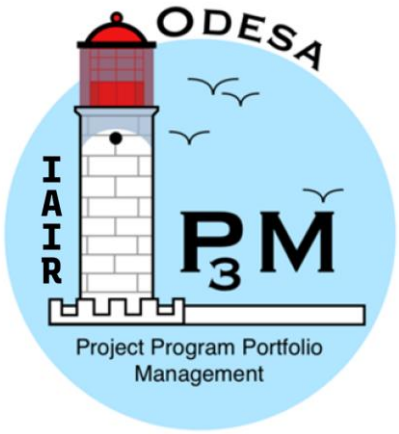
TABLE OF CONTENTS



An Applying Empathy to IT Project Management

Anna Khristich[1], Iryna Blyznyukova[2], Pavlo Teslenko[3], Kateryna Hrabina[4] and Svitlana Kolot[3]

[1] *International Labor Organization, Geneve, Switzerland*
[2] *Cherkasy State Technological University, Cherkasy, Ukraine*
[3] *Odesa National Polytechnic University, Odesa, Ukraine*
[4] *Sumy State University, Sumy, Ukraine*

Abstract

The work considers empathy as a key component of the Design Thinking technology in IT project management. It is shown that design thinking technology is one of the varieties of flexible technologies of software product creation. In addition, design thinking is a client-oriented technology for IT project management. It is shown that empathy is a key factor of design thinking which provides IT project team with a number of competitive advantages. The first advantage of using empathy is the creation of such a project product which will satisfy the expectations of a customer to the fullest extent. The second advantage is the reduction of project product development time by reducing the time of feedback from the customer.

The work analyzes the essence and types of empathy that project team members will have to have. It is shown that empathy is a property of personality, which can be developed through seminars and trainings for project team members, considering gender characteristics and primary skills.

Keywords

IT project, design thinking, empathy, Agile, IT project team, IT project management.

1. Introduction

The evolution of IT project management methodology has evolved from methods using rigid planning to methods using flexible management techniques. This transition has been accompanied by an increase in the

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: khristich@ilo.org (A. Khristich); mirago@ukr.net (I. Blyznyukova); teslenko@op.edu.ua (P.Teslenko); kate.grabina@gmail.com (K.Hrabina); kolot@op.edu.ua (S. Kolot)
ORCID: 0000-0002-6578-6732 (A.Khristich); 0000-0001-7486-7983 (I.Blyznyukova); 0000-0001-6564-6185 (P.Teslenko); 0000-0003-0950-4486 (K.Hrabina); 0000-0001-9145-9017 (S.Kolot)


involvement of the client in the project work. In techniques of rigid project planning, the customer "was present" in the project only two times, first at formation and approval of the terms of reference, the second - at the acceptance of a project product in operation. Modern, flexible approaches require almost constant involvement of the customer (possibly the end-users of the project product) in the design and development processes. Nowadays, more and more IT companies are using a so-called client-oriented management style [1]. One recent management technique that combines agile software technology with a customer-oriented management style is design thinking [2]. One of the core elements of Design Thinking is the empathy that IT project team members must demonstrate towards the customer [3].

2. Main Part

In this regard, it is relevant to analyze/study the compatibility of such concepts as an individual's ability to participate, empathize with third party problems, immerse in the customer's "environment" to understand their "pain", identify the problem that caused them to initiate the project, on the one hand, and on the other hand, the individual's ability to make project decisions, to choose the only solution among many possible ones, abstract, say no, achieve the project goals. Let us emphasize the fact that in most cases, these qualities should be possessed by the same people - members of the IT project team. To illustrate the above, we will give a metaphor: hardly a taxi driver, pouring tears of sympathy to passengers' problems, will take them quickly, and most importantly safely, to their destination. To investigate this question, we will analyze and compare the processes of IT project management, with the processes of empathy and achieving the necessary level of participation by the team members of that project. This is necessary to make recommendations for the management of an IT project team that will use Design Thinking as an approach in the development of a software product.

It can be said that Design Thinking technology is essentially the result of the development of a client-centered approach aimed at the project client, at the end-user of the project product. It allows you to identify the customer's problems, which were the reason for initiating the project.

If the corporate culture of an IT company prioritizes the satisfaction of customer expectations, and this determines the successful completion of a project, then the technology of Design Thinking most fully meets these requirements. Design Thinking [4] is a way of identifying customer issues through a process of empathizing with the people affected and then using that information to make design decisions.

To date, there are five stages in Design Thinking technology: 1) empathy, 2) focus, 3) idea generation, 4) prototyping, 5) testing [4].

Empathy is used to gather and analyze information about the client and the final users of the stakeholders who will be directly or indirectly involved in the future software product of the project. It is not about a classical assessment of the customer for the formation of the terms of reference. The essence of this phase and technology Design Thinking in general is that the members of the IT project team conceived in the problems of the applicant, which became the cause of project initiation. This makes it possible to propose the most appropriate project solutions and to test them on themselves at the same time, assuming the role of the client/final customer.

The second stage, focus, is understood as the development of the vision of the future software product, as such, which will solve the above problems.

The generation of possible solutions can be represented as the beginning of formalization of the concept of what the software product should be and the choice of one for the further creation of the product prototype. The fourth stage — prototyping, the process of an embodiment of the idea, of one of the selected options for testing. We should pay attention to the term "reduction of the idea". It is used to cover the broadest sense of the word: development, design, coding, layout, modeling. The point is that the prototype should be submitted to the customer in the shortest possible time with minimum consumption of resources and costs, and it can be one of the product functions or MVP, rather than an element of the code or system structure. This can be a drawing of the mobile add-on screen on the scale of the device to be used by the users.

The fifth stage of the Design Thinking is testing. At this stage, the project team receives feedback from the customer and/or users of the software product. Based on the feedback, a decision is made whether to change (refine) the prototype or to go back to the focus and idea generation stage if the end-user is dissatisfied with the software product. If the user is satisfied, then the project team tests the project product, depending on the technique used for development and management. What is meant here is that testing can be done for the complete product, or during development, for a single unit, function, MVP, etc.

It should be pointed out that at the end of the first stage, the "manifestation or action of empathy" does not end. The team must remain "immersed in the customer's problems". And this is not dictated by fashion or the

status of Design Thinking technology! The criterion here is the speed at which the design work is produced, that the work is done with quality, and that the product is needed by the customer and meets the expectations of the end-user. The essence that can combine these criteria - speed, quality and usefulness - is the state of the project team members when performing the project works: requirements gathering, design, development, change management, testing and others. Only by being empathic to the customer's problems can these jobs be done quickly. Otherwise, it will take time to develop the MVP, hand it over to the customer, time for the customer to get to know the MVP, form their feedback and hand it over to the project team.

It should be noted that this approach (interaction with the customer, getting feedback from him throughout the life cycle of the project) is already implemented in various methodologies of an agile approach to software development — Agile [5]. This allows rapid changes, challenging assumptions and adapting project products to changing information or requirements.

Let's consider an example of one agile technology that implements the above-described process of interacting with the customer to test the intermediate product and make changes. Sprint in Scrum is such an example.

Before we compare Design Thinking technology with agile IT project management technologies, let's look at the key tenets of the Agile Manifesto, which form the customer-centricity of agile technology [6]. And the first principle that the Agile manifesto declares is customer satisfaction. This principle is defined as the highest priority, which is implemented through frequent and continuous delivery of an intermediate working product (prototype), taking into account the constant changes generated through feedback from the customer. And customer feedback, too, must be carried out on an ongoing basis. Accordingly, all these recommendations are implemented by the project team, which must have the appropriate competencies. The Agile manifesto postulates that such a team must be self-organizing and continuously improve their management and development processes.

Note also that the most effective method of communication and information exchange is face-to-face.

Thus, we can argue that Design Thinking is fully consistent with the manifesto and principles of Agile and can be included in the family of agile technologies for IT project development.

Next, let's analyze to what extent the development processes performed by Design Thinking technology are similar to the development processes performed by SCRUM methodology. To do so, let us briefly analyze Sprint by the criterion of client-oriented orientation in the management processes [7].

As you know, SCRUM has three roles, the team, the scrum master and the product owner. Typically, the product owner is the customer's representative who participates in decision-making processes related to the development of the software product. Sometimes, the product owner may be a member of the development team who takes the customer's side and fully lobbies for their interests. This may occur when the customer, for various reasons, cannot participate in the development of the project. In this case, the 'team product owner' must empathize with the customer's problems and translate them to the development team. Next, consider the processes of sprinting.

As you know, there are five processes in SPRINT: planning the sprint, reviewing it, retrospectively, scrum meetings and the sprint itself as a project product development process, or more precisely the incremental product. Sprint planning will take place once, at the very beginning of its lifecycle. The entire team is involved in the planning, with clearly delineated roles and participation. The product owner defines the scope and content of the tasks for the current sprint (sprint backlog). The team accepts the proposed tasks and discusses how to solve them. Note that since there is no project leader (team) role in the SCRUM team, all decisions are made by the team itself, collegially. At this stage, the team does not empathize with the customer's problems but receives them in a formalized form from the product owner. The product incremental development then takes place over one to four weeks. At the end of the sprint, usually on the last day, customer feedback takes place. This includes the processes of 1) pre-planning the next iteration, 2) demonstrating the product increment to the customer or product owner, and 3) retrospectively.

The formation of a feedback loop with the customer/end users of the project product takes place at the end of the sprint, during the demonstration of the product increment in front of the customer (or if he could not be present, in front of the product owner).

One member of the project team presents the results of the sprint to the customer. During this meeting, the client has to give his opinion, comments or approvals regarding the product developed during the sprint. However, it should be noted that the team members are not tasked to be empathic. They accept feedback on their work from the client, although there is usually an emotional component here as well, which can only be counted by mastering empathy techniques.

Unlike SCRUM, Design Thinking technology involves empathy from project team members at all stages of product development.

To define the functional features of empathy in IT project team management, let's consider some basic definitions of empathy. Empathy (Greek empatheia - empathy, sympathy) is a conscious understanding of the inner world or emotional state of another person [8]. The original approaches to understanding empathy (Freud, Lipps, Rogers, Baron and others) defined empathy as an individual's ability to empathize, as the ability to put oneself in the other's shoes. Freud believed that empathy is based on perceiving the subjective world of another person as if the perceiver were that other person. In this, the person feels the pain of the causes as if he or she feels it for him or herself [9]. An essential aspect of empathy, according to C. Rogers, was the feeling-self in the other person's life world [10]. It has been pointed out that a person's capacity for empathy is directly related to his or her emotional capacity, empathy will have a low level if the individual has the slightest intellectual impairment, in particular limited perception and observation and stereotyped thinking, which provokes primitive decisions. It is productive to complement the situational mediation of empathy as an affective response (Hoffman, 1984), which allows for a more accurate analysis of the findings [11]. As a special, "emotionally colored", as opposed to rational, type of interpersonal cognition, empathy allows us to differentiate between different types of people's understanding of each other [12].

Accenting the role of understanding in the manifestation of empathy has expanded approaches to its interpretation as a way of knowing the inner world, the mental processes of the other person, as seen and perceived by the person himself in relation to whom empathy is manifested. For example, "the ability to know emotionally the experience of another from within his reference system..." [13] is "a way of perception, of knowing, related to the other's consciousness, through which one gains access to the other's inner world..." [14]. From the position of the phenomenon of cognition empathy is defined as: insinuation into objects of cognition; understanding of feelings of another person; understanding of another person with the help of feelings; understanding of the inner world of another "from within", from the point of view of his inner phenomenological perspective of this phenomenon. These processes are carried out within the framework of oppositions describing cognition and singling out understanding as a special cognition: rational cognition - sensual, "non-intellectual" ("not only intellectual") cognition. In the first, initial opposition, empathy is cognition of the senses and/or cognition through the senses. In so-called "cognitive empathy," it refers to the cognitive reconstruction of another's inner world, the intellectual acceptance of a role or another's point of view, the identity of the mental processes of the subject and object of empathy, and the ability to predict other people's behavior [15].

In the context of empathy research in IT project team management, the functional orientation of empathy towards the inner world of the other person, which can be regarded as a goal, subject and source of knowledge through empathy, empathy in the empathy process, is significant.

The following types of empathy are considered: emotional - based on the mechanisms of projection and imitation of motor and affective reactions of the other; cognitive-based on intellectual processes of comparison and analogy; predicative - manifested as the ability to predict the affective reactions of the other in specific situations. When processing information about a partner on the unconscious level intuitive empathy is considered.

In the oppositional dichotomy, empathy is seen as: empathy rational, "intellectual" - belonging, attention to another individual, intensive analytical processing of information about him; empathy emotional, "not intellectual, other" - emotional experience: experiences, feelings.

According to the time of action empathy is divided into short-term acting in a specific situation at a given time, and long-term acting over a long time, which requires additional information about the object of empathy Long-term empathy can sometimes consist of a set of actions, subordinated to one goal [16].

The psychological modes and mechanisms of empathy include imitation, contagion, identification, social reflection and decentration, each of which can be the basis of a type of empathy, among which rational and affective are most commonly distinguished. Their choice depends on the functions that empathy serves and may include cognitive, affective and conative components. A special role in the mechanism of empathy is played by deconcentration - the rearrangement of perceptions, which contributes to the formation of a different perspective of the observer on the object of empathy so that he could understand and feel the experiences of the other person.

The psychological modes and mechanisms of empathy include imitation, contagion, identification, social reflection and decentration, each of which can be the basis of a type of empathy, among which rational and affective are most distinguished. Their choice depends on the functions that empathy serves and may include cognitive, affective, and conative components. A special role in the mechanism of empathy is played by deconcentration - the rearrangement of perceptions, which contributes to the formation of a different perspective of the observer on the object of empathy so that he could understand and feel the experiences of the other person [17]. Although the Davies model [17] bears an obvious behaviorist imprint, it does help both to organize the many empathic processes and phenomena and to systematize approaches to their study, which has allowed

Davies to build on it the most reliable and valid empathy test available at the moment. It is a "service", "non-substantive" model.

Empathy is seen as a process, a state of being, an attitude, a trait or disposition. The essential difference between empathy in complex forms of human activity is that its manifestation will depend both on the specifics of the professional activity and the specific situation. For some professional activities, the empathy ability is considered to be the most important professionally relevant quality, in particular pedagogy, psychology and medicine. Nowadays, project management, in particular IT project management, can also be added to this list.

Thus, the conscious use of different types, psychological ways and mechanisms to develop empathy becomes one of the main challenges in the management of IT project teams that use the Design Thinking concept.

3. Conclusions

Analyzing the above, it can be stated that Design Thinking technology meets all the criteria and requirements of flexible software development technologies. In addition, Design Thinking has the characteristics of a client-oriented approach and is an extension and development of it. Empathy as a key factor of Design Thinking will provide several benefits to the IT project team. The first major benefit of applying empathy is that the project product created will meet the customer's expectations to the fullest extent possible. The second benefit is that the response time in the feedback loop from the customer will be shortened, i.e., the project development time will be shortened.

An analysis of the nature and types of empathy poses two important interrelated challenges to the team that will be applying empathic management techniques in practice. The first task is to keep in mind when forming a team that empathy is a personality trait that can be developed, so a lack of initial level of empathy should not be the main criterion for including participants in the team. The second task is to design and conduct workshops and training sessions for the development of empathic skills in the project team members, taking into account gender specifics in the development of empathy. The above-mentioned tasks are subject to further study in order to formulate recommendations for the management of the IT project team using Design Thinking as a software product development technology.

4. References

[1] George Boulden. Customer Focus: the ‘secret ingredient’ in great project management (2017). URL : https://www.boulden.net/blog/customer-focus-the-secret-ingredient-in-great-project-management/

[2] Tim Brown. Design Thinking. Harvard business review (2008). URL : https://readings.design /PDF/Tim%20Brown,%20Design%20Thinking.pdf

[3] Tim Stobierski. How to become a more empathetic leader (2018). URL : https://www.northeastern.edu/graduate/ blog/become-an-empathetic-leader/

[4] Nadine Rochester. Design Thinking Finds Its Place In Project Management (2019). URL : https://blog.adobe.com/en/publish/2019/11/18/design-thinking-finds-its-place-in-project-management#gs.qhv5wj

[5] Design Thinking - IT Industry. URL : https://www.tutorialspoint.com/design_thinking/design_thinking_it_industry.htm

[6] Robert C Martin. (2020) Clean Agile : back to basics. Boston : Pearson, 205p.

[7] Scrum: Atlassian. URL: https://www.atlassian.com/ru/ agile/scrum

[8] V. Zinchenko, B. Meshcheryakov Big psychological dictionary. URL: http://library.nuft.edu.ua/ebook /file/Zinchenko_V_Bolshoyi_Psihologicheskiy.a6.pdf

[9] Sigmund Freud. (2011) Wit and Its Relation to the Unconscious. Dover Publications, 416p.

[10] Carl Rogers. (2003) The Quiet Revolutionary : An Oral History Paperback. Penmarin Books, 352 p.

[11] Martin L. Hoffman. (1989) Empathic emotions and justice in society. Social Justice Research, volume 3, pages 283–311.

