# Mathematical Model of Management Decision Making that Takes Into Account the Technical and Human Factors

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**Abstract.** Mathematical decision-making management model that will allow the manager or decision-maker to develop and make management decisions in the current situation, taking into account the use of both the achievement of modern technical means and the staff involved in solving the problem. Accordingly, an important factor is the level of technical means used to solve the emerging problem, but also the preparedness of the personnel, namely the level of their training in the current situation. The mathematical model of the managerial decision of the head of the organization is synthesized, which allows to achieve the goal of management, taking into account the available human and technical resources. Attention is drawn to the possibility of recognizing and developing a managerial decision according to the further logic of counteraction and, as a result, to eliminate the arising difficulties. Transitional states of the system in four basic basic states obtained under the influence of different intensity of influence at a given time. Willingness to withstand emerging threats saves a temporary resource and redistributes it to other everyday tasks. The results obtained make it possible to apply the obtained mathematical model in social and economic systems, as well as to solve the inverse problem in management.

**Keywords**: mathematical model, managerial decision, decision maker, technical factor, qualification, human factor

## 1 Introduction

Issues of analysis, modeling, optimization, and, most importantly, improvement of management processes and mechanisms for making managerial decisions in social and economic systems in order to increase the efficiency of their functioning, have always been considered by the decision-maker (PLR) as paramount and important for achieving the very goal of management.

With the introduction of information technologies in the life of the society, the burden on the heads of organizations to develop a management decision, the purpose of which is to achieve the goals set, has also increased. For this purpose, the creation of a mathematical model of the management decision of LPR with the possibility of their adjustment to achieve the management goal is an urgent task.

Various scientists L. N. Abalkin, S. A. Ayvazyan, V. E. Boikov, A. A. Dregalo, A. A. Koshkin, N. V. Sololova, V. I. Ulyanovsky, S. A. Strybul and others considered the influence of the human factor on managerial decision-making [1-7].

Mathematical modeling of differences in social and economic systems and their practical application, including the development of human and social potential, focused on A. A. Akaev, G. H. Good, A. N. Kolmogorov, O. I. Larichev, R. E. Makol, G. Malinetsky, A. I. Orlov, A. A. Samara,J. Forester, G. R. Khasaev and others [8-14].

These methods are based on analysis rather than synthesis. Our method, based on the synthesis of a mathematical model of the management decision of the LPR in social and economic systems, allows us to form processes with predetermined properties, which allows us to form management for guaranteed achievement of the management goal [15-17].

On the basis of this we can draw the following conclusion that in publications to inform management decisions it is argued that to build a mathematical model of man's decisions is very difficult, not to say impossible, but the analytical dynamic model of decision decision maker assesses information technology, human factors, breakdowns of tasks, thereby ensuring achievement of management objectives. This combination of factors determines the relevance of this work.

## 2 Synthesis of a mathematical model of a management decision

To synthesize our mathematical model, we will adhere to the leading scientific and scientific-pedagogical school of St. Petersburg "System integration of public administration processes" included in the register of leading scientific and scientific-pedagogical schools of St. Petersburg, which is based on the natural-scientific approach(EPP) to create conditions that in turn will guarantee the achievement of this goal [18, 19].

EPP is defined as the integration of the properties of human thinking, the surrounding world, and the connection of these two components through cognition, graphically, we can represent this expression [20].

In turn, these principles are implemented by an unchangeable, and therefore stable, repeating relationship of object properties and actions for their fixed purpose, that is, the law of preserving the object in integrity (ZSOC) and the following methods, such as decomposition, aggregation and abstraction.

Academician of the USSR Academy of Sciences Anokhin P. K. pointed out and experimentally confirmed that for the synthesis of the system it is necessary to identify the "basic regularity" in the General theory of functional systems [21].

Anokhin P. K. for the first time established that a person always carries out his activities on the basis of the scheme - "excitement - recognition of excitement- reaction to excitement" within the system. At the same time, he pointed out three main properties of the system:

- integrity;
- the system "works" always on the result;
- there is always some system-forming factor for the manifestation of system properties [21].

Anokhin P. K. identified these properties experimentally and turned to specialists in the theory of systems, first of all to Mesarovich, in order to identify the main laws of the construction and functioning of the system; to obtain a formalized criterion for determining the system. However, I did not get answers to my questions from the authorities of that time (1955-1973) [22, 23].

In 1985, this problem in the theory of systems was put and solved in 1996 by G. Burlov [24, 25].

