of actual dates of the project. It will be possible to focus on activities limiting the entire project. Setting a basis for control of the course of works at any moment of performance thereof.

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About the Author

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***Streszczenie.** W niniejszym artykule zaprezentowano zasadnicze zagadnienia dotyczące procesu planowania badań naukowych w naukach o bezpieczeństwie w oparciu o metody należące do badań operacyjnych. Badania operacyjne należą do tych obszarów, które są intensywnie rozwijane a także implementowane w kierunku bezpieczeństwa i polepszania działalności w obszarach, takich jak: planowanie, organizowanie, realizowanie czy też kontrolowanie różnego rodzaju przedsięwzięć. Stąd zagadnienia dotyczące zakresu badań operacyjnych, ich podstaw metodologicznych, jak i zastosowania metod programowania sieciowego w zakresie planowania procesu badawczego wymagało szerszego wyjaśnienia w kontekście nauk o bezpieczeństwie. W konsekwencji powyższych treści odniesiono się do modelu decyzji, stwierdzając, że każda związana z problematyką badań bezpieczeństwa wzmaga zapotrzebowanie na metody analizy i obiektywnej oceny. Każde, bowiem przedsięwzięcie, w tym szczególnie te związane z badaniem bezpieczeństwa, związane jest z określonymi celami, których osiągnięcie wymaga posiadania odpowiednich sił i środków. W niniejszym opracowaniu odniesiono się do istoty czasu realizacji przedsięwzięcia, który bardzo często jest ograniczony i może być wykorzystany w rożny sposób, o czym przesądzają konkretne warunki, w jakich prowadzone są dane działania natury technicznej, organizacyjnej czy innej. W konsekwencji powyższych treści stwierdza się, że proces badawczy charakteryzuje się prowadzeniem sekwencji czynności zmierzających do osiągnięcia celu badania, rozwiązania problemu badawczego czy też weryfikacji hipotezy w określonych ramach czasowych. Stwierdza się także, że każdy proces badawczy posiada określony czas trwania i można pokusić się o stwierdzenie, że z reguły jest on niepowtarzalny.*

***Резюме.** В данной статье представлены основные вопросы, касающиеся процесса планирования исследований в области наук о безопасности на основе методов, относящихся к оперативным исследованиям. Оперативные исследования касаются тех сфер, которые интенсивно развиваются и внедряются для обеспечения безопасности и совершенствования деятельности в: планировании, организации, проведении или контролью различных видов деятельности. Поэтому дальнейшего рассмотрения заслуживают вопросы, касающиеся рамок оперативных исследований, их методологической базы и применения методов сетевого программирования для планирования процесса в контексте наук о безопасности. В связи с вышеуказанным, автор относится к модели принятия решения, утверждая, что каждое решение, связанное с исследованиями в области безопасности повышает необходимость применения метода анализа и объективной оценки. Каждый вид деятельности, особенно связанный с исследованиями в области безопасности, связан с конкретными целями, для достижения которых требуются соответствующие силы и средства. В данном исследовании автор указывает на сущность периода времени реализации деятельности, которое очень часто ограничено и может использоваться различными способами, что определяется конкретными условиями, при которых проводятся технические, организационные или другие мероприятия. В связи с этим делается вывод о том, что процесс исследования характеризуется последовательностью действий, направленных на достижение цели исследования, решение проблемы исследования или проверку гипотезы в течение определенного периода времени. Указывается также, что каждый исследовательский процесс имеет определенную продолжительность и в связи с этим можно констатировать, что он, как правило, неповторимый.*