[12] G. Andreeva. (2017) Social psychology: a textbook for higher educational institutions. URL: https://www.studentlibrary.ru/book/ISBN9785756708271.html

[13] Håkansson, J., & Montgomery, H. (2003). Empathy as an interpersonal phenomenon. Journal of Social and Personal Relationships, 20(3), 267–284. https://doi.org/10.1177/0265407503020003001

[14] O'Hara, M. (1997). Relational empathy: Beyond modernist egocentricism to postmodern holistic contextualism. In A. C. Bohart & L. S. Greenberg (Eds.), Empathy reconsidered: New directions in psychotherapy (pp. 295–319). American Psychological Association. https://doi.org/10.1037/10226-013
[15] Arnold P. Goldstein, Gerald Y. Michaels. (1985). Empathy. Development, Training, and Consequences
[16] Ponomareva M.A. Empathy: theory, diagnostics, development: Monograph / M.A. Ponomarev. - Minsk: Bestprint, 2006. - 76 p.
[17] Mark H. Davis. (1996) Empathy. A Social Psychological Approach. 272 p

The Investigation of Threats of Information Security in Use of Distance Learning Web Technologies

Liudmyla Fonar[1], Maxim Mazurok[2], Larysa Nozdrina[3], Mykola Pidhornyy[4]

[1] *Odesa National Polytechnic University, Odesa, Ukraine*
[2] *WiseTech Global, Sydney, Australia*
[3] *Lviv Educational-Scientific Institute of State University "University of Banking", Lviv, Ukraine*
[4] *Cherkasy State Technological University, Cherkasy, Ukraine*

Abstract

The active introduction of distance learning over the years requires research into the protection of information in the exchange and storage of data. One of the distance learning systems of Odesa Polytechnic University is Google Classroom. The main advantage is free services, administration of the institution, login with a regular Gmail account. The study of Google Classroom information security threats for users was conducted. A comparison of administrative measures in 2020-2021 was made. Potential threats to information security for distance learning web technologies have been identified. The implementation of the recommendations will strengthen the information security of distance learning. The developed recommendations can be used as part of a full-fledged system of protection against unauthorized access.

Keywords

Distance learning system, higher education institution, information protection, Google Classroom, web technologies, administration

1. Introduction

The use of web technologies of distance learning (WTDL) allows students to obtain the necessary knowledge remotely from the school at any convenient time. The rights and responsibilities of participants in the educational process in distance learning are regulated by the "Regulations on distance learning" [1] and the Law of Ukraine on Higher Education [2].

An urgent problem of the higher education system in Ukraine in recent years is the analysis of the use of web technologies for distance learning in a pandemic. The need to conduct the educational process with the impossibility of attending classes, classrooms, laboratories and communicate in the usual conditions of the student group - all this has led to stressful working and learning conditions. Higher education institutions had to solve new problems of distance learning and use either their own works or already popular and widespread services and learning platforms. The forced transition of many educational institutions to the web space requires an analysis of the security of use of various services. It is important to study the threats to information security for personal data of students and teachers, assessment systems, data collection and storage. Also, the use of online services in education increases the requirements for user authentication, as distance learning in many cases complicates the objectivity of knowledge assessment.

With the introduction of distance learning systems in front of the institution and students there are problems with the selection of software and the rational use of educational information resources created on their basis [3]. Therefore, the urgent problem is to create an educational space with the help of web technologies and the organization of secure access of users to resources. Another important aspect is the psychological and

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: fonar@op.edu.ua (L.Fonar); maxim@mazurok.com (M.Mazurok); nozdrinalarisa1@gmail.com (L.Nozdrina) pmv1971pmv@gmail.com (M.Pidhornyy)
ORCID: 0000-0002-7478-6742 (L.Fonar); 0000-0002-9542-920X (L.Nozdrina); 0000-0002-5881-9217 (M.Pidhornyy)

pedagogical aspect of the use of distance learning, which can be conducted in synchronous or asynchronous form.

Organizational support of applicants from the teacher during the distance learning of courses in the vast majority of forms a positive and friendly learning environment. It is necessary to ensure the availability of means of operational electronic communication of participants in the educational process with the administration of the educational institution, the teacher, among themselves. Most often it is possible to organize through a forum, chat, e-mail, social media pages, messengers, etc. [4-8].

However, the use of web technologies in distance learning environment has its advantages [9-15]: the ability to store large amounts of data, simplify publication, placement of educational materials, continuity of the educational process, group orientation (corporatism), collaboration teachers and students, activation of independent activity, the possibility of integration of academic disciplines, facilitate data collection, reduce paperwork between teachers and applicants, simplify access to materials, lectures, guidelines and sometimes even improve communication between participants in the learning process.

The purpose of the study is to analyze of the security of Google Classroom at the University "Odesa Polytechnic" and changes in the administration of the educational platform for 2020-2021 in conditions of forced quarantine and distance learning.

2. Analyze of the security of Google Classroom

The use of Google Classroom [18] in the educational process corresponds to [1]: it is information and communication technologies of distance learning – technologies for creating, accumulating, storing and accessing web resources (electronic resources) of academic disciplines (programs), as well as providing organization and support educational process with the help of specialized software and means of information and communication, including the Internet.

Google Classroom allows you to work with applicants both asynchronously and synchronously - using Google Workspace for Education Fundamentals [19], a set of free Google tools and services designed specifically for educational institutions and organizations engaged in home learning. The privacy of users' personal data is ensured by Google's services.

User data that is created in the Google Classroom services or uploaded there is encrypted during storage. In addition, all G Suite services run over HTTPS, so data is also protected when transferred between data centers and accessed from a single device.

Organizational units allow you to divide into user segments and provide a variety of services, settings and permissions to different users. Carefully designed structure of administration and organization of the service is crucial for effective management of the G Suite for Education account. At the beginning of the implementation of the service in the primary institution in the Google Admin console, all users and devices are combined into only one organizational unit, this unit is called a top-level organizational unit. Therefore, initially, all administrator settings apply to all users and devices in the account.

To create different settings for different groups of users or devices, you need to add a lower-level subdivision that uses groups. The organizational units of the first level are organized according to the roles of "students" and "teachers".

For each user (student and university lecturer) who needs to create a separate account, you need to add the following information to the table in the column: name, surname, e-mail address, path to the organizational unit. After filling in the table, it is saved as a CSV file (.csv) in UTF-8 encoding.

An attacker, both external and internal, in pursuing an attack may pursue the following goals:

- excess of privileges;
- obtaining unauthorized access to resources;
- gaining control over the course;
- gaining access to the internal system of the university;
- theft of intellectual property;
- theft of evaluation materials;
- gaining access to personal data;
- disclosure of personal data;
- making changes to the database of educational information with grades and modules;
- obtaining unauthorized access to official information of the educational institution;

- violation of the integrity or destruction of educational materials;
- violation of the integrity or destruction of data about the educational process;
- violation of access to training materials for SDO users.

When carrying out attacks, an attacker can use:

- vulnerabilities in web applications
- vulnerabilities in services;
- weak passwords;
- shortcomings of the authentication process;
- configuration and administration errors;
- malware;
- weaknesses in the information protection system;
- spam, phishing.

Potential threats to the information of the distance learning system are presented in table 1:

Table 1

Potential Danger

Element	Head 2	Head 3
Web interface (exchange of information, access to courses and materials)	Forgery of intersite requests - CSRF, attacks on the client's browser, remote code execution and refusal to service web-application services, spam, phishing.	Violation of the confidentiality, integrity and accessibility of information and services of web applications.
Server (subsystems: management of training courses; testing, calendar, administration)	Searching for passwords, increasing user privileges, administration errors, port scanning;	Violation of confidentiality, integrity and availability of information, infiltration of IP.
Database (training courses, lists of academic groups, personal data, libraries, information)	Accidental or intentional deletion / modification of data in databases and transaction logs, theft of personal data, unauthorized access to databases and journals.	Waiver of obligations and actions, infringement of copyright, violation of integrity and confidentiality.

To counter the current threats to university distance learning systems and reduce risks within acceptable limits, various mechanisms and means of information protection, organizational, legal, technical and programmatic nature are used, which must take into account a number of features related to their operation: the system of distance education of the university should be available to applicants, teachers and administrators around the clock; between firewalls and SSL applications do not always provide protection against hacking of the distance education system, as access to the website from external networks must always be open;

Therefore, protection against threats should be provided both at the stage of design and development of the distance education system itself by creating a secure code, and in the process of its operation and making, if necessary, timely adjustments.

When an administrator checks teachers, he forbids "non-teachers" to create Classes. If a teacher has mistakenly identified himself as a "student", the administrator must add the teacher to the "Teachers" group to enable classes to be created. In the general case, the Administrator can specify who has the right to create Classes at the university.

The following settings are available:

1. all in this domain (teachers and students);
2. teachers awaiting confirmation and verified teachers;
3. only proven teachers.

Only proven teachers can create Classes at Odesa Polytechnic University. The following are options to control the access of external users to the group:

1. Public on the Internet - any user from the university and beyond can view the list of groups in the catalog. Depending on the group settings, users can:

- view the group page and discussion archive;
- manage group subscriptions;
- send messages to the group.

If this option is selected, you can specify the following settings:

- group owners will be able to add to their groups users with external addresses, users not from the university domain. If you disable this option, external addresses from user groups are not deleted;
- group owners will be able to allow external users to send emails to groups.

2. Access is limited: access to university groups is available only to employees of the educational institution. However, if the group already has external members, they will still be able to send email to their group.

In 2020, it was possible to join the course in Google Classroom at the University "Odesa Polytechnic" in the following ways [20]: follow the link sent by the teacher; indicate the course code provided by the teacher; accept the invitation sent by the teacher by e-mail.

In 2021, the access policy was changed and now you can join the Class only by invitation, sent by the teacher by e-mail to university accounts. This method protects course data from third-party access. When inviting students to a faculty member from the university domain, he does not have to know or collect emails from each student, just know the last name and first name - all accounts are already entered by the administrator into the system and the teacher can find the right student without his mail.

At Odesa Polytechnic University, the system is configured so that the teacher creates groups and adds users to them, there can be several groups. A teacher can add another university teacher to the group by university account, but cannot add teachers with third-party accounts (in 2020 this possibility was still maintained). This ban also increases data protection and prevents unauthorized access to confidential information.

3. Conclusions

After analyzing the administration of the distance education system of the University "Odesa Polytechnic", the following conclusions and recommendations can be made:

1. Setting up multiple administrator and super administrator accounts can help with the loss or hacking of the super administrator account.
2. Be sure to require two-step verification for accounts and use security keys for two-step authentication.
3. Prohibition of using the super-administrator account for daily activities is required.
4. E-mail alerts should be configured to track the activity of potential security risks, such as suspicious login attempts, mobile hacking, or changes made by another administrator.
5. The ban on adding Google Classroom to groups strengthens security measures and the protection of users' personal data.

The current state of education requires the use of distance learning. Quality education, which can be obtained using these methods, provides an opportunity to receive education that meets the economic conditions of our country. Economically sound education promotes the emergence and development of high quality professionals in the labor market. In turn, this contributes to the development of the country's economy.

The implementation and application of recommendations to improve the security of distance education systems contributes to the improvement of teaching methods and the quality of education, which has a positive impact on the education system. The use of the proposed methods has a long-term perspective, namely the economic and social effect can be expected after the employment of graduates.

4. References

[1] About the approval of the Regulations on distance learning URL: https://zakon.rada.gov.ua/laws/show/z0703-13#n18

[2] Law of Ukraine on Higher Education URL: https://zakon.rada.gov.ua/laws/show/1556-18#Tex

[3] V. Oleksyuk Unified authentication as a step towards the creation of the educational space of general educational institutions // Scientific journal of NPU named after M. P. Drahomanov. Series 2. Computer-oriented educational systems : collection of scientific . — K. : NPU named after M. P. Drahomanov, 2012. Issue №13 (20). Pp. 188–193. URL: http://elar.fizmat.tnpu.edu.ua/handle/123456789/87. (in Ukrainian)
[4] M. Nazar. Components of efficient distance learning course. New Computer Technology, 17, 114-128. 2019. URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/954
[5] M. Nazar. Specificity of psychological influence of training of Internet users // Osvita doroslykh v Ukraini : IX Mizhnar. nauk.-prakt. konf.,: zb. nauk. prats. – K. : EKMO, 2008. – S. 102-104.
[6] M. Nazar. Potencialy internet-treningiv dlja optymizacii' psyhologichnogo stanu studentiv / Nazar Maksym Mykolajovych // Psyhologija i osobystist': Naukovyj zhurnal. - Poltava: Instytut psyhologii' imeni G.S. Kostjuka NAPN Ukrai'ny, 2013. - № 1 (3). - S. 120-130.
[7] J. Suler The Psychology of Cyberspace / John Suler. – New Jersey : Science and Technology Center of Rider University, 2007. – URL: https://truecenterpublishing.com/psycyber/psycyber.html
[8] M. Zhaldak, Problems of informatization of the educational process in secondary and higher educational institutions. Kompiuter u shkoli ta simi 3, 8–15 (2013).
[9] O. Djachenko The didactic potential of cloud technologies in the study of computing disciplines by bachelors in system analysis. New Computer Technology, 17, 159-162. 2019 URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/959
[10] O. Merzlykin S., Semerikov Perspektyvni khmarni tekhnolohii v osviti [Prospective cloud technologies in education] / Merzlyki O. V., O. // Khmarni tekhnolohii v suchasnomu universyteti (KhTSU-2015) : materialy dopovidei naukovo-praktychnoho seminaru. – Cherkasy : ChDTU, 2015. – S. 31-33.
[11] O. Kryvonos, The use of information and communication technologies in education. Vydavnytstvo ZhDU im. I. Franka, Zhytomyr, 2012.
[12] J. Bersin The blended learning book: best practices, proven methodologies, and lessons learned / Josh Bersin. – San Francisco : Pfeiffer, 2004. – 319 p.
[13] Anna Iatsyshyn, V. Kovach, Y.Romanenko, Andrii Iatsyshyn. Cloud services application ways for preparation of future PhD // Cloud Technologies in Education : Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018 / Edited by : Arnold E. Kiv, Vladimir N. Soloviev. – P. 197-216. – (CEUR Workshop Proceedings (CEUR-WS.org), Vol. 2433). – URL: http://ceur-ws.org/Vol-2433/paper12.pdf
[14] E. Tuncay, Effective use of cloud computing in educational institutions. Procedia – Social and Behavioral Sciences 2(2), 938–942 (2010). doi:10.1016/j.sbspro.2010.03.130
[15] T. Vakaliuk, Khmarni tekhnolohii v osviti (Cloud technology in education). ZhSU Publishing House, Zhytomyr (2016)
[16] G. Tkachuk Organization of the current student's knowledge control of using the online service Kahoot!. New Computer Technology, 16, 142-146. 2018 URL: https://ccjournals.eu/ojs/index.php/nocote/article/view/829
[17] I. Allen, J/ Seaman. Online Nation: Five Years of Growth in Online Learning. Solan-C. – 2007. – 26 p. – URL: http://sloanconsortium.org/sites/default/files/online_nation.pdf
[18] Classroom https://edu.google.com/products/classroom/?modal_active=none
[19] Education Fundamentals https://edu.google.com/products/workspace-for-education/education-fundamentals/
[20] I. Dorofeeva, L. Fonar Proceedings of the Youth Scientific League. - Vinnytsia, Ukraine – 2020. – 27-29. https://doi.org/10.36074/27.11.2020.v2.02.

Application of Information Technologies in Anti-Risk Management of Agro-Industrial Complex Projects' Stakeholders

Andrii Biloshchytskyi[1], Oksana Denchyk[2], Konrad Krol[2] and Oksana Kyrychenko[2]

[1] *Astana IT University, Nur-Sultan, Kazakhstan*
[2] *«KROK» University, Kyiv, Ukraine*

Abstract

These theses are devoted to the necessity of applying information technologies in agro-industrial complex projects. The review of innovative technologies used to improve the efficiency of agricultural production has been carried out. The mathematical model of anti-risk management of agro-industrial complex projects' stakeholders is presented, which shall be used to calculate the mentality and risks of project stakeholders in order to reduce the overall risk of the agricultural project.

Keywords

Project, model, IT in agro-industrial complex, risk management, stakeholders' management

1. Introduction

The agriculture in Ukraine requires optimization of production in order to increase the volume and quality of livestock and crop production, rational use of resources, including natural resources, and environmental protection [1, 2, 3].

Applying a comprehensive approach to solving the issues of agricultural production shall increase the efficiency of such production [4, 5]. The world's leading IT companies have developed their own technological solutions in order to improve the efficiency of agricultural production and automate accounting processes in the land cadastre system. More and more often farmers in Ukraine implement innovative technologies in the production process, understanding the economic efficiency of such investment [6]. It should be noted that the use of information technologies increases the productivity and efficiency of managerial work, allowing to apply a new way to solve many issues, that means that there is the need to develop and apply the latest technologies in the management processes in connection with the agricultural projects.