The solution is based on identifying the law of integrity preservation.

Knowledge of the integrity conservation law allows you to build (synthesize) adequate models of complex systems.

The management decision will consist of the properties of the management object, the methodological level, the methodological level, and the technological level. By the properties of an object, we will understand objectivity, integrity, and variability. The system research apparatus based on the SSCI requires considering the synthesized process at three levels:

Methodological: (purpose-formation of the condition of existence of the process). At this level the idea of "Management" is "the Creation "Subject to" conditions to realise the potential "of the control object»;

Methodological: (formation of conditions for transferring the control object from the current state to the required one). At this level of representation of the concept of "Management" it is "The impact of the Subject on the object of management"; justified and developed programs and plans of the components of the system of higher education institutions;

Technological: (algorithmic-implementation of the conditions for transferring the control object from the present state to the required state). At this level of representation of the concept of "Management "it is "Conditions for the implementation of the impact" of the Subject on the object of management"; plans and programs of the components of the state (municipal) management system are implemented [26].

Let's introduce a number of definitions that we need:

A management decision is a condition for realizing the purpose of the object that it manages in the appropriate environment in order to achieve the management goal.

Environment — a set of factors and conditions in which the activity is carried out.

Information and analytical work — continuous extraction, collection, study, display and analysis of data about the situation [26].

Having decomposed the concept of "management decision" into three basic elements — "environment", "information and analytical work" and "solution", it is necessary to proceed to the synthesis of the solution model.

As noted, three components are reflected in three principles. The first principle is the three-component nature of knowledge:

- abstract representation or condition of existence (methodology), the formation of conditions for the existence of the process;

- abstract-concrete representation or cause-and-effect relationships (methods), the formation of cause-and-effect relationships occurs;

- a specific representation (technologies, algorithms), the formation of conditions for the implementation of cause-and-effect relationships.

The second principle is the integrity of the world, which is expressed in the WSSC [26].

The third principle is cognizability of the world expressed by methods: decomposition, abstraction and aggregation.

Guided by the principles of three-component cognition, integrity and cognizability, we will carry out the synthesis of a model of a Manager's managerial decision [26].

At the first level, using the decomposition method, which is expressed in the division of the management decision into three basic components ("situation", "the decision itself" and "information and analytical work"), which correspond to the "object", "purpose" and "action" [26].

At the second level, we use the method of abstraction, which is expressed in the separation of the "object or situation" with the frequency of manifestation of the problem in front of the person (Δtpp). "Purpose" ("Solution») we identify with the frequency of neutralization of the problem (the average time of adequate response to the problem) by a person (Δtnp). "Action" ("information and analytical work") is identified with the frequency of identification of the problem (the average time of recognizing the situation) (Δtip).Temporary characteristics are justified by the fact that only temporary resources for a person are irreplaceable.

To create a management decision model we will need to make certain assumptions and assumptions:

1. Examines managerial decision decision-maker in the form of management information system (hereinafter – ICS). The management system is based on this solution.

2. The time Intervals between the moments of detection of the facts of manifestation of problems are random values.

3. The discovered facts in time form a stream that is very close to the Poisson flow.

4. Processing time on the required characteristic is that the value is random.

5. The data Processed in the system on the signs of the problem is further distributed among the allocated forces and means that solve the corresponding target tasks.

6. The case is Considered when the time of residence of the required signs (facts) of the problem in the scope of the control system is very limited and is commensurate with the time required for their identification, as well as data processing and taking adequate actions on these signs.

7. The System is prepared to solve problems of recognizing and neutralizing problems.

8. The system under Development is designed to assess the potential opportunities of LPR in the contour of the state (municipal) management system, depending on the current situation [27].

Under such assumptions and assumptions management solution can provide the following structural diagram, which links the three basic elements of managerial decisions:

- furnished or generating flow facts (problems), which should be the adequate response of the $\lambda$;

- information and analytical activities (monitoring, identification, recognition of the problem that occurred before the LPR) with the intensity v1;

- neutralization of the problem faced by the Manager (development of a solution for using the resources of the power of the LPR) with the intensity of v2.

A block diagram of the concept of an information management system as a link between the three basic elements of a management decision is shown.

To form an adequate solution, the three basic elements must satisfy the following inequality [28].

That is, the sum of the average time spent on identifying the problem and neutralizing it, divided by the average time of manifestation of the problem, must be less than or equal to one.

Special mention should be made of the property of a result-oriented management decision within the framework of its effectiveness or achievement of the management goal.

Efficiency is a property that characterizes the degree of achievement of the goal or the degree of implementation of the system's capabilities, embedded in it by the developer, within certain restrictions, and is evaluated by a certain indicator [29].

Since the purpose of a management decision is to recognize the situation and develop a team to use resources, it is advisable to choose the probability that each problem that occurs before the LPR is recognized and neutralized as an efficiency indicator. Just this indicator is identified with the result that the system is aimed at, in our case, this is the probability of recognition and neutralization that we have considered: $P = F(\Delta t\text{pp}, \ \Delta\text{tip}, \ \Delta\text{tnp})$, where $\Delta t\text{pp}$ - average time for the problem to manifest; $\Delta\text{tip}$ - the average time to identify the problem; $\Delta\text{tnp}$ - average time to develop a management solution aimed at neutralizing the problem, P- an indicator of the effectiveness of implementing a management decision [30].

By setting the appropriate level of the performance indicator for the implementation of the RRN management decision shown in formula, having the relationship of this value with the three basic characteristics, based on the current situation, we can choose the appropriate "deltas" of information and analytical work and neutralization.

In this setting of the problem, we can present the process of creating a model of management decision of LPR in the following graphic.

The graph is formed based on the following features of the process of forming a management decision.

LPR can perform two functions: identification and neutralization of the problem. These functions are manifested in human activity in four different combinations.

Therefore, the LPR solution has four basic States:

A00-LPR does not identify or neutralize;

A10-LPR identifies and does not neutralize;

A01-LPR does not identify or neutralize;

A11-LPR identifies and neutralizes.

In accordance with the described feature of the management decision, in order to understand the fact in which the decision-making process is located, it is necessary to enter the probabilities of finding the decision-making process in these four States. We, respectively, get four probabilities P00, P10, P01, P11, corresponding to finding the system in the States A00, A10, A01, A11.

The characteristic of system transitions is shown let's Assume that the system is in the initial state A00. When a problem occurs under the influence of intensity, it goes to the A10 state, i.e. the state of recognizing the problem. From this state, the system under the influence of intensity v1 moves to the state A01, in which the system begins the process of neutralizing the problem with intensity v2 and transfers the system to the state A00. This situation is possible if the problem is neutralized, but the next problem has not yet formed. If there is a problem, the system switches to the A11 state under the influence of intensity.

While in the A11 state, under the influence of V1 intensity, the system goes to the A01 state if the problem is recognized, and goes to the A10 state under the influence of v1 intensity if one problem is neutralized. Then the next problem comes in and needs to be recognized. The process is repeated.

To determine the probabilities of finding the process of forming a management decision, the proposed approach allows using the Kolmogorov-Chapman system of differential equations.

If the process occurring in the system described by this system of differential equations lasts long enough, it makes sense to talk about the limiting behavior of probabilities Pi(t) at . In some cases, there are final (limit) probabilities of States , where i = 0, 1, … , n.

They do not depend on the state of the system S at the initial moment. It is said that in the system S a limit steady state is established during which it passes from state to state, but the probabilities of the Pi states do not change anymore.

Without violating the generality of reasoning, in order to obtain the conditions for the existence of the process of formation of a managerial decision model, we transform the system of differential equations to a system of linear homogeneous algebraic equations.

This is a system of linear algebraic equations for four unknown probabilities of finding our system P00, P10, P01, P11, which are interconnected by the following relation: $P_{00} + P_{10} + P_{01} + P_{11} = 1$.

The probabilities you are looking for will no longer depend on time. The solution of this linear algebraic system of equations is the following relations: $P = \nu_1\nu_2 / \lambda(\lambda + \nu_1 + \nu_2) + \nu_1\nu_2)$. For the process to exist, we need to know the probability of the system being in a state in which both the problem and the recognition process are absent. This situation corresponds to state A00. Consequently, the probability of recognizing and solving the LPR problem is determined by the last obtained relation, namely P00.

Having received the condition for the existence of the organization management process, we will consider the factors that directly affect the management process: technical and human factors.

## 3 Influence of technical and human factors on management decision-making

As a result of applying the considered methods of decomposition, abstraction and aggregation, we have transformed the concept of "management decision" into a mathematical model of management decision and is expressed by the formula, where P, as we have already said, is the probability that the problem appearing before the LPR is recognized and resolved. This is a condition for the existence of the organization's management process.