Due to the fact that the agricultural projects are characterized by a high degree of risk [7, 8], the use of industry-specific IT solutions in the agricultural project anti-risk management can significantly reduce the level of unforeseen costs and increase the success of such projects. The success of agricultural projects directly depends on the satisfaction of the stakeholders by the result (product) of such projects [9, 10]. In order to achieve satisfaction with the result of the project, it is necessary to understand what expectations from the project have any of the stakeholders [11]. Often not all expectations are voiced and spelled out, and furthermore, they may be changed during the course of the project. Therefore, the project team shall conduct management activities regarding stakeholder expectation to ensure stakeholders' satisfaction with the product of a relevant project. The management of project stakeholders is an important part of the project management [12, 13]. The stakeholders have a direct impact on the outcome of the project, both the success and failure of such project. The risks associated with the stakeholders are critical and can be devastating to the project [14, 15]. The source of such risks is the misunderstanding caused by the difference in mentality and culture of the project stakeholders [16, 17, 18]. The development and application of models and methods of anti-risk management of projects' stakeholders, taking into account such differences, shall reduce the riskiness of agricultural projects and increase the effectiveness of management within framework of such projects.

P3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: a.b@astanait.edu.kz (A.Biloshchytskyi); oksanadenchyk@gmail.com (O.Denchyk); krolkonrad61@gmail.com (K.Krol)
oksanaKS@krok.edu.ua (O.Kyrychenko)
ORCID: 0000-0001-9548-1959 (A.Biloshchytskyi); 0000-0002-8386-8379 (O.Denchyk); 0000-0003-1130-167X (K.Krol);
0000-0001-5244-8323 (O.Kyrychenko)

2. Main part

The successful conduct of any business, including agrarian, requires the understanding of how specific planned result will be achieved. For this purpose, the process management shall be applied.

When applying the process approach, the software AllFusion BPwin Data Modeler (BPwin) is usually used to develop a process model in IDF0 notation (AS IS) and a process model (TO BE) [19].

The peculiarity of process management is that the concept of "business process" is defined as a sequence of actions aimed at achieving final, measurable and specific result [20].

According to the principle of management, such a business process consists of elements with specific and measurable "inputs" and "outputs". The manager controls the limits of the sub-processes.

Basic elements and concepts of the IDEF0 [21]:

The IDEF0 graphical language is simple and harmonious. The methodology is based on four basic concepts.

1. Activity Box.

The Activity Box is graphically depicted. Each of the four sides of such Activity Box has a specific value (role), namely:

- The top side means the Control;
- The left side means the Input;
- The right side means the Output;
- The bottom side means the Mechanism.

2. Interface arc (Arrow)

Interface arcs are often called threads or arrows.

Each Interface arc (Arrow) shall have its own unique name (Arrow Label). With the help of such Interface arcs (Arrows) different objects are displayed, to a greater or lesser extent define the processes taking place in the system. Depending on which side a given interface arc (Arrow) approaches, it is called "input", "output" or "control". Besides, the "source" (beginning) and "receiver" (end) of each functional arc can only be the Activity Boxes, and "source" can only be the output side of the box, and "receiver" - any of the remaining three sides. It should be noted that any Activity Box according to the requirements of the standard shall have at least one control Interface arc (Arrow) and one output Interface arc (Arrow). Each Activity Box within a considered single system shall have its own unique identification number.

The mandatory presence of control Interface arcs (Arrows) is one of the main differences of the standard IDEF0 from other methodologies of DFD (Data Flow Diagram) class and WFD (Work Flow Diagram) class.

3. Decomposition

Decomposition is used to divide into parts a complex process into its constituent functions. The level of detail in the process is determined directly by the developer of the model. The decomposition enables a gradual and structured presentation of the system model through the hierarchical structure of individual diagrams, which makes it less cluttered and easier to apply.

The IDEF0 model always starts with a representation of the system as a whole - one Activity Box with Interface arcs (Arrows) extending beyond this area. Such diagram with one Activity Box is called a context diagram and is denoted by the identifier "A-0".

In the process of decomposition, the Activity Box, which in the context diagram shows the system as a whole, is detailed in another diagram. The resulting diagram of second level contains Activity Boxes that display the main sub-functions of the Activity Box of the context diagram and called a Child diagram in relation to it (each of the Activity Boxes belonging to the Child diagram, respectively, is called a Child Box). In turn, the Activity Box-ancestor is called the Parent Box in relation to the Child diagram, and the diagram to which it belongs - the Parent Diagram. Each of the sub-functions of the Child diagram can be detailed by a similar decomposition of its corresponding Activity Box. It is important to note that in any case of decomposition of the Activity Box, all Interface arcs (Arrows) entering or leaving this box are fixed in the Child diagram. This achieves structural integrity of the IDEF0 model.

Often there are cases when it does not make sense to continue to consider individual interface arcs (Arrows) in Child diagrams below a certain level in the hierarchy, or vice versa, individual arcs (Arrows) have no practical sense above some level. On the other hand, there is a need to get rid of individual "conceptual" Interface arcs (Arrows) and not to detail them deeper than some level. To solve such issues, the IDEF0 standard provides the concept of tunneling. The designation of "tunnel" (Arrow Tunnel) in the form of two parentheses around the beginning of Interface arc (Arrow) denotes that this arc has not been inherited from the parent Activity Box and appeared (from the "tunnel") only in this diagram.

There are often cases where it does not make sense to continue to consider within individual Interface arcs (Arrows) in Child diagrams below certain level in the hierarchy, or vice versa - individual Interface arcs (Arrows) do not make practical sense above some level. On the other hand, there is a need to get rid of individual "conceptual" Interface arcs (Arrows) and not to detail them deeper than some level. To solve such issues, the IDEF0 standard provides the concept of tunneling. The designation of the "tunnel" (Arrow Tunnel) as two parentheses around the beginning of the Interface arc (Arrow) denotes that this arc (Arrow) is not inherited from the functional Parent Box and appeared (from the "tunnel") only in such diagram.

In turn, the same designation around the end (of Arrow) of the Interface arc (Arrow) in immediate vicinity of the box-receiver means the fact that in the Child diagram (in relation to this box), such arc (Arrow) will not be displayed and considered. More often it happens that separate objects and their corresponding Interface arcs (Arrows) are not considered at some intermediate levels of the hierarchy, in this case, they are first "dipped into the tunnel" and then, if necessary, "returned from the tunnel".

4. Glossary

For each of the elements of the IDEF0: diagrams, Activity Boxes, Interface arcs (Arrows), the existing standard involves the creation and support of the set of appropriate definitions, keywords, narratives, etc. that characterize the object represented by such an element. This set is called the Glossary and it is a description of the essence of such an element. The Glossary harmoniously complements the visual graphic language, providing diagrams with the necessary additional information.

In addition, special software products are used in agricultural activities. Thus, special programs for agro-management based on the geoinformation systems, innovative GPS global positioning systems, as well as the special sensors are used in crop production and specialists are provided with aerial photos and satellite images [22]. The use of the achievements of geospatial information systems makes it possible remotely to assess the condition of crops, the presence of diseases in the fields, to automate business processes at agricultural enterprises and to introduce precision farming technologies. In the EU countries, modern technology creates the possibility of operational monitoring of the correctness of provision of state support to the particular farmer for the cultivation of particular crop.

In livestock farming, in addition to the IT tools for any management (1C, "M.E.Doc"), specialized IT products are also used. For example, the development of Pantheon Farming" [23] allows the introduction of modern information management systems in livestock farms.

The Danish farm management program AgroSoft [24], has proven itself well in pig breeding; it allows to perform targeted works on the parent and commercial flocks of pigs, makes it possible to analyze and control the following elements: productivity (number of viable piglets at farrowing, number of weaned piglets at the age of 28 days, nest weight, number of farrows per year per one sow, percentage of fertilization of sows, average daily gain); unproductive feed-days of mother flock appearing due to untimely fertilization of the sows; longevity and duration of effective use of parent flock; movement of the flock; rate of stocking, etc.

The AgroSoft program allows its users quickly and efficiently to manage, control and analyze the condition of the pig farm at any time convenient for the manager, as well as for any period of activity that is entered in the program.

The Dutch program UniformAgri is used in cattle breeding, it is accounting and dairy farm management system [25], which helps to work with all age and sex groups of cattle and work with historical flock data. It is also possible to connect the feed computer and monitor the quality of feed mixing, as well as the amount of feed consumed by one head per day.

The UniformAgri program enables daily monitoring of the productivity of each cow, calculation of the lactation peak according to the Dutch calculation method (SPP Analysis), monitoring flock reproduction with reports and analyses.

This program allows farm workers to monitor the health status of each animal by such indicators as the number of somatic cells in milk, biochemical indicators of animal blood tests, as well as the use of medications for prevention and treatment of animals on the farm.

Agricultural enterprises carry out mandatory registration of animal diseases, as well as the implementation of therapeutic and preventive measures in the flock with indication of relevant identification number of the animal, name of the medication, dose and duration of relevant treatment. Taking into account the impact of milk quality on human health, these activities are the requirement of the State veterinary and phytosanitary service of Ukraine and mandatory for dairy product processing enterprises. If any disease affecting the quality of milk is detected, the animal shall be removed from the main flock and further work with it shall be carried out by the veterinarian of such enterprise. Only after laboratory examination of the health of such an animal and confirmation that its products are safe for human consumption, which shall be confirmed by granting permission

of the local veterinary service, the cow shall be returned to the main flock, and its products (milk) can be delivered to consumers.

The UniformAgri program, besides the aforementioned list, allows to generate reports on any indicators. For example, productivity indicators for each group or animal, milk quality indicators, fertilization schedule, percentage of fertilization, number and weight of born calves with indication of animal sex, animal health indicators and other ones.

This program allows to keep a "diary" that reminds farm workers every day, with which groups what measures need to be taken. It is also possible to control, monitor and analyze the condition (state) of the farm online.

The IT products used in agriculture can be ranked not only by animal species, but also by the tasks. For example, WinPasze (Poland), Korm Optima (Russia), AgroSoft (Denmark) and others are used to calculate the mixed fodder recipes.

Provision of farm animals with all necessary nutrients is an important component of farming enterprises.

When calculating rations for animals, the nutrients of each ingredient of mixed fodder shall be taken into account. These characteristics are obtained by laboratory analysis of raw materials and indicated in certificates of quality. Without such studies, the enterprise will not be able to accurately calculate the ration, and the animals will not receive the necessary nutrients from the feed, which can lead to the decrease in productivity of such animals and even diseases, and as a consequence, the profit loss of the enterprise.

Programs for the calculation of mixed fodder when balancing the rations also take into account the price of raw materials, which is appropriate due to the fact that the cost of feeding the animals is about 70% of all costs of their maintenance.

In order to implement agricultural production projects within the planned time and budget in a successful manner, the project team requires the use of some software. Microsoft Project management software, developed by Microsoft Corporation, is widely used in project management. Microsoft Project helps the project manager to develop plans, allocate resources to the tasks, track progress of the works, and analyze scope of the works. This program creates a schedule based on the critical path. The schedule of the works can be made based on the resources used. The work sequence is visualized on a Gantt chart.

The application of project approach in agro-industrial business is one of the important elements in achieving the goal of improving the efficiency of agricultural activities. Application in practice of project management methods, especially anti-risk management of agro-industrial projects shall help to reduce the costs of the unforeseen expenses of agricultural producers. The weighty risks that significantly affect the course of the project include risks associated with project stakeholders, and the agrarian projects are no exception.

International standards of project management: PMBOK PMI [26], P2M [27], ICB IPMA [28], ISO 21500 [29] are widely used for management of the project stakeholders and project anti-risk management, which separately indicate the processes of management of the project stakeholders and anti-risk management. It should also be noted that the above mentioned standards of project management do not take into account the peculiarities of agricultural projects. Therefore, given the importance of development of the agricultural sector of Ukraine, there is a need to develop and implement models and methods that take into account the specifics of stakeholders and risks associated with them within the framework of agricultural projects.

Agricultural project results can be considered successful, if they meet or exceed stakeholders' expectations. To understand stakeholders' expectations at the planning stage of the project, it is necessary to collect and carefully analyze information about each of the project stakeholders, which will significantly increase the likelihood of project success. Particular attention should be paid to the mentality of each of the project stakeholders. The analysis of the stakeholders' mentality is conducted at the stage of project stakeholders' identification, which is a quite complex process and requires the use of computer technologies. The main components of the mentality of an individual are knowledge, social position, cultural level, interest, value system, practices and skills of project stakeholders, formalized mental space of stakeholders (MSSH), which can be represented as the formula below [30]:

$$\{K_{sh}, SC, C, I, V_{sh}, P_{sh}, S_{sh}\} \subset MSSH, \quad (1)$$

where K_{sh} – the set of knowledge of stakeholders;
SC – the set of their status positions;
C - the set of their cultural level;
I – the set of their interests;
V_{sh} – the set of their values;

P_{sh} – the set of their practices;
S_{sh} – the set of their skills.

Taking into account the model of mental space of the stakeholders of agricultural projects developed by the author, which visualizes the different and common in the mentality of each of the project stakeholders, it can be concluded that the more common in the mentality of the project stakeholders, the easier and more effective it will be to manage them. This statement means that the agreement between the project participants will be reached naturally, communication will be more effective, and it will reduce the likelihood of risks due to the misunderstandings between the project stakeholders, and as a result it shall reduce the overall risk of the project.

Meaning,

$$Msz \rightarrow max, Msr \rightarrow min, Rsi \rightarrow min, Rs \rightarrow min, R \rightarrow min. \quad (2)$$

where Msz - common in the mental space of stakeholders;
Msr – different in the mental space of stakeholders;
Rs_i – the risk of the i-th project stakeholder;
Rs – general risk from stakeholders of project;
R - general risk of project;
S- stakeholder of project;
n- number of stakeholders of the project.

General risk from stakeholders of project can be represented as the formula below:

$$Rs = \sum_{i=1}^{n} Rs_i, \quad (3)$$

The practice of agricultural projects management, given the high degree of riskiness of projects in this field, shows that it is more appropriate to focus not only on the duration of the project by the method of the critical path, but also on the risks of such project. Thus, according to [31] it is more appropriate to focus on such sequence of works in the project, which shall lead to the smallest losses in connection with the risks.

The measure of the risks by increasing the performance time and estimated cost of the project in quantitative terms is equal to:

$$Risk = \sum_{i=1}^{b_{кр}} Risk_i, \quad (4)$$

where Risk – the risk of project;
$Risk_i$ - measure of risk of work of a critical path connected with increase in time of performance and estimated cost of work;
$b_{кр}$ - the number of works on the critical path of the project network schedule.

$$Risk_i = \sum_{j=1}^{m} Risk_i^j, \quad (5)$$

where $Risk_i^j$ - measure of risk from a risky event of the j-th type, which affects the performance of the i-th work;
m - the number of types of risky events that affect the performance of the i-th work.

$$Risk_i^j = P_i^j \times C_i^j \quad (6)$$

where P_i^j - the probability of a risky event of the j-th type when performing the i-th work;
C_i^j - the amount of losses from the risky event of the j-th type when performing the i-th work.

Having obtained the results of calculations according to the abovementioned formulas with the usage of information technology solutions, it is necessary to build alternative options of the project network schedule so that on the critical path the project stakeholders who have more in common in the mental spaces, were appointed as the executors of the works, and necessary calculations for determination of their risks and the risk of the project as a whole were made, as well as to choose the network schedule option, where the risk of the critical path will be minimal, and to develop in advance the countermeasures in order to combat such risks.

3. Conclusions

Consequently, the application of project management methodology and the use of modern IT solutions in the agro-industrial complex allows to perform the formation of synergy, ensuring the dynamics of production development, as well as to increase the efficiency of project management of agricultural enterprises. The

application of models and methods of anti-risk management of projects' stakeholders, taking into account the characteristics of each of them, in particular their mentality, allows to foresee timely conflict situations and to act appropriately to reduce the risk of agro-industrial projects.

4. References

[1] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. COM (2019) 640 final. URL : https://ec.europa.eu/info/files/european-green-deal-communication_en.pdf (accessed: 08/10/2021).

[2] Communication. Sustainable food – "farm to fork" strategy. URL : https://ec.europa.eu/info/law/better-regulation/have-you-say/initiatives/12183-Farm-to-Fork-Strategy (accessed: 27/01/2020).

[3] Special Report. Climate Change and Land. URL : https:ipcc.ch/srccl (accessed: 27/01/2020).

[4] Denchyk, O. R. Seasonal risk management method in agro-industrial projects. Science and Education a New Dimension. Natural and Technical Sciences. Budapest, VI I(26). I. : 215 (2019): 47-50. doi:10.31174/SEND-NT2019-215VII26-12.

[5] Denchyk, O. R., Krol, K. J. Method of integrated risk managements for agroidustrial projects. Science and Education a New Dimension. Humanities and Social Sciences. Budapest, VII (34). I.: 205 (2019): 25-29. doi: 10.31174/SEND-HS2019-205VII34-06.

[6] Denchyk, O. R. (2016). Information technologies of project management in the agro-industrial complex. Proceeding of the III International scientific-practical Conference "Information technology and interaction", Kyiv: "Kyiv University", 115-116.

[7] Kahan, D. Managing risk in farming. Rome: FAO, 2008. URL : https://www.fao.org/uploads/media/3-ManagingRiskInternLores.pdf. (accessed: 27/01/2020).

[8] Lipari, M., Watson, H. Re-thinking managing risk in agriculture: a comprehensive approach. 20th International Farm Management Congress. Québec: Non-Peer Review Papers & Posters, Vol. 2, (2015): 140-151. URL : http://ifmaonline.org/wp-content/uploads/2016/01/15_NPR_LipariWatson_P140-1511.pdf. (accessed: 27/01/2020).