Further, if we consider the average detection time of the problem, which consists of at least two components: the human factor(training of personnel, psychophysiological capabilities) and the factor of technical equipment(the introduction of modern technical tools and modern software). It should be noted that:

- the human factor (CF) is a factor that is taken into account in the solution model as the average time for identifying the problem (recognizing the situation) based on personal psychophysiological characteristics (PVC) of the LPR;

- factor technical equipment (IT) is a factor which in the model solution is the average time to harness the power of hardware and software including web technologies, Internet technologies aimed at the early detection of problems and thereby reduce the time of searching and finding (definition) of the problem; (this characteristic is always not a positive value, since, by definition, it reduces the duration of the problem search).

The average Troubleshooting time will also consist of two factors, human and technical:

- the human factor is a factor that is taken into account in the mathematical model of the solution during the neutralization of the problem (the development of a team to use the resources necessary to neutralize the problem) based on personal psychophysiological data of the LPR;

- the factor of technical equipment in the solution model will be taken into account by the average time of using the hardware and software complex including Web technologies. this complex is aimed at reducing the time necessary to neutralize the problem and eliminate the problem (this value is not positive, since, by definition, it reduces the duration of neutralization of the problem.

Such an interpretation of the basic components of the mathematical model of the decision of the head of the organization has allowed to link these elements with the characteristics of Web-technologies and via an indicator of the effectiveness of implementation of management decisions P (the probability that each problem posed to the decision maker recognizes them and neytralizuya).

## 4 Practical application

Ensuring the work of an organization in the social and economic system is a certain organized process. Independent scientific and practical interest is to ensure the smooth operation of all departments of the organization.

Usually, with the frequency of (the average time of manifestation of the problem), problems occur or changes occur that negatively affect the entire process of work (training). Therefore, the work environment is characterized by an intensity of activity $\lambda$. Monitoring is characterized by V1 intensity. The process of eliminating the problem that has arisen before the Manager (developing a solution for using the resources of the power of the LPR) is characterized by the intensity of V2.

If the problem occurs 1 time a week, and experimentally found that the average time to identify the problem $\Delta Tip$ =0.125 weeks, and the average time to neutralize the problem $\Delta Tnp$ =0.125 weeks. Then we can say that the management efficiency indicator for this task is P =0.79. This means that the management is carried out with a fairly high guarantee.

If the problem occurs once a week, and experimentally found that the average time to identify the problem $\Delta Tip$ =0.111 weeks, and the average time to neutralize the problem $\Delta Tnp$ =0.111 weeks. Then we can say that the indicator of management efficiency in this problem is P =0.81. This means that the management is carried out with a fairly high guarantee.

The obtained condition for the existence of the process allows us to determine the probabilities of P on the basis of an experimental study of $\Delta Tip$ and $\Delta Tnp$, and thus assess how well the management decision is formed in the organization's management system.

## 5 Conclusion

The classic definition of management technology is to work with the available resources expressed in the hardware and software complex (technical means used to achieve the goal) and the human factor (readiness to understand their psychophysiological capabilities in the current situation). The resources to manage will be:

- information resources.
- activity resources;
- environment resources.

Therefore, the management technology is the transformation of the received information data and available resources in order to achieve the goal of management in the conditions of available hardware and software and personnel involved in the implementation of tasks.

The resulting analytical dynamic (mathematical) control model allows:

1. Establish interaction between the monitoring group's divisions and the management system's development and implementation group's divisions.
2. Evaluate the effectiveness of the organization's management system divisions.
3. Make management decisions for the LPR to achieve management goals.