[9] Krol, K. J., Danchenko, O. B. Identification of stakeholder risk in agro-industrial projects. Proceeding of the scientific-practical Conference "Topical issues of modern science and practice", Kyiv: KROK University, (2018) 435-437. URL : https://library.krok.edu.ua/media/library/category/materiali-konferentsij/2018-11-15_materiali-%D1%81onference-krok.pdf. (accessed: 27/01/2020).

[10] Kendrick, T. Identifying and Managing Project Risk. New York, NY : American Management Association (AMACOM), 2015.

[11] Pedersen, E. R. All Animals are Equal, But … : Management Perceptions of Stakeholder Relationships and Societal Responsibilities in Multinational Corporations. Business Ethics. Vol. 20. No. 2, (2011): 177-191.

[12] Wysocki, R. K., McGary, R. Effective Project Management: Traditional, Adaptive, Extreme. Third Edition. John Wiley and Sons, 2003.

[13] Cleland, D. Project stakeholder management. Project Management Journal. Vol. 17(4), (1986): 36–44.

[14] Krol, K. J. Stakeholders risk management in agro-industrial projects. Proceedings of Scientific Works of Cherkasy State Technological University Series Economic Sciences, № 55. (2019): 51-58. doi: 10.24025/2306-4420.0.55.2019.187408.

[15] Danchenko, O. B., Kolomytseva, O. V., Denchyk, O. R., Krol, K. J. Method of risk and opportunities management in project of agro-industrial complex. Proceedings of Scientific Works of Cherkasy State Technological University Series Economic Sciences, № 54. (2019): 60-65. doi: 10.24025/2306-4420.0.54.2019.178564.

[16] Verenych, O. V. Development and implementation of formalized model of mental space of project or program environment. Eastern-European Journal of Enterprise Technologies, Vol.2, № 3 (80), (2016): 21-31. DOI: 10.15587/1729-4061.2016.65635.

[17] Verenych, O.V., Bushuyev, S. D. Interaction researching mental spaces of movable context, stakeholder and project manager. Organization, Technology and Management in Construction: an International Journal. Vol. 10, I.: 1, (2018): 1684-1695. doi: 10.1515/otmcj-2016-0021.

[18] Verenych O., Dorosh M. S. Blended Mental Space: the methodology for creation and approaches for it's management. 30th IPMA WC. (2017): 30-37. doi: 10.1109/STC-CSIT.2017.8099423.

[19] Danchenko, O. B. Practical aspects of business process reengineering. Kyiv: KROK University, 2017.

[20] Stevenson, W. J. Operations Management. McGraw-Hill Education, 2014.
[21] Rother, M., Shook J. Learning to See: Value-Stream Mapping to Create Value and Eliminate Muda. Ver. 1.3, The Lean Enterprise Institute, 1999.
[22] Konyushok, S. A. Modern information systems in agriculture. Precision farming. Proceeding of the II International student scientific-technical Conference "The world of telecommunications and informatization", Kyiv: State University of Telecommunications, (2016): 81-87.
[23] Pantheon Farming. URL : https://www.datalab.ch. (accessed: 27/01/2020).
[24] AgroSoft. URL : http://www.agro-oblik.com/agrosoft.html. (accessed: 27/01/2020)
[25] UniformAgri. URL : http://www.uniform-agri.com.ua. (accessed: 27/01/2020).
[26] A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Six Edition. USA : PMI, 2017.
[27] A Guidebook of Program & Project Management for Enterprise Innovation Japan : Project Management Association of Japan (PMAJ), 2017.
[28] IPMA I. C. B. IPMA Competence Baseline Version 3. The Netherlands: Nijkerk, 2006.
[29] ISO 21500 : 2012 Guidance on project management. URL : https://www.iso.org/standard/50003.html (accessed: 27/01/2020).
[30] Verenych, O. V. Management of mental space of projects and programs: the dissertation of the doctor of technical sciences: 05.13.22. Kyiv, 2018.
[31] Danchenko, O. B. Information technology of formation of anti-risk works at construction of difficult power objects: dissertation of the candidate of technical sciences: 05.13.06. Cherkasy University of Engineering and Technology. Cherkasy, 2000.

The Accuracy Research of Nonlinear Dynamic Objects Modelling Using Time Delay Neural Network

Oleksandr Fomin, Viktor Speranskyy, Oleksandr Bondar, Andrii Orlov and Valentyn Krykun

Odessa National Polytechnic University, Odesa, Ukraine

Abstract

The work solves the problem of nonlinear dynamic objects modelling. The purpose of the work is to improve the accuracy of nonlinear dynamic objects identification under conditions of a priori uncertainty. The a priori uncertainty is caused by insufficient study of processes occurring in diagnostic objects due to operation in a wide range of external conditions and the lack of possibility to use special test signals. The goal is achieved by developing a method for identifying models in the form of Volterra series, which simultaneously describe the nonlinear and inertial properties of the object, are able to take into account the states caused by changes in both parameters and structure of the object. The apparatus of neural networks with time delays is considered as a method of identification, providing convenience in modelling both in test and in functional mode. The contribution to information technology is the algorithm of Volterra kernels evaluation using time delay neural nets and pseudocode that implements each stage of this algorithm. The most essential results: the method of identification of nonlinear dynamic objects models with the use of information relation of Volterra series and time delay neural networks has been further developed. Significance of the results: application of the offered method allows to provide high accuracy identification of the nonlinear dynamic objects which are in a functional mode. The proposed method tested on experimental data. The test results demonstrate advantages of the suggested method for nonlinear dynamic objects modelling.

Keywords

Nonlinear dynamic objects, modelling, Volterra series, time-delay neural networks

1. Introduction

The scientific and technological progress is closely related with the increasing complexity of technical systems and devices, which leads to the increased requirements for reliability and safety of technical equipment and demands the best possible detection of technological faults. Because of this, the tasks of creating the adequate mathematical models of the studied objects [1-3] are of great importance as they allow increasing the accuracy of the modelling results during design and further functioning of technological systems.

Increase in the complexity of control objects (CO) in the industries and technical engineering, increasing demands for validity and consistency of diagnostics lead to the problems of developing new efficient methods of mathematical support systems for information extraction and processing from the observations, which allow to provide the specified requirements and automate the process of control of the object.

The purpose of the work is to improve the accuracy of nonlinear dynamic objects identification under conditions of a priori uncertainty. A priori uncertainty is caused by the insufficient study of the processes occurring in the objects of diagnosis due to the operation in a wide range of external conditions and the lack of opportunities to use test signals of a special form (δ-function, step function, harmonic signal).

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: fomin@op.edu.ua (O. Fomin); speranskiy@opu.ua (V. Speranskyy); baa@op.edu.ua (O. Bondar); 9901053@stud.op.edu.ua (A. Orlov); 9901020@stud.op.edu.ua (V. Krykun).
ORCID: 0000-0002-8816-0652 (O. Fomin); 0000-0002-8042-1790 (V. Speranskyy); 0000-0001-7132-6057 (O. Bondar); 0000-0002-3256-5044 (A. Orlov); 0000-0002-3764-9255 (V. Krykun).


To achieve the goal it is necessary to analyze the current state of the general problem of mathematical models in the identification systems of nonlinear dynamic objects. It is necessary to add to the review the methods of identification based on deterministic dependences, renewal of models of objects and models created based on piecewise integration methods as an effective apparatus for description of nonlinear dynamical properties of CO.

2. Relevant works

Linear dynamical models or models that take into account information only about the properties of static characteristics of CO are widely presented in the theory of identification [4, 5]. Nonlinear dynamic objects, including those with continuous characteristics and unknown structure, which can be regarded as a «black box» [6, 7], represent the basis of modern complex objects. Examples of such objects are energy objects [8], modules of flexible automated manufacturing in Industry 4.0 class systems [9], etc.

Methods of mathematical modelling and experimentation are the main tools for investigating complex nonlinear dynamical OC [10]. A convenient form of description of dynamical properties of the object is representation of the relationship between its input and output signals in an explicit form, when differential equations are not required. Such a representation, which takes into account nonlinear and inertial properties of the object, is the description based on the expansion of operator $\mathbf{A}_\tau(t)$ into integral-step series [11].

For a wide class of nonlinear inertial objects the dependence between the influence $\mathbf{X}(t)$ and reaction $\mathbf{Y}(t)$ in explicit form can be represented by the functional degree-dependent Volterra series [12, 13].

For example, the description of an object with one input and one output in the clock domain in the form of an integral Volterra model looks like:

$$y(t) = \sum_{n=0}^{\infty} \int_0^t \dots \int_0^t w_n(t, \tau_1, \dots, \tau_n) \prod_{i=1}^{n} x(\tau_i) d\tau_i \qquad (1)$$

where $x(t)$ і $y(t)$ – input and output signals of the system, accordingly; $w_n(\tau_1,\dots,\tau_n)$ – Volterra kernel of the n-th order (n=1,2,3,...), symmetrical to the real variables $\tau_1,\dots,\tau_n$; w_0 – the valued member of the series (under zero initial conditions $w_0(t)\equiv 0$); t – current time.

Using of Volterra series is a universal way to represent the properties of nonlinear dynamic objects. However, due to the complexity of mathematical apparatus of Volterra kernel description and large volume of primary diagnostic data, the values obtained by parameterization of Volterra kernel $\{w_k(t_1,t_2,\dots,t_k)\}_{k=1,2,\dots,K} \Rightarrow \mathbf{x}=(x_1,x_2,\dots,x_n)'$ (K – order of the model; n – size of the signs space; the dash – transposition of the vector). In practice, it is accepted to use a discretization operator: $x_j = w_n(t_j - \tau,\dots, t_j - \tau)$, $t_j = j\Delta t$, where Δt – is a discretization term.

The discrete form of Volterra series for the description of objects looks like:

$$y(n) = w_0 + \sum_{k=0}^{M} w_1(k)x(n-k) + \sum_{k_1=0}^{M}\sum_{k_2=0}^{M} w_2(k_1,k_2)x(n-k_1)x(n-k_2) + \sum_{k_1=0}^{M}\sum_{k_2=0}^{M}\sum_{k_3=0}^{M} w_3(k_1,k_2,k_3)x(n-k_1)x(n-k_2)x(n-k_3) + \dots \qquad (2)$$

where $x(n)$ і $y(n)$ – input and output signals of the system in a discrete form, accordingly; $w_n(k_1,\dots, k_n)$ – Volterra kernel n-th order in discrete form (n=1,2,3,...), symmetrical to the real variables $k_1,\dots,k_n$; n – flow duration; [0, M] is the interval of summation, practically limited by the end duration of the memory effect in the system.

In practice, they often replace Volterra series with a polynomial and sometimes limit themselves to the first 2-3 members of the series. The structural scheme of the model in the form of Volterra polynomial in the time area is presented in Fig. 1.

Thus, for informative description of nonlinear dynamical objects it is reasonable to use the most universal nonlinear nonparametric dynamical models based on integral-state Volterra series [11, 14], which describe the state of the object in the form of a sequence of invariant to the type of the input signal components – multidimensional Volterra kernel.

Volterra models are a handy mathematical apparatus for modelling of objects with weak nonlinearity. Due to the simultaneous consideration of nonlinear and dynamical properties of CO, Volterra models provide a high accuracy of identification [10, 11, 14].

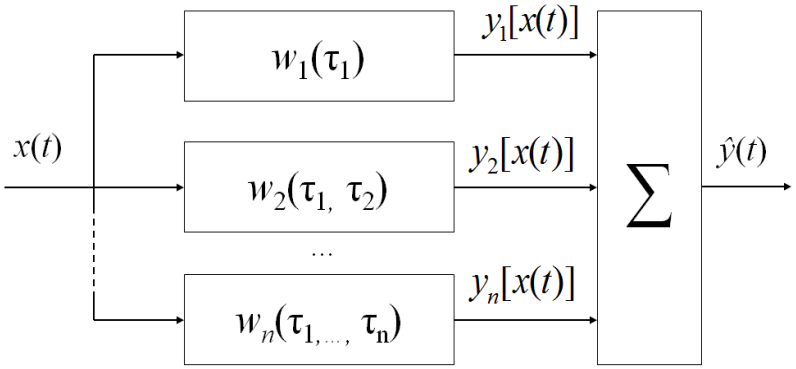


Figure 1: The structural diagram of the model in the form of the Voltaire polynomial in the time area

The properties of nonlinear dynamical systems models based on functional Volterra series conditioned to their wide application for solving problems of modelling, identification, and synthesis of nonlinear systems.

However, the use of Volterra models for the identification of nonlinear dynamical systems of high order is at a loss by several restrictions: practical inability to expand the evaluation of higher-order kernels (due to the increased size of the kernel representation) and strict requirements to the amplitude and shape of the input test signals. Also, the disadvantages of Volterra models are the complicated procedure of model identification, which prevents the widespread use of such models in automated control systems and diagnostics.

In view of the problems of using the mathematical apparatus of OC description in the form of Volterra models, in particular, the calculation limitations when evaluating high order Volterra kernels, it is necessary to search for new effective ways of identification of dynamical objects with nonlinearity of higher orders. As such approach piecewise with time-delay neural nets (TDNN) are considered. On the other hand, neuron structures are significantly more difficult for studying behavior of nonlinear dynamic models than Volterra series analytical models, so the search for ways to combine the advantages of both approaches is a promising area of research for solving the problem of identification of informational models.

The above calls for looking for joint efforts for using Volterra models and three-layer TDNN. In fact, the neural approach to modelling nonlinear dynamic objects is getting more and more attention, especially in recent years [15-17], because their teaching procedure requires only the measured data of the studied object.

The disadvantage of the neural network approach is that it does not provide the analytical expression that is often necessary when modelling the OC. Nonlinear analysis of systems often requires an analytical model (the equation, which represents the input-output relationship), which allows to make conclusions about the system operation. This approach is aimed at establishing nonlinear relations and general dynamic behavior of the object.

Analytical models try to accurately express the measured behavior of the object, formulating the equation, which represents the measured parameter, which can be a function of several independent variables. However, behavioral models on the base of Volterra series preserve their efficiency only for weak nonlinearities and require important efforts to identify the kernels [18].

Growing interest in the use of both approaches to the modelling of nonlinear dynamical systems motivates a comparative study to establish the link between both models and to improve modelling when modelling is combined to increase the speed and accuracy of modelling.

This work sets the problem of establishing an informational link between nonlinear dynamic Volterra models and piecewise TDNN to improve the accuracy of model identification in the form of Volterra series by evaluating higher-order Volterra kernels with the help of TDNN.

3. Neural Network nonlinear modelling

3.1. Neural Nets Architecture

Dynamical models based on three-layer neural networks are an effective apparatus for modelling nonlinear dynamical objects with nonvariable characteristics, in particular, TDNN [19-21].

A typical structure of a three-layer neural net with one output is shown in Fig. 2. Such net is able to perform nonlinear imaging of input signals $\mathbf{X}(\tau)$ into output signals $\mathbf{Y}(t)$ at any moment of time t. Since the input signal

X(τ) in neural net is represented as an orderly discrete sequence in time, we consider it as listening to the input with a delay, where for each time the index of time moment increase.

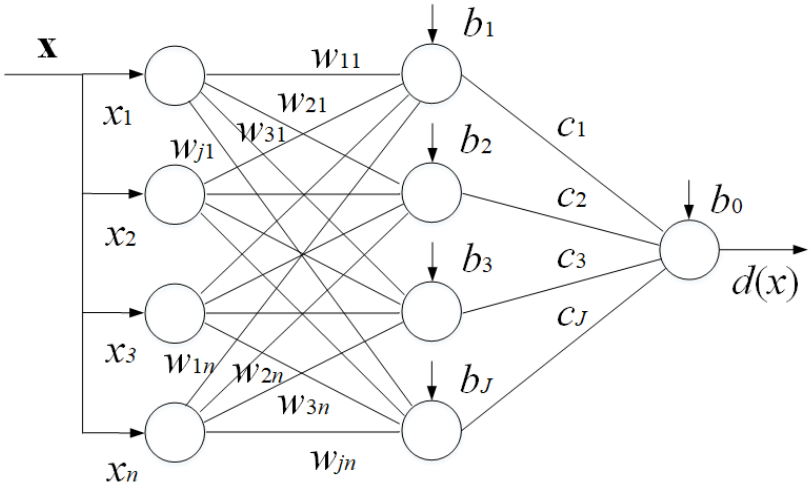


Figure 2: Typical structure of a three-layer neural net with one output

The neural network structure used for modelling nonlinear dynamical objects is composed of three layers. The input layer is composed of the input neurons associated with the signs of the training set. The incoming layer is composed of *J* neurons with nonlinear activation functions. The output layer is composed of a single neuron, which, as a rule, has a linear activation function.

The «input-output» relationship for a three-layer TDNN with *M* inputs and one output is as follows:

$$y(n) = b_0 + s_0 \sum_{i=0}^{K} r_i^2 S_i \left(b_i + \sum_{j=0}^{M} r_{i,j}^1 x(n-j) \right) \quad (3)$$

where b_0, b_i – displacement of neurons of the output and input neural net layers respectively; S_0, S_i – activation functions of the output and input neural net`s layers respectively; r_i^2, $r_{i,j}^1$ – valued coefficients of output and input neural nets layers accordingly; *K* – number of neurons of the input neural nets layers.

In some cases, for widespread activation functions in the form of hyperbolic tangent and polynomial activation function the «input-output» relation for a three-layer TDNN with *M* inputs and one output looks like (4) and (5) accordingly [19].

$$y(n) = b_0 + s_0 \sum_{i=0}^{K} r_i^2 than \left(b_i + \sum_{j=0}^{M} r_{i,j}^1 x(n-j) \right) \quad (4)$$

$$y(n) = b_0 + s_0 \sum_{i=0}^{K} r_i^2 S_i \left(b_i + \sum_{j=0}^{M} r_{i,j}^1 x(n-j) \right)^n \quad (5)$$

There are many classes of neural nets in the literature: with several hidden layers, non-significant activation functions, non-deterministic wagons, bell-coupled ones, and so on.

However, they lead to a much more complicated relationship with the discrete Volterra models, which prevents them from being aligned with neural nets as fundamental and general approaches to modelling of nonlinear dynamical models built based on the «input-output» experiment.

It is extremely important to note that the use of non-sigmoidal activation functions can provide significant methodological advantages and increase the efficiency of modelling as shown in [22].

3.2. Time Delay Neural Network

TDNN are the networks that are able to effectively learn dynamic nonlinear behavior with high-order nonlinearity [13, 19, 20], if they are trained with «input-output» data samples with time-intervals at different levels of the shift at the same time.

The use of TDNN in information systems provides unique capabilities for modelling complex nonlinear dynamic processes. This fact appears to be extremely important for building behavioral models that can have nonlinear characteristics with different input data. To ensure the processing of dynamical information, the network architecture must be organized accordingly. It is also necessary to use certain neural networks training algorithms.

Despite a sufficient number of architectural solutions, in practice the standard topology of the three-layer perceptron is used. In this case, the output signal is generated by a single neuron, most often with a linear activation function. The input signal is received by means of successive sets of input data, each of which will differ from the previous set by one value from the input set. The neural net with M+1 inputs neurons, one hidden layer with J neurons in it and one output neuron is shown in Fig. 3.

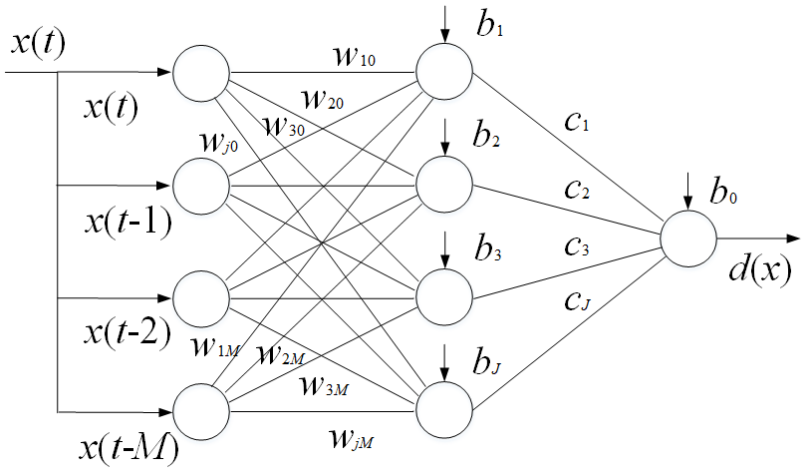


Figure 3: TDNN in the form of a three-layer perceptron

For a given network, the output signal $y(t)$ determines by the formula (3). Further development of the delay line idea leads to a model of the network with time delays in all layers of the network. Output signal of the network at the moment t_k depends not only on the input signal $x(t)$ at that moment, but also on the values of the input data $x(t\text{-}1)$, $x(t\text{-}2)$, … , $x(t\text{-}M)$ at the moment $t\text{-}1$, $t\text{-}2$, … , $t\text{-}M$, where M – is the length of delay (memory), which is set by the measure.

The input memory M must be set so as to adequately represent the memory effect of the dynamic object`s behavioral model. The number of neurons J is selected to be the best fit to the training sample (inputs and outputs of the CO). Each hidden neuron make a nonlinear transforming of weighted sum of relevant input data, using a particular activation function.

3.3. Relationship of time-delayed neural nets and Volterra models

The literature contains attempts of indirect assessment of Volterra kernels based on equivalent three-layers neural net with sigmoidal or polynomial activation functions [13, 19, 22]. The main drawback of the above activation functions is that all neurons are switched on in the analog mode.

This means that all activations must be processed to describe the network output, which is a costly computational procedure with a large number of neurons in the network. To reduce the computational volume, and, therefore, to increase the speed of neural net learning as an activation function, the polynomial activation functions can be used.

Analyzing the obtained expression (5), we can conclude that it is isomorphic to the discrete Volterra series form (2). Thus, the Volterra kernels values can be expressed through the valued coefficients $r^1_{i,j}$ and r^2_i, a_h and the value of the shift of the hidden neurons b_j of the net. For an activation function in the form of a polynomial of the third power the expression (5) can be written in the form of:

$$y(n) = b_0 + s_0 \sum_{i=0}^{K} c_0 r_i^2 b_i^3 + \sum_{i=0}^{K} c_1 r_i^2 \sum_{j=0}^{M} \left(r_{i,j}^1 x(n-j) \right)^3 + \\ + \sum_{i=0}^{K} c_2 r_i^2 b_i^3 \sum_{j=0}^{M} r_{i,j}^1 x(n-j) + \\ + \sum_{i=0}^{K} c_3 r_i^2 b_i \sum_{j_1=0}^{M} \sum_{j_2=0}^{M} r_{i,j_1}^1 r_{i,j_2}^1 x(n-j_1) x(n-j_2) + \\ + \sum_{i=0}^{K} c_4 r_i^2 \sum_{j_1=0}^{M} \sum_{j_2=0}^{M} \sum_{j_3=0}^{M} r_{i,j_1}^1 r_{i,j_2}^1 r_{i,j_3}^1 x(n-j_1) x(n-j_2) x(n-j_3) \quad (6)$$

The expression (6) makes it possible to calculate higher-order Volterra kernels:

$$w_0 = b_0 + \sum_{i=0}^{K} c_0 r_i^2 b_i^3, \\ w_1(k) = \sum_{i=0}^{K} c_1 r_i^2 b_i^2, \\ w_2(k_1, k_2) = \sum_{i=0}^{K} c_3 r_i^2 b_i \sum_{j_1=0}^{M} \sum_{j_2=0}^{M} r_{i,j_1}^1 r_{i,j_2}^1, \quad (7) \\ w_3(k_1, k_2, k_3) = \sum_{i=0}^{K} c_4 r_i^2 \sum_{j_1=0}^{M} \sum_{j_2=0}^{M} \sum_{j_3=0}^{M} r_{i,j_1}^1 r_{i,j_2}^1 r_{i,j_3}^1$$

The expressions (7) are evaluates Volterra kernels of 0–3 orders on the base of TDNN. Similarly, it is possible to define expressions for the Volterra kernels of higher orders.

The method of higher order Volterra kernels evaluation using TDNN investigated in Section 4 where a model of the nonlinear dynamic test object builds. The obtained results prove the possibility of building Volterra models of nonlinear dynamic objects using TDNN and training samples on the base of the input signals $x(t)$ of the special form (δ-functions, step functions, harmonic signals) and output responses $y(t)$.

3.4. Algorithm of Volterra kernels evaluation using time delay neural nets

Value of the established relationship between TDNN and Volterra models lies in the possibility of further development of the algorithm for Volterra kernels evaluation directly using the parameters of the neural network [19, 22].

This relationship can be useful for analysis of nonlinear dynamical objects and interpretations of its model. In addition, because neural models are more complex in comparison with compact Volterra models, relationship between TDNN and Volterra models makes it possible to apply neural models in automated control systems and diagnostics.

On the base of established relationship between TDNN and Volterra models algorithm of nonlinear dynamical objects identification developed. The algorithm of Volterra kernels evaluation using TDNN consists of the following steps (Fig. 4).

Step 1. *Variable initialization.* Set the training sample parameters: n – the length of discrete signal $x(i)$, $i=1,\ldots n$, k – the number of signals $x^l(t)$ (result of measurements according to «input-output» experiment) in the training sample $l=1,\ldots k$; set the neural net parameters: M – the length of delay (memory), J – the number of neurons in the hidden layer, coefficients b_r, c_r ($r=1,...,J$) and synaptic weights $W_{j,r}$ ($j=1,...,M+1$) initialize by means of uniform distribution on interval (0,1); set the object's model parameter: p – order of the model $y(t)$.

Step 2. *Formation of the training sample.* Set training sample $\boldsymbol{X}$ of dimension [pn, M+1] from the number of signals $x^l(t)$; set the vector of benchmark values $\boldsymbol{Y}$ of dimension [pn, 1].

Step 3. *TDNN training*. Calculating coefficients b_r, c_r and synaptic weights $W_{j,r}$ on the base of training sample X and the vector of benchmark values Y.

The neural network trains using one of the well-known algorithms, such as Levenberg-Marquardt algorithm.

To reduce the computational complexity and increase the speed of learning TDNN it is recommended to use ReLu activation functions in the neurons of the hidden layers.

Step 4. *Evaluation Volterra kernels*. Calculating Volterra kernels $w^i(t)$, $i=1,\ldots p$, on the base of coefficients b_r, c_r and synaptic weights $W_{j,r}$ by the expression (7) – function *v_k*($\boldsymbol{b}$,$\boldsymbol{c}$,$\boldsymbol{W}$,$\boldsymbol{X}$,$\boldsymbol{Y}$).

Step 5. Volterra model. Get the nonlinear dynamic model $y(t)$ on the base of Volterra kernels $w^i(t)$ by the expression (2) – function $v\_m(\boldsymbol{w}, x(t))$.

Each block of the algorithm (Fig. 4) is accompanied by pseudocode that implements the current task.

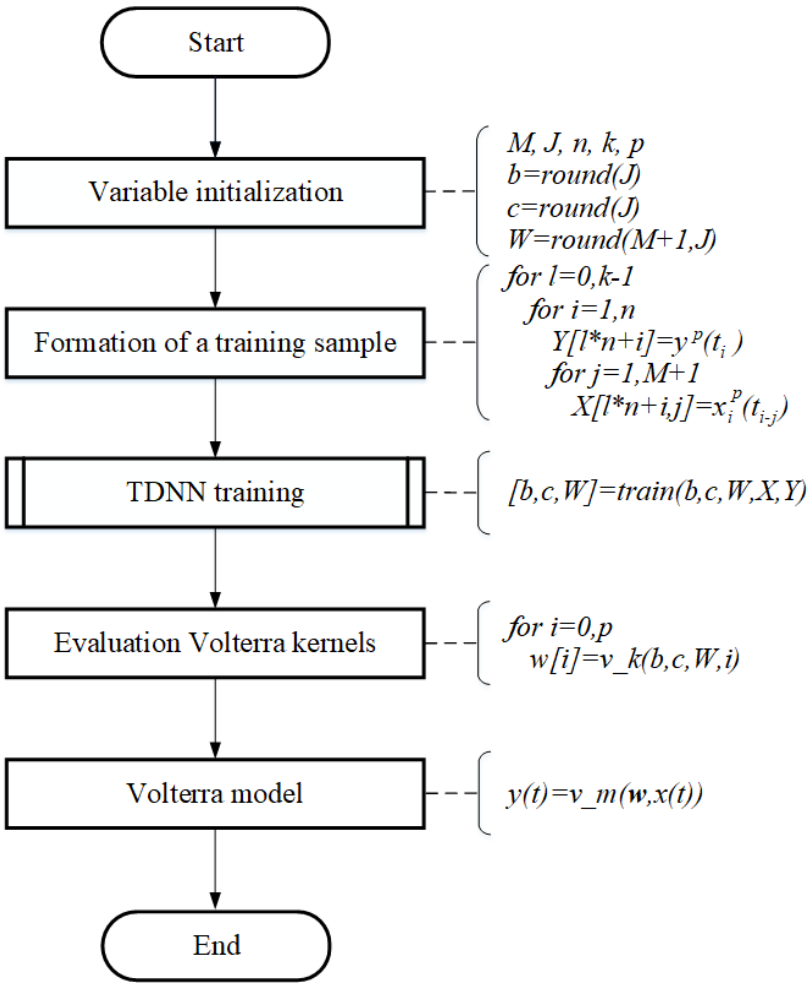


Figure 4: The algorithm of Volterra kernels evaluation using TDNN

4. Experimental Setup

The efficiency of the suggested identification method investigates using as an example a test nonlinear dynamical object. The test object used is the first order object with quadratic nonlinearity in a feedback relation [23] (Fig. 5). This object is described by the Riccati's equation:

$$\frac{dy(t)}{dt} + \alpha \cdot y(t) + \beta \cdot y^2(t) = u(t). \qquad (8)$$

where α and β – constant coefficients.

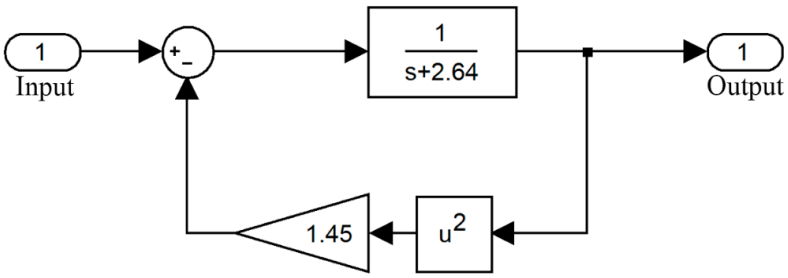


Figure 5: Structure diagram of the test nonlinear dynamical object

The analytical form of the non-parametric Volterra model of the third order under zero initial conditions is as follows:

$$y(t) = \int_0^t w_1(\tau_1)x(t-\tau_1)d\tau_1 + \\ + \int_0^t\int_0^t w_2(\tau_1,\tau_2)x(t-\tau_1)x(t-\tau_2)d\tau_1 d\tau_2 + \\ \int_0^t\int_0^t\int_0^t w_3(\tau_1,\tau_2,\tau_3)x(t-\tau_1)x(t-\tau_2)x(t-\tau_3)d\tau_1 d\tau_2 d\tau_3, \quad (9)$$

where the Volterra kernels of first, second and third order are equal, respectively:

$$w_1(\tau_1) = e^{-\alpha\tau_1}, \\ w_2(\tau_1,\tau_2) = \frac{\beta}{\alpha}(e^{-\alpha(\tau_1+\tau_2)} - e^{-\alpha\tau_2}), \quad \tau_1 \le \tau_2, \\ w_3(\tau_1,\tau_2,\tau_3) = \frac{1}{3}\left(\frac{\beta}{\alpha}\right)^2 (e^{\alpha(\tau_1-\tau_2-\tau_3)} + 3e^{-\alpha(\tau_1+\tau_2+\tau_3)} - \\ -4e^{-\alpha(\tau_2+\tau_3)} - 2e^{-\alpha(\tau_1+\tau_3)} + 2e^{-\alpha\tau_3}), \quad \tau_1 \le \tau_2 \le \tau_3. \quad (10)$$

The diagonal sections of Volterra kernels are obtained by assuming $\tau_1=\tau_2=\tau_3=t$:

$$w_2(t,t) = \frac{\beta}{\alpha}(e^{-2\alpha t} - e^{-\alpha t}), \\ w_3(t,t,t) = \left(\frac{\beta}{\alpha}\right)^2 (e^{-3\alpha t} - 2e^{-2\alpha t} + e^{-\alpha t}). \quad (11)$$

The analytical expressions (10) for the Volterra kernels $w_1(t)$, $w_2(t,t)$, $w_3(t,t,t)$ are used as benchmark for comparison of the kernels evaluation $\hat{w}_1(t)$, $\hat{w}_2(t,t)$, $\hat{w}_3(t,t,t)$ obtained on the basis of "input-output" experiment according to the proposed method.

For experimental estimation of diagonal sections of the Volterra kernels of the n-th order ($n \ge 2$) the object is tested by means of n test pulses with different amplitude at different moments of time. With appropriate response processing we get diagonal sections of n-dimensional integrals from n-th-order kernels $w_n(\tau_1,\ldots,\tau_n)$.

The identification of first, second, and third order Volterra models was also carried out based on TDNN.

5. Results

The percent normalized root-mean-square error (PNRMSE) criterion is used for accuracy estimation when experimentally determining of the Volterra kernels. The estimates of the Volterra kernels identification errors on the base of the PNRMSE criterion using TDNN are shown in Table 1.

Table 2

Accuracy estimation for the identification of n-th order Volterra kernels

Volterra kernel	PNRMSE criterion	Number of iterations
1 order	5,05	27
2 order	9,06	34
3 order	19,01	41

Figure 6 shows the plot of the first-order Volterra kernel $w_1(t)$ and it's estimation $\hat{w}_1(t)$ using TDNN. Figures 7, 8 shows the plots of the diagonal sections of second $w_2(t,t)$ and third order Volterra kernels $w_3(t,t,t)$ respectively as well as their estimations $\hat{w}_2(t,t)$ and $\hat{w}_3(t,t,t)$ using TDNN.

The obtained simulation results allow to get nonlinear dynamic model in the form of Volterra series (2) with an expected accuracy of 5-19% as compared to the analytical model.

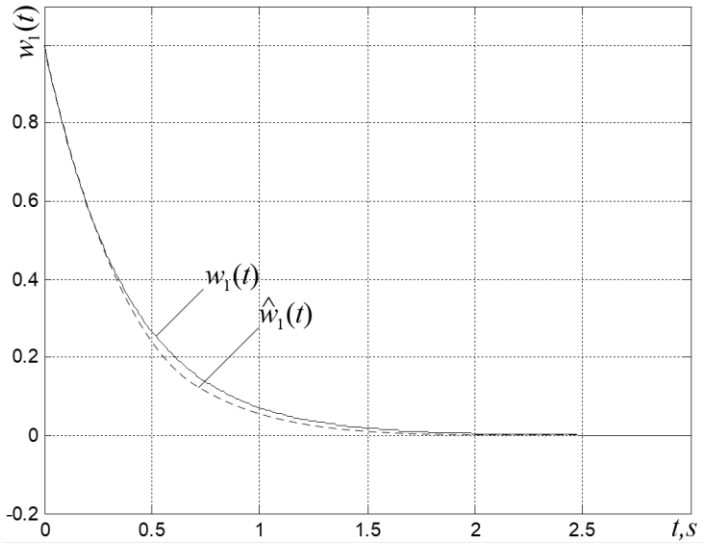


Figure 6: The first-order Volterra kernel $w_1(t)$ and it's estimation $\hat{w}_1(t)$

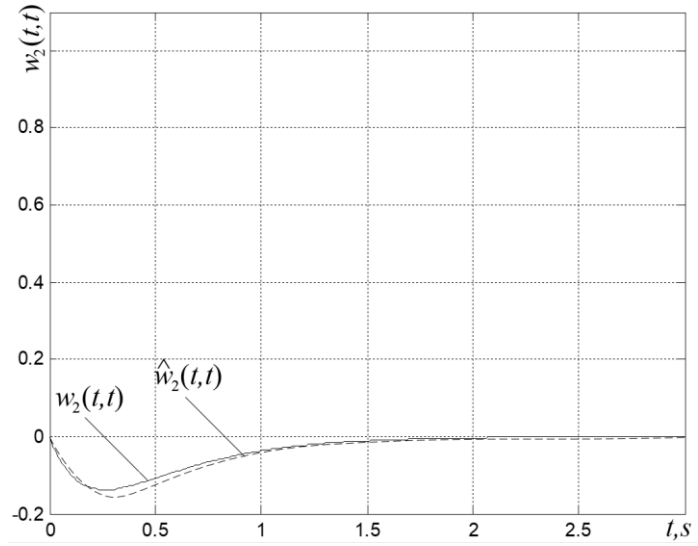


Figure 7: The diagonal section of second Volterra kernel $w_2(t,t)$ and it's estimation $\hat{w}_2(t,t)$

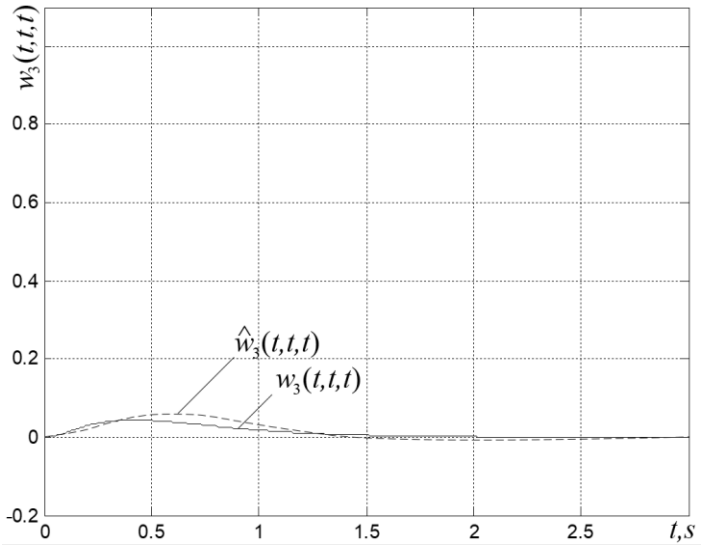


Figure 8: The diagonal section of third order Volterra kernel $w_3(t,t,t)$ and it's estimation $\hat{w}_3(t,t,t)$

6. Conclusion

The results of this research are as follows.

1. The approach to identification of nonlinear dynamic models on the base of Volterra kernels has been developed and substantiated. The disadvantages of this approach to the identification are: the numerical limitations in the evaluation of high order Volterra kernels, which forces one to look for the new and efficient ways to identify dynamic objects with non-linearity of higher orders. As such an approach is suggested TDNN.

2. An informational relation between nonlinear dynamic models in the form of Volterra series and TDNN has been established. On the base of this relation the method for evaluating higher-order Volterra kernels developed. It allows increasing the accuracy of nonlinear dynamic models identification in the form of Volterra series by evaluating higher-order Volterra kernels using TDNN and training samples on the base of the input signals of the special form (δ-functions, step functions, harmonic signals) and output responses.

The method allows simulation in both test and functional modes. However, the main limitation of this method is the speed, which is limited by the training time of the neural networks. Therefore, the subject of further research may be the use of methods to increase the training speed of TDNN.

The algorithm of Volterra kernels evaluation using TDNN and pseudocode that implements each stage is suggested.

The application of the developed method for the identification of the test nonlinear dynamic object allows getting the nonlinear dynamic model on the base of Volterra kernels with error of 5-19% in comparison with analytic models in the form of Volterra series.

7. References

[1] J. Schoukens, L. Ljung, Nonlinear system identification: a user-oriented roadmap, Preprint submitted to IEEE Control Systems Magazine, 2019.

[2] A. C. Meruelo, D. M. Simpson, S. M. Veres, Ph. L. Newland, Improved system identification using artificial neural networks and analysis of individual differences in responses of an identified neuron, in: Neural Networks, volume 75, 2016, pp. 56–65. doi: 10.1016/j.neunet.2015.12.002.

[3] R. Murray-Smith, T. Johansen, Multiple model approaches to nonlinear modelling and control, CRC Press, 2020.

[4] A. Agresti, Foundations of linear and generalized linear models, Wiley series in probability and statistics, 2017.

[5] A. A. Lanne, Nonlinear dynamical systems: synthesis, optimization, identification, L. VAS, 1985. (in Russian)

[6] C. Rudin, J. Radin, Why are we using black box models in AI when we don't need to? A lesson from an explainable AI competition, volume 2, no. 1, Harvard Data Science Review, 2019. doi: 10.1162/99608f92.5a8a3a3d.

[7] R. Guidotti, A. Monreale, S. Ruggieri, F. Turini, F. Giannotti, D. Pedreschi, A survey of methods for explaining black box models, in: ACM Computer Surveys, volume 51, no. 5, 2018, pp. 1–42. doi: 10.1145/3236009.

[8] O. O. Fomin, O. D. Ruban, O. V. Rudkovskyi, Method for construction the diagnostic features space of switched reluctance motors based on integral dynamic models, in: Problemele energeticii regionale, no. 4, 2020, pp. 35–44. doi: 10.5281/zenodo.4316968.

[9] O. Fomin, O. Derevianchenko, Improvement of the quality of cutting tools states recognition using cloud technologies, in: Lecture notes in mechanical engineering, 2020, pp. 243–252. doi: 10.1007/978-3-030-50794-7_24.

[10] G. B. Giannakis, A bibliography on nonlinear system identification and its applications in signal processing, communications and biomedical engineering, in: Signal Processing, EURASIP, volume 81, no. 3, 2001, pp. 533–580. doi: 10.1016/S0165-1684(00)00231-0.

[11] G. Favier, A. Y. Kibangou, T. Bouilloc, Nonlinear system modelling and identification using Volterra-PARAFAC models, in: International journal of adaptive control and signal processing, Wiley, volume 26, no. 1, 2012, pp. 30–53. doi: 10.1002/acs.1272.

[12] G. Govind, P. A. Ramamoorthy, Multilayered neural networks and Volterra series: The missing link, in: Proceedings of International Conference on Systems Engineering, 1990, pp. 633–636. doi: 10.1109/ICSYSE.1990.203237.

[13] V. Z. Marmarelis, Zh. Xiao, Volterra models and three-layer perceptrons, in: IEEE Transactions on neural networks, volume 8, no. 6, 1997, pp. 1421–1433. doi: 10.1109/72.641465.
[14] G. Birpoutsoukis, Volterra series estimation in the presence of prior knowledge, Ph.D. thesis, Vrije Universiteit Brussel, 2018.
[15] H. Eivazi, H. Veisi, M. H. Naderi, V. Esfahanian, Deep neural networks for nonlinear model order reduction of unsteady flows, Physics of Fluids, volume 32, no. 105104 (2020). doi: 10.1063/5.0020526.
[16] C. A. Mitrea, C. K. M. Lee, Z. Wu, A comparison between neural networks and traditional forecasting methods: case study, in: International journal of engineering business management, volume 1, no. 2, 2009, pp. 19–24. doi: 10.5772/6777.
[17] A. R. Rao, M. Reimherr, Non-linear functional modelling using neural networks, 2021. URL: https://arxiv.org/abs/2104.09371.
[18] R. Pintelon, E. Louarroudi, J. Lataire, Nonparametric estimation of time-variant dynamics, in: 17th IFAC Symposium on System Identification, Beijing, China, 2015.
[19] G. Stegmayer, M. Pirola, G. Orengo, O. Chiotti, Towards a Volterra series representation from a neural network model, in: WSEAS Transactions on Circuits and Systems, archive 1, 2004, pp. 55–61.
[20] M. Sugiyama, H. Sawai, A. H. Waibel, Review of TDNN (time delay neural network) architectures for speech recognition, in: IEEE International Sympoisum on Circuits and Systems, volume. 1, 1991, pp. 582–585. doi: 10.1109/ISCAS.1991.176402.
[21] L. Wenyuan, L. Zhu, F. Feng, W. Zhang, Q.-J. Zhang, L. Qian, G. Liu. A time delay neural network based technique for nonlinear microwave device modelling, in: Micromachines, Basel, volume 11, no. 9: 831, 2020. doi: 10.3390/mi11090831.
[22] O. Ruban, Diagnostic models and methods of their reduction in continuous dynamic Objects identification systems, Ph.D. thesis, Odesa national polytechnic university, 2020.
[23] V. D. Pavlenko, S. V. Pavlenko, V. O. Speranskyy, Interpolation Method of Nonlinear Dynamical Systems Identification Based on Volterra Model in Frequency Domain, in: Proceedings of the 7th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, volume 2, Berlin, Germany, 2013, pp. 138–142. doi: 10.1109/IDAACS.2013.6662664.

A Synergetic Approach to Project Training in IT

Tetiana Trofymenko[1], Mykhaylo Lobachev[1], Varvara Kuvaieva[1], Igor Tochonov[2]

[1] *Odesa National Polytechnic University, Odesa, Ukraine*
[2] *Donbas National Academy of Civil Engineering and Architecture, Kramatorsk, Ukraine*

Abstract

The article describes the original methodology of project training in IT, which is implemented at the Department of Artificial Intelligence and Data Analysis of Odeska Politeknika. The method makes it possible to double the speed of assimilation of educational information by students and get one hundred percent employment of students in their specialty after graduation. This method develops students' creative thinking and their communication skills. The article provides a theoretical justification of the method from the standpoint of synergetics. The integrative complexity of the IT project training system is shown, nonequilibrium phase transitions in it are considered, the class of systems to which the IT project learning system belongs is determined. This work will be useful for university teachers, not only for IT specialties, but also for students of technical specialties and representatives, in particular, HR specialists of various IT companies interested in highly qualified specialists.

Keywords

Project training, synergetic approach, complex system, information

1. Introduction

Currently, graduates of Ukrainian universities face an acute problem of finding a job. Higher education in Ukraine has become almost mass, but not every university graduate can find a job in his specialty. In order to improve the social adaptation of students, future specialists and magistertrs, a special method of project training has been introduced at Odeska Politeknika [1]. It allows students already at the stage of studying at the university to find future employers and organize a future place of work for themselves. This method is based on the deep cooperation of the university, the student, teachers and the customer of the learning process (stakeholder) [2]. Various companies, both domestic and foreign, act as customers of students' training. Already at the stage of studying at the university, students and future employers get to know each other better, and employers have the opportunity to see students in action – how they perform real production tasks. This approach is beneficial to both students, the university, and the industry – the system, conventionally called [2] 3WIN, works: all three sides are the winners - both the university, the student, and the customer company. Moreover, what is especially important, this method develops students' creative skills – students solve creative tasks, and the teacher sets students up to search for non-standard solutions. This increases the competitiveness of future specialists in the labor market. The training does not follow the standard method, as it happens with ordinary, non-project training at a university, but according to a special method of creative development of students.

The purpose of this work is the theoretical substantiation of the method of project training in IT as a method that develops the creative abilities of students and a detailed presentation of the methodology, which made it possible to double, compared with the classical one, to increase the speed of information assimilation by students, as well as drastically increase the competitiveness of graduates of the department of Artificial Intelligence and Data Analysis in the labor market – to increase to one hundred percent of graduates employed in the specialty.

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: trofimenkotg@op.edu.ua (T. Trofymenko); lobachev@op.edu.ua (M. Lobachev); vkuvayeva@op.edu.ua (V. Kuvaieva); tmkc0001@gmail.com (I. Tochonov)
ORCID: 0000-0003-0621-8863 (T. Trofymenko); 0000-0002-4859-304X (M. Lobachev); 0000-0002-9350-1108 (V. Kuvaieva); 0000-0003-0251-2395 (I. Tochonov)

This work will be useful for university teachers, not only for IT specialties, but also for students of technical specialties and representatives, in particular, HR specialists of various IT companies interested in highly qualified specialists

2. Main part

The purpose of our teaching method is, first of all, the development of students' creative abilities, the activation of self-development processes in the student's psyche. Why is this relevant? Because robotics is currently developing rapidly, and all non-creative processes will soon be carried out by robots, and people will be needed only in creative processes. Thus, in order to be in-demand specialists, students must acquire creative skills while studying at the university and activate self–development processes in their psyche – so that these processes go on continuously, allowing them to improve professional skills constantly and constantly synthesize new and new ideas and creative solutions, which is especially important for such creative and complex intellectual activities as work in the IT field.

What are the processes of self-development in the human psyche? These are, first of all, processes accompanied by non-equilibrium phase transitions, when, as a result of some activity, the human psyche and information in the environment of the human psyche acquire new qualities, new properties [3]. Such phenomena require inclusion in the consideration of not just information processes in the training system, but a synergetic approach at the macro level [4], since traditional approaches to information research, based ultimately on Shannon's entropy approach [5], do not allow either to explain or describe qualitative changes in information in the recipient's (student's) thesaurus – when suddenly new knowledge is born in the student's brain, that is, his own original idea of how to perform a task, that is, a non-equilibrium phase transition occurs. In our case, the macroscopic approach to information in the project-based learning system consists in including the recipient's psyche into the macro system with information as an information development medium [6, 7, 8, 9]. It is the consideration of information in a macrosystem with the recipient's psyche that makes it possible to synthesize the method of creative training and self-development of students. The teacher does not conduct an ordinary, classical survey on a summary or textbook. Students themselves find tasks to work in the classroom with the help of curators from customer firms. Firstly, students are interning at the firms where they will work after graduation. Secondly, curators from customer firms give actual production tasks to students so that they do not consider any theoretical tasks in the learning process, but solve only real practical tasks that are already facing real firms that have real customers of IT products. If a theoretical topic is considered in the lesson, for example, functional cost analysis (FSA), then it is considered not theoretically, not on imaginary objects, but on concrete practical examples when students perform those tasks that they received from customer firms. At the same time, if it is a question of creating a device, the teacher does not limit students to the element base, and if it is a question of creating software, the teacher does not limit students to a specific programming language. The student should be able to consciously choose both the programming language and the element base and the functional solution of the device or the organization of the software, including the programming style (for example, is there a need for object-oriented programming), based on the goals of the customer and the requirements put forward by him for what functions the development should perform: in the end, the student is not even limited to whether these functions should be performed programmatically or hardware, he should be able to justify his choice – how it is cheaper, more convenient, more profitable for the customer to perform certain functions that the customer needs. Usually classes are held in the form of business games: students are divided into teams, each of which has its own task. In each team, brainstorming is carried out during the lesson to choose the optimal solution, and then the division of labor is usually carried out – each team member has his own task. It can be software or hardware development, and it can also be a feasibility study of the project and even sales letters and promotion of the project on the Internet. It is also widely practiced to change roles between students: some students can play the role of teachers and conduct a survey, while others can be in the role of students and answer. Both students in the role of teachers and real teachers ask questions not for memorizing the material, but for the ability to find a creative, unusual solution to the problem and justify it. The teacher often asks questions like "What do you think ...?", "What do you think about this?", "What other solution could you offer?", "Why do you offer such a solution?", "On what basis do you think so?", "What benefits will this give to the customer?", "What are the advantages of this solution, and what are its disadvantages?". Such questions are aimed at activating the processes of self-development in the student's psyche. This is not a test of knowledge, but the activation of creative processes in the student's psyche. With this method, there is no clear division into technical and organizational-economic cycle subjects, they are harmoniously combined, since it is

impossible to effectively perform modern IT development, not a theoretical task, but a real practical one, without conducting a feasibility study of the development and without thinking about promoting this development and the target audience that will buy this development. Students are trained to work in a modern market economy. At the same time, the teacher's stimulation of students' creative activity leads to the fact that even those students who previously, with traditional training, were not inclined to offer original creative solutions to problems, offer such ones. And this indicates the development of information in the environment of the student's psyche. The teacher does not offer ready-made solutions for memorization, but with all his behavior stimulates this creative process – the birth of new knowledge in the student's psyche, which falls under the definition of self-organization processes in the psyche [10] and information [6]. At the same time, interesting discussions often arise among students, as well as between students, teachers and representatives of customer firms. In the course of discussions, students learn to defend their points of view, as well as clearly and competently formulate their ideas, which is very important for increasing their competitiveness in the labor market. When the development is ready, each team holds a presentation of its development. At the same time, each student has the opportunity to speak out and tell about his personal results, about how he participated in the development. Students' performances are conducted in the form of a public speaking training. First, the teacher tells the technique of public speaking and shows exactly how to effectively speak in public. Then each student goes out in front of the audience and speaks briefly for about three minutes. After each speech, a tactful discussion of the speech takes place: the speaker is praised for successful moments in the speech, in general, for everything that can be praised, then all who wants tactfully express wishes – what else could be improved in the speech. Thus, all students acquire the skills of public speaking and defending their opinions and their developments. What is also very important is that students acquire the professional communication skills necessary for an IT developer: they discuss the technical task (TT) for development with the customer, make their proposals in the TT. Nowadays, communication skills are very important for almost all professions, including IT specialists, and it is difficult to find a workplace without a proper level of communication skills. Many employers consider communication skills even more important than the purely professional skills of IT developers, since in the field of IT, all development tools are still changing very quickly, some new technical tools are constantly appearing, and IT specialists still need to learn new professional knowledge constantly. Therefore, if a person does not know, say, some programming language, but has general technical literacy, it's not a big deal: this person will master this programming language, but if this person does not know how to communicate with people and is a source of conflicts in the team, then his value as a specialist immediately falls, and such a specialist is usually not wanted to hire. At the same time, the development of effective communication skills is a more complex process than the assimilation of some new programming language, and due to the psychotype of the personality of a computer specialist, it is usually difficult for programmers and other computer scientists to acquire communication skills, it is difficult for them to develop them. Therefore, it is especially important that the learning environment at the university be conducive to the development of communication skills, which is provided by the teaching method considered in this paper.

It should be noted that the stated teaching method increases students' interest in studying, which entails an increase in students' academic performance and their interest in novelties of technology and means of promoting developments. And this increases the pragmatic informativeness according to Harkevich [11] of all information flows in the system of project training. Moreover, the informativeness of a bidirectional information flow (between each of the three components of the system - the university, the customer and the student) can change abruptly (may have a non-equilibrium phase transition), since this macrosystem ("university - student-customer") is sensitized to the customer component: what is important for the customer (based on his purely practical task) becomes immediately important for the other components of the system - the student and the teacher. Thus, the informativeness of this or that message, of this or that informational impact in the macrosystem "university - student - customer" can change drastically, acquiring new qualitative characteristics - increased pragmatic informativeness in the sense of Harkevich [11]. Thus, we observe the integrative complexity of the macrosystem "university - student - customer" in understanding [10], which manifests itself, in particular, in the dynamic complexity in understanding [10] – in the appearance of non-equilibrium phase transitions in the system "university - student - customer" and the synthesis of new knowledge based on the processes of self-development of the psyche and information. This is, of course, a manifestation of synergy in the "university - student – customer" system. In addition, the synergetic effect is manifested in new pragmatic aspects that all components of this macrosystem and information flows between them have when they are combined into this macrosystem, and which they did not have before this alliance. Moreover, the change in the pragmatic aspects of information flows, in particular, the benefits acquired by each participant of the macrosystem, occurs non-linearly: the benefit of everyone from participating in the macrosystem is not equal to

the sum of the benefits of everyone without participating in the macrosystem, and the total benefit of the entire macrosystem is not equal to the sum of the benefits of each participant. Thus, project-based training requires studying precisely with the tools of synergetics, since, of course, it is a synergetic object. From the point of view of the classification of this macrosystem, it is certainly nonlinear (we have shown this), has structural (many levels and connections in the organization of this system) and dynamic complexity in understanding [10], and also has relatively independent behavior of subsystems with high purposefulness and selectivity of the system, which allows, according to [10], to classify this system as open. Why can we talk about the relatively independent behavior of subsystems in a given macro system? Well, firstly, the psyche of each individual is unique and independent, and since the teacher in the teaching method under consideration stimulates the student's independent creative thinking, we can state the fact that the student thinks independently of the teacher: the teacher does not inspire or suggest ready-made solutions to the student, but encourages the student to look for different solutions to the problem and analyze them, compare them and could identify which of the solutions is more profitable to apply. And it doesn't matter if the student makes a mistake. Mistakes are the natural results of creativity. In this method, the teacher does not punish students for mistakes. We can even say that there are no mistakes with this method, because even if some unsuccessful solution is synthesized, it is analyzed by students together with customers and teachers and the weaknesses of this solution and ways to eliminate them are found, and students acquire useful engineering and communication skills. And secondly, students, customers and teachers interact in this case only within the framework of a certain situation – training, and there are many other spheres of life in which each of the components of the macrosystem under consideration acts autonomously. After all, a person's life is not just about studying. But these autonomous actions somehow affect the psyche of each of the participants in the educational process - both the psyche of the student, the psyche of the teacher, and the psyche of the customer's representative. And therefore, this influence extends to the entire macrosystem of project-based training. In addition, this macrosystem, of course, acts purposefully, and its purpose is the formation of a creative specialist. Moreover, this creative process makes the student an active component of the macro system. The student here is not an object of influence, upbringing, education, but a subject - an active actor and an equal participant in the training process. All this, of course, speaks in favor of the fact that the considered macrosystem of project training is open, according to the definition given in [10] by Y.V. Sachkov. Moreover, the integrative complexity of this macrosystem manifests itself in its adaptability to the market - depending on pragmatic indicators, this or that information becomes more or less valuable for the student, the means used by students in solving practical tasks set for them by customer firms are constantly changing, adaptively adapting to the market, and there are no identical classes: each lesson in each group is original. Because each student faces different practical tasks formulated by customers, and each team and each student find their own solutions. This leads to a high level of integrative complexity of the project-based learning system. Such systems, of course, should be studied by synergetic methods. The limited size of this article does not allow for a complete study of the macrosystem of project-based training, and this topic is very promising in terms of scientific research. In particular, it is necessary to investigate in more detail the integrative, in particular, the dynamic complexity of this system, in particular, to investigate nonequilibrium phase transitions. This will improve the teaching method – increase the speed of synthesis of new knowledge by students.

3. Conclusions

The article describes the original method of project training in IT, which is implemented at the Department of Artificial Intelligence and Data Analysis of Odeska Politeknika. The method makes possible to double the speed of assimilation of educational information by students and get one hundred percent employment of students in their specialty after graduation. This technique develops students' creative thinking and their communication skills. The article provides a theoretical justification of the method from the standpoint of synergetics. The integrative complexity of the IT project learning system is shown, nonequilibrium phase transitions in it are considered, the class of systems to which the IT project learning system belongs is determined. Further research of the system of project training in IT as a synergetic object will improve the teaching method and further increase the competitiveness of graduates of the department in the labor market.

4. Refences

[1] Lobachev M.V. Project training as a tool for building and developing inter-university R&D clusters M.V. Lobachev, S.G. Antoshchuk // Project Management 2017: the 13th International Scientific and Practical Conference (UPMA-2017). – Mikolaev, 2017. - P. 64-65

[2] Lobachev M.V., Antoshchuk S.G., Kharchenko V.S. Strategy 3 WIN sustainable cooperation of the IT industry R&D startup school.//Radio-electronic and computer systems. Kharkiv: KHAI, № 1 (85), 2018. – P. 71 -75

[3] Lobachev M. V., Trofimenko T.G. The system of project training in information technologies as a synergetic object //Prospects: Odesa: South Ukrainian National Pedagogical University named after K. D. Ushinsky, Helvetika publishing house. – 2019. – №1. – С. 61 – 68.

[4] Haken Hermann. Information and self-organization: A Macroscopic Approach to Complex Systems. – Springer Series in Synergetics, 3rd Edition, Kindle Edition, 1991. – 240 p.

[5] 5. Claude E. Shannon: "A Mathematical Theory of Communication", Bell System Technical Journal, Vol. 27, 1948. –379–423, 623–656 p.

[6] Trofymenko T.G. Methodology of information research as a synergetic object. Monograph// Depositor.rukop. GNTB of Ukraine, 1994. -109 p., No. 2263-Uk94

[7] Yershova-Babenko I. V. Psyhosynergetics strategy of human activity. Sources of nonlinearity of social environments as the psyhosynergetics bases of social self-organizing / I. V. Yershova-Babenko. – K., 2005. – С.21–26.

[8] Yershova-Babenko I. Space-temporal axial centering conception in the “geometries” of car and driver / I. Yershova-Babenko, O. Goncharova //The 14th geometry and graphics international conference (august 5–9, 2010 y. – Kyoto). – Kyoto, 2010. – P. 370–371.

[9] Trofymenko T.G. Philosophical aspects of textual information impact on a person// Prospects: Odesa: South Ukrainian National Pedagogical University named after K. D. Ushinsky, Helvetika publishing house. – 2019. – №2. – С. 4 – 12.

[10] Ershova-Babenko I.V. Methodology of the study of the psyche as a synergetic object. Monograph. - Odesa: ODEKOM, 1992. - 123 p.

[11] Harkevich A.A. On the value of information// Problems of cybernetics. – Vol.4– p.54.

The Information Model of Behavioral Risk Management for an Art-project

Olena Danchenko[1], Olena Bielova[2], Olga Zaiats[3], Iryna Rubalko[2]

[1] *Cherkasy State Technological University, Cherkasy, Ukraine*
[2] *«KROK» University, Kyiv, Ukraine*
[3] *National Transport University, Kyiv, Ukraine*

Abstract

These theses are devoted to the need to use an information model in the management of behavioral risks of an art project by a project manager. The analysis of creative sphere specifics is carried out and the concept of teams' management for art projects in the conditions of instability with elements of chaos-management is developed. A conceptual model of behavioral risk management - "Palette" was developed and presented, this model clearly demonstrates the process of combining risks from different sources and the role of the project manager in this process. Work on the development of a conceptual model revealed the need to create an information model (DFD) of behavioral risk management for art project team. The information model is an important tool for creating an effective information space with a clear, understandable system of timely integration of information and well-established communications between the art project manager, team and customer, which will increase efficiency in the process of behavioral risk management.

Keywords

Project, model, behavioral risks, art project, team management

1. Introduction

Recently, interest in the relationship between the traditional model of management and the cultural and creative spheres has grown significantly. These spheres are becoming important economic industries due to several factors: successful activity of some cultural and creative organizations, the opportunity to change the vision of the usual problems of society, namely, approach to innovation, product design, ways of thinking and more, through a creative look. Yet in the transition from a planned to a market economy, the creative sphere is one of the last areas of human activity, which has not been able to fully adapt to the requirements and conditions of the modern market. Creative projects, from the standpoint of organization, implementation and system management, are more complex. They are implemented in conditions of high uncertainty with a large number of risks. Therefore, the introduction of a project approach in the creative sphere will give a significant positive result in improving the quality of organization and implementation of creative activities [1].

Scientific works on the application of the project approach to creative projects have not yet received extensive research in world science. Among the separate articles devoted to this question, we can highlight the most important scientific works of the following authors: Azarenkov L.S. [2], Mochalov D.V. [3], Danchenko O.B. [4], Bas D.V. [5, 6], Rybalko I.V. [1, 7, 8,9], Bulavina D.M. [10], Novikova G.M. [11], Beloblotsky N.V. [12], Voitkovsky S.B. [13], Comandishko E.F. [14], Korneeva S.M. [15], Tulchinsky G.L. [16].

Applying the term "project" to creative activity, definitions of a creative project or art project were made:

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: elen_danchenko@ukr.net (O.Danchenko); belovaelenag@gmail.com (O.Bielova); zaiats.olga.v@gmail.com (O.Zaiats) rybalkoi@ukr.net (I.Rubalko)
ORCID: 0000-0001-5657-9144 (O.Danchenko); 0000-0001-9359-6947 (O.Bielova); 0000-0002-6574-4516 (O.Zaiats); 0000-0002-5332-2666 (I.Rubalko)

- art project is understood from the standpoint of expanding the scope of an organized event and is defined as a structural form of cultural communication based on a systemic organization that has specific goals, objectives and resources [17].
- art project is a completed cycle of artistic activity aimed at creating an original work of art in conditions of limited time and resources [5].

2. Main part

The development of science for a long time had a narrowly disciplinary nature, where each scientist was a highly qualified specialist within one particular discipline. That is, scientific discoveries had a branch principle. But now times have changed and the strategy of science development has reached the next level - interdisciplinary, i.e. conducting research at the intersection of several scientific fields. This step has become not just a trend in the modern scientific world, it has really shown its effectiveness. The combination of several disciplines resulted in unusual, interesting and innovative discoveries that helped accelerate progress.

During the stage of studying the subject area [18, 19] it was clear that, in addition to the methodology of project management, it became extremely important to pay attention to the psychological aspects of creative personality and features of art projects. To consider and analyze the psychological aspects it was necessary to turn to research in psychology. In turn, the identification and analysis of the peculiarities of the implementation of art projects showed clear differences from traditional management [20, 21] and, moreover, from the project approach, which are more inherent in chaos management [22, 23]. These three key factors defined the disciplines at the intersection of the concept of managing art project teams in conditions of instability with elements of chaos management. Euler's diagram, which depicts sets and relations between them, was used to graphically represent the concept. Type of relationship - intersection.

In our case, each set (A, B, C) is a discipline (psychology, project management, chaos management). The intersection of sets forms a set consisting of elements belonging to sets A, B and C simultaneously. That is, the intersection of sets is a synthesis of scientific approaches (Fig. 1).

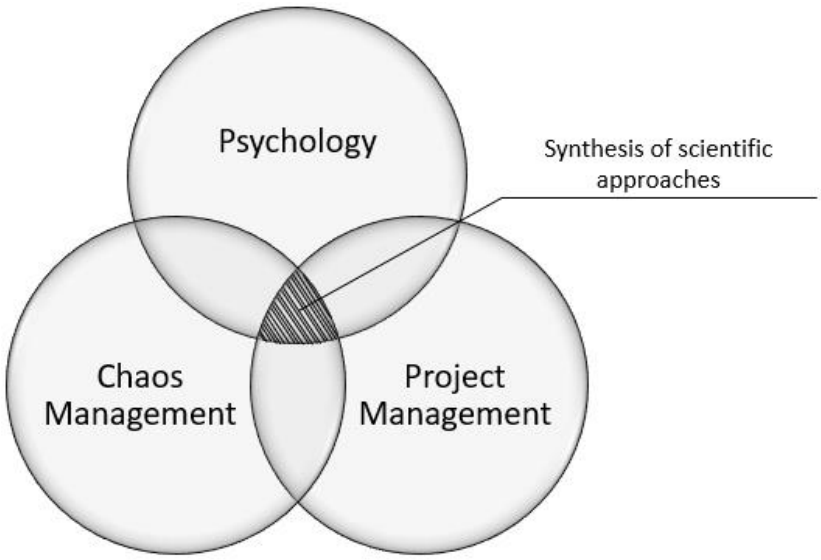


Figure 1: The concept of managing art project teams

Team management of any project is not only the organization of the work of team members in terms of planned processes, resources and motivation. Risk management takes one of the most important places in the work of a manager.

If we turn to history, the problem of risk has interested and attracted the attention of the scientific world in the early twentieth century. The impetus for this was F. Knight's book "Risk, Uncertainty and Profit" [24]. Although human risk assessment has existed since ancient times, as evidenced by drawings of gambling scenes in Egyptian tombs, on ancient Greek vases. But it was from the 1920s that risk analysis studies began to be conducted in various fields. Thus, the concept of "risk" is also interdisciplinary, used in many social and natural sciences.

Project team management, or project human resource management, according to the PMBoK standard includes planning, project team recruitment, development and management (control, communication, problem solving, change and conflict management) [25]. Managing an art project team includes all of these processes, including identifying and managing all of the behavioral risks involved:

- with the specifics of art projects [1];
- psychology of creative personalities [7];
- remote work format (distributed projects);
- weak formalization.

Many risks of an art project have a primary source - human activity. Therefore, they can be attributed to the group of behavioral risks, ie the reasons for which are the decisions and actions of specific people (project team members and stakeholders). In the scientific literature [26, 27, 28] the group of behavioral risks in the personnel is defined as a set of employees who potentially have a tendency to harm the company by their actions [29]. In the works of modern Ukrainian and foreign researchers can be found the terms "personnel risk", "social behavior", "risks of loyalty", "risks of staff behavior", "illegal behavior", "destructive behavior that contains risks", etc. Moreover, there is synonymy in the interpretation not only of their essence, but also in the formation of essential features on the basis of an interdisciplinary approach [29]. Behavioral risks in the context of the implementation of art projects can be defined as destructive behavior of a member of the art project team, which may interfere with the receipt of the product of an art project or the success of the project as a whole.

Each risk can manifest itself, both individually and in combination with others. It is to realize this factor that a conceptual model of managing an art project team was created, which clearly demonstrates the process of combining risks from different sources and the role of the project manager in this process. Risks from different sources, mixing with each other, change both the probability of occurrence and the strength of the impact on the project. That is why the idea arose to develop a conceptual model of team management of an art project in the form of an art palette, which symbolically shows that the art project manager is also an artist who must understand the origin of the sources of risk and, as the artist mixes pure paints on the palette to obtain new shades and colors, can identify as many options as possible to react to the combination, overlap and interaction of different types of risks on each other. The ability of the project manager to combine individual parts into one overall picture is extremely important for understanding the existing problem situations and conflicts in a rather difficult environment for the implementation of such projects. And the ability to decompose the general into separate parts means to "see" the source of risk and, accordingly, to anticipate some problematic situations and conflicts in the work of an art project team in advance, by creating a plan of measures to prevent risks. This is the art of the art project manager, which significantly and accurately conveys the conceptual model in the form of an artist's tool - a palette (Fig. 2).

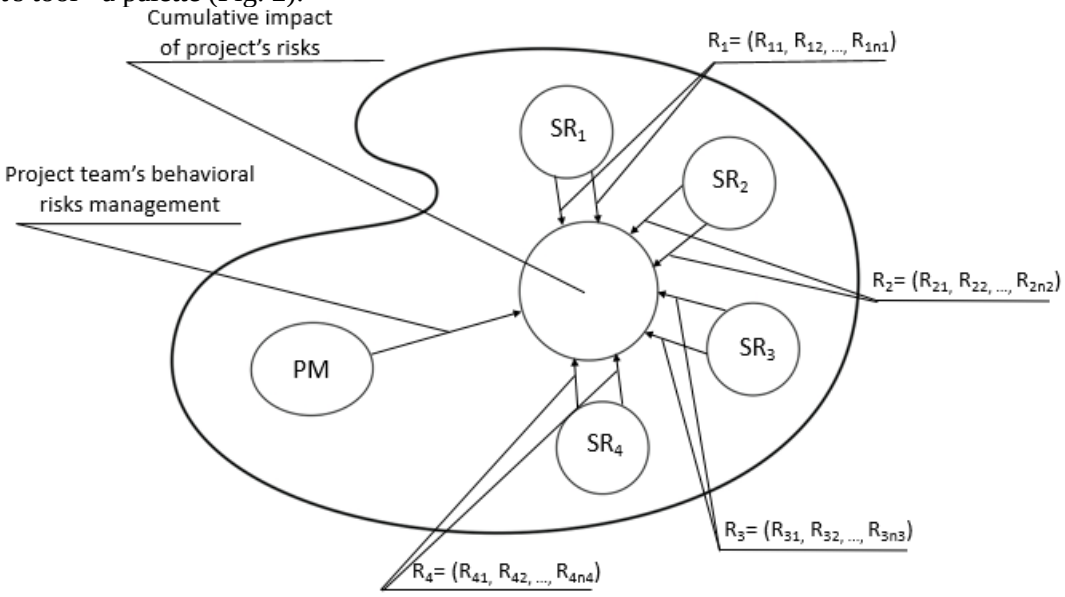


Figure 2: Conceptual model of behavioral risk management of art projects -"Palette"

All risks of the art project, conditionally divided into four sources (SR - source of risk) of their occurrence and symbolize the "pure" colors: SR1 - the first source (specifics of art projects); SR2 - the second source

(psychology of creative personalities); SR3 - the third source (remote work format); SR4 - the fourth source (weak formalization of art projects).

Each source has a number of risks. Thus:

1. R1 – the set of risks of the first source with the number of n risks (R11, R12, …, R1n1);
2. R2 – the set of risks of the second source with the number of n risks (R21, R22, …, R2n2);
3. R3 – the set of risks of the third source with the number of n risks (R31, R32 …, R3n3);
4. R4 – the set of risks of the fourth source with the number of n risks (R41, R42 …, R4n4).

During the project life cycle at all stages, risks from all four sources are mixed, creating new threats to the successful implementation of the project and determining the overall impact of risks on the project (place on the palette where the artist mixes "pure" paints). And just as the artist confidently holds the palette in his hand, pushing his thumb into a special hole, so does the project manager (PM) to control and manage all the risks of an art project.

Work on the development of a conceptual model revealed the need to create an information model for managing the behavioral risks of an art project team using graphical notation of the data flow diagram (Data Flow Diagrams, DFD). This notation is designed to model information systems in terms of storage, processing and transmission of data, taking into account the work with data, and visualizes the processes of data processing. The information model is a convenient tool for the art project manager, which will clearly demonstrate how information is exchanged, where data is stored, what mistakes can be made when moving (exchanging) information in the process of team risk management.

Next, we construct a a context-level data stream diagram to show where the data comes from and between whom there is an exchange (data flow, which determines the qualitative nature of the information transmitted through a particular connection from source to receiver [30]), what exactly is the data and who needs it, who processes it and where the results are sent (Fig. 3).

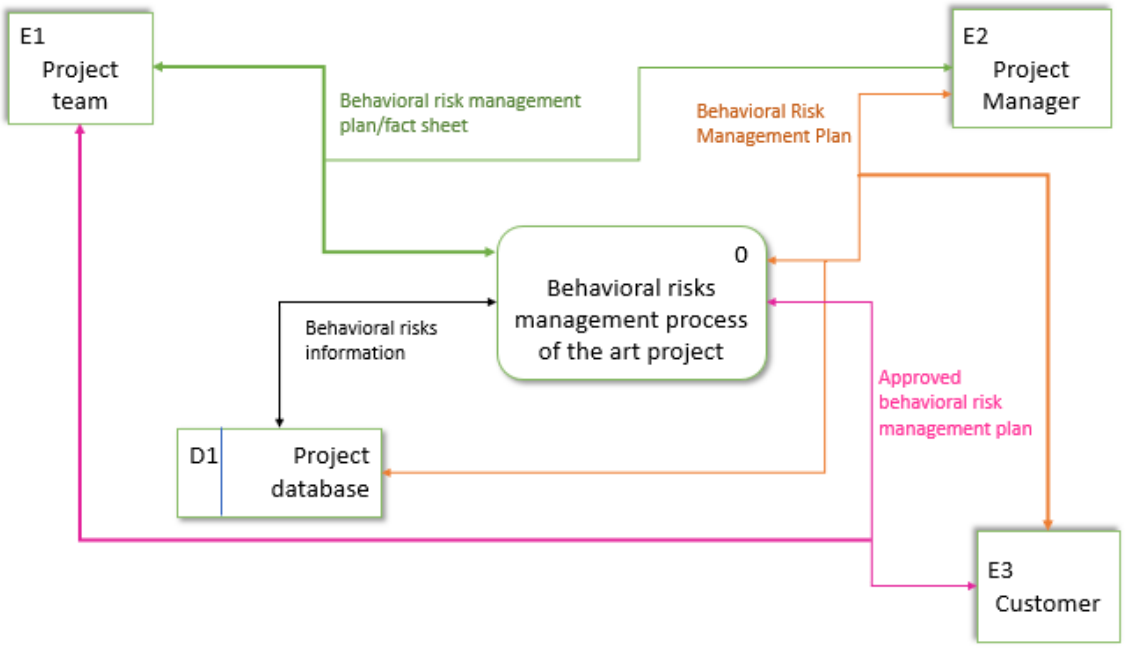


Figure 3: Context diagram of information model for behavioral risk management of an art project

From the diagram it becomes clear that stakeholders in the process of managing behavioral risks of an art project are the project manager, project team and customer. The project manager creates a behavioral risk management plan, approves it from the customer and passes it on to the project team. The project team receives a plan from the project manager and, after its implementation, sends him the fact of execution. At the same time, the project team also receives information about the risk management plan from the customer. All information about behavioral risks of an art project, including the management plan, the project manager stores in the project database.

The DFD model belongs to hierarchical models, where each process can be decomposed to refine the context diagram, which is a top-level diagram. Detailing the process of behavioral risk management of an art project is as follows (Fig. 4).

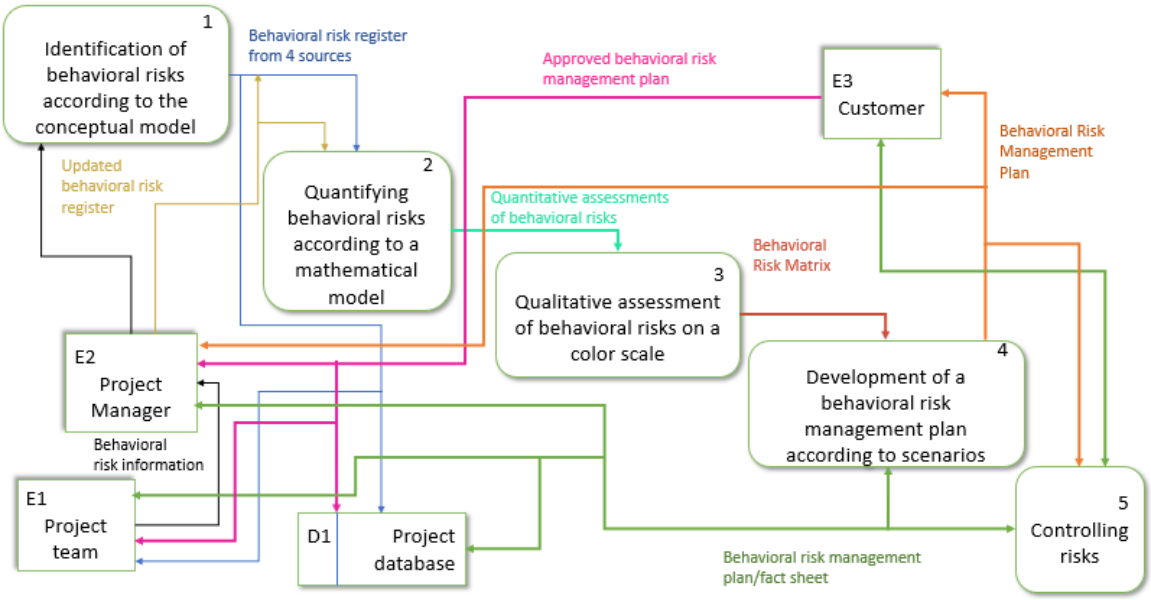


Figure 4: Detailing of information model for behavioral risk management of an art project

A detailed information model shows that the project manager receives information on behavioral risks from the project team, analyzes it and, as a result of identifying behavioral risks according to the conceptual model "Palette", creates a register of risks, dividing them into 4 sources, which sends to the project database and project team. Next, the register is used by the manager for quantitative evaluation on a mathematical model and qualitative evaluation on a color scale. Based on the obtained results, a behavioral risk management plan is developed according to the scenarios. The plan must be agreed by the customer. Therefore, the next step of the project manager is to send it for approval and obtain an approved risk management plan, which is communicated to the project team and sent to the project database for storage. Implementation of the risk management plan by project team members is monitored by the project manager and the customer. The behavioral risk management plan is sent to the customer, the project manager, the project team and sent to the project database. The project manager analyzes the result and, if necessary, makes adjustments to the risk register and again performs quantitative and qualitative analysis if new risks have been identified, or changes to existing behavioral risk management scenarios, in case of ineffective previous scenario. Then sends the updated plan to the customer for approval.

3. Conclusions

An information model of behavioral risk management of an art project is an important tool for creating an effective information space with a clear, understandable system of timely integration of information and established communications between the art project manager, team and customer, which will increase efficiency in behavioral risk management.

Further research is conducted in the direction of developing a mathematical model for assessing behavioral risks, a color scale of behavioral risks of art projects and scenarios for combating behavioral risks. Considering that the creative sphere by its specificity is high-risk and art projects are realized in the conditions of high uncertainty, it is necessary to continue working on the development of methods to combat behavioral risks, so that the art project manager gets an effective and efficient tool to prevent behavioral risks, or reduce the negative impact on the project in case of their occurrence.

4. References

[1] Rybalko I.V., Danchenko O.B., Melenchuk V.M., Berezensky R.V. Project approach in the creative sphere. Bulletin of the National Technical University "KhPI". Series: Strategic management, portfolio, program and project management. Kharkiv: NTU "KhPI", 2020. Vol. 1. P. 24-30.

[2] Azarenkov L.S., Ganitseva E.A., Kozhevina M.S. [and oth.]. Experience of project management in the field of culture [Electronic resource]: textbook for universities; under common ed. of L.S. Azarenkov. Ural. state ped. un-t. Ekaterinburg, 2018. 1 electron. disk (CD-ROM).
[3] Mochalov D.V. Culture management and art management: interconnection and interdependence. KazGUKI Bulletin. 2011. Vol. 4. URL: http://cyberleninka.ru/article/n/menedzhment-kultury-i-art-menedzhment-vzaimosvyaz-i-vzaimoobuslovlennost (date of the application: 25.11.2020).
[4] Kolomytseva O., Verenych O., Bielova O., Palonna T., Pepchuk S., Danchenko O. Forming of integrated understanding of project terms: Faulk's algorithm as one of the formalized approaches. ENTREPRENEURSHIP AND SUSTAINABILITY ISSUES (Web of Science, Emerging Sources Citation Index, SCOPUS Q1). 2020. Is. 7(4). ISSN 3215-3225. DOI: https://doi.org/10.9770/jesi.2020.7.4(42).
[5] Bas D.V. Art projects, their features and definitions. Bulletin of Cherkasy State Technological University. Series: Technical Sciences. 2016. Vol. 3. P. 57-62.
[6] Bas D. Values-oriented management of art projects. Topical areas of fundamental and applied research XI : Proceedings of the Conference (North Charleston, 27-28.02.2017). North Charleston, SC, USA: CreateSpace, 2017. Vol. 2. P. 222.
[7] Rybalko I.V., Chayun N.S., Bielova O.I. Psychological aspects of creative personality and their influence on the implementation of an art project. Management of complex systems development: a collection of scientific works. Kyiv: KNUBA, 2020. Vol. 44. P. 34-42.
[8] Rybalko I.V., Danchenko O.B. Possibilities of application of the project approach in the creative sphere. Project management in the development of society. Project management in the context of digitalization of society: abstracts of the XVII International scientific-practical conf. (Kyiv, May 15-16, 2020). Kyiv: KNUBA, 2020. P. 301-305.
[9] Rybalko I.V., Danchenko O.B., Bielova O.I. Effectiveness of project approach in forming of creative personality in art activities. State, regions, entrepreneurship: information, socio-legal, socio-economic aspects of development: II International Conference. (Kyiv, November 20, 2020). Kyiv: University of Economics and Law "KROK", 2020. URL: https://conf.krok.edu.ua/SRE/SRE2020/paper/view/164.
[10] Bulavina D.M. Project activity in the field of culture as a mechanism for the implementation of cultural policy: dis. ... cand. of cultural sciences: 24.00.01. Moscow, 2007. 167 p.
[11] Novikova G.N. Art Management Technologies: A Study Guide. M.: Publishing House MGUKI, 2006. 178 p. ISBN 5-94778-098-4.
[12] Beloblotsky N.V. Music Festival Marketing. Art-manager. 2003. Vol. 2. P.20-25.
[13] Voitkovsky S.B. Fundamentals of Management and Project Management in Art on the Examples of Personal Experience and Capable Projects of the Author: A Brief Overview for Beginning Performing Arts Managers and Students of the Higher School of Performing Arts. M.: NAM-publ., 2001. 128 p.
[14] Komandyshko E.F. The specifics of art management technologies in the training of future specialists in social and cultural activities. Military University Bulletin. 2011. Vol. 2 (26). P. 49-54.
[15] Korneeva S.M. Music management: a textbook for university students studying in the specialty "Music Management" (061166) and specialties of culture and art (050000). M.: UNITI, 2006 (SUE IPK Ulyanovsk Printing House). 303 p.
[16] Tulchinsky G.L., Gerasimov S.V., Lokhina T.E. Cultural Special Event Management: A Study Guide. SPb.: Lan, Planet of Music, 2009. 381 p.
[17] Dyganova E.A., Savelyeva N.S. Modern approaches in the field of art project management. Arts and Arts Education in the Context of Intercultural Interaction. Materials of the V International Scientific and Practical Conference (Kazan, November 16, 2016). Kazan, 2016. P. 302-307.
[18] Chong D. (2009). Arts Management (2nd ed.). Routledge. https://doi.org/10.4324/9780203865347.
[19] Goodwin J. (ed). (2008). International Art Markets: the essential guide to collectors and investors, London: Kogan Page.
[20] A Guidebook of Program & Project Management for Enterprise Innovation. Japan: Project Management Association of Japan (PMAJ), 2017.
[21] Individual competence baseline for Project, Programme and Portfolio Management (IPMA ICB). IPMA. Version 4.0. 2017. 431 p.
[22] DeShon, R. & Svyantek, D. J. (1993). Organizational Attractors: A Chaos Theory Explanation of why Cultural Change Efforts Often Fail. Public Administration Quarterly. Vol. 17. Is. 3. P. 339-355.
[23] Shelton C. (2003). From Chaos to Order: Exploring New Frontiers in Conflict Management. Presented at the Midwest Academy of Management Conference. Kansas City: Charlotte Shelton & John Darling.

[24] Knight F. Risk, Uncertainty and Profit; translation from English by M.Ya. Kazhdana. Evolutionary Economics Center. M.: Delo, 2003. 359