## Reference


1. Abalkin, L.: Intensification and Economic Growth. Problems of Economic Transition. Taylor & Francis Journals. vol. 29(2), pp. 64-78. (1986)
2. Adaskina, Yu. V., Panicheva P.V., Popov, A. M .: Sentimental analysis of tweets based on syntactic links. In computer linguistics and intellectual technologies: based on the materials of the annual international conference Dialogue. Moscow, pp.25–35 (2015)
3. Boikov, V. E.: Socio-political factors of the development of Russian society. Sociological research. vol. 11, pp. 42 (1995)
4. Andronchev, I.K., Dmitriev, D.S., Solovova, N.V.: Management of the educational process of the university by means of information and com-munication technologies. Bulletin of Samara University. Economics and Management. vol. 8 (119), pp. 240-247 (2014)
5. Rudnichenko, M.D., Gezha, N.I., Belyaev, K.O., Kuzmin, A.D.: Performance analysis of machine learning model ensembles. In III All-Ukrainian scientific-practical conference of young scientists, students and cadets "Information protection in information and communication systems". Lviv. pp.259-260 (2019)
6. Lysenko, V.D.: Text sentiment analysis for forecasting stock market prices. Young scientist. vol. 22, pp.420-423 (2018)
7. Gud, G. H., Makol, R. E.: Sistemotekhnika. Sovetskoe radio. Moscow. 384 p. (1962)
8. Kolmogorov, A. N. Fomin, S. V.: Elements of the Theory of Functions and of Functional Analysis. Moscow.454 p. (1960)
9. Larichev, O. I.: Theory and methods of decision-making. Logos. Moscow (2003)
10. Malinetsky, G. G.: Mathematical foundations of synergetics: Chaos, structures, computational experiment. URSS. Moscow ( 2017)
11. Garshina, V.V., Kalabukhov, K.S., Stepantsov, V.A., Smotrov, S.V.: Development of a system for analyzing the tonality of textual information. Gerald of VSU, series: system analysis and information technology. vol. 3, pp.185-194 (2017)
12. Pavlov, Yu.N., Maystruk, K.A .: Comparison of text tonality assessment methods. Young scientist. vol. 12, pp.59-64 (2016)
13. Loukachevitch, N., Kotelnikov, E., Rubtsova, Y.: SentiRuEval: testing object-oriented sentiment analysis systems in Russia. In proceedings of International Conference Dialog-2015. Moscow. 313 p. (2015)
14. Rubova, Y.V.: Building a body of texts for tuning the tone classifier. Software Products and Systems. vol. 109, pp.72–78 (2015)
15. Burlov, V.G., Grachev, M.I.: Transport systems management model taking into account the possibility of innovation. Tekhniko-tekhnologicheskie problemy servisa. Technical and technological problems of service. vol. 4. pp. 34-38. (2017)
16. Burlov, V.G., Grachev, M.I.: On the management mechanisms of an educational institution of higher education based on web-technologies. In the collection: information control systems and technologies. pp. 200-203. (2017)
17. Burlov, V.G., Grachev, M.I.: Development of a mathematical model of traffic safety management with account for opportunities of web technologies. Collected: Transportation Research Procedia, pp. 97-105 (2017)
18. Shybaiev, D.S., Otradskaya, T.V., Stepanchuk, M.V., Shybaieva, N.O., Rudnichenko, N.D.: Predicting system for the estimated cost of real estate objects development using neural networks. ZhSTU Herald. Technical science. vol.83, pp.154-160 (2019)
19. Silge, J., Robinson, D.: Text Mining with R: A Tidy Approach. O'Reilly Media (2017)

20. Burlov, V.G., Grachev, M.I.: Analytical-dynamic model of management decision in socio-economic systems on the example of the head of a educational institution of higher education. T-Comm, vol. 13, no.10, pp. 27-34 (2019).
21. Anokhin, P.K.: Systemic mechanisms of higher nervous activity. Moscow. The science. 453 p. (1979)
22. Mesarovich, M., Mako, D., Takahara, I.: Theory of hierarchical multilevel systems. Teoriya ierarhicheskih mnogourov-nevyh system. Moscow. 344 p. (1973)
23. Mesarovic, M., Takahara, N.: General theory of systems: mathematical foundations. Moscow. 311 p. (1978)
24. Chaudhuri, A.: Visual and Text Sentiment Analysis through Hierarchical Deep Learning Networks. Springer (2019)
25. Aggarwal, C.C.: Machine Learning for Text. Springer (2018)
26. Yi, C, Qingbao, H., Zejun, L., Jingyun, X, Zhenhong, C., Qing, L.: Recurrent neural network with pooling operation and attention mechanism for sentiment analysis: A multi-task learning approach. Knowledge-Based Systems (2020)
27. Saerom, P., Jaewook L., Kyoungo K.: Semi-supervised distributed representations of documents for sentiment analysis. Neural Networks. vol.119, pp.139-151 (2019)
28. Rahul, A., Surabhi, M.: NLP based Machine Learning Approaches for Text Summarization. pp.535-538. (2020)
29. Hung, C.C., Song, E., Lan, Y.: Foundation of Deep Machine Learning in Neural Networks (2019)
30. Burlow, V. G., Grachev, M. I., Shlygina, N. S.: Adoption of management decisions in the context of the uncertainty of the emergence of threats. Proceedings of 2017 20th IEEE International Conference on Soft Computing and Measurements SCM 2017. vol. 1 pp. 310-313 (2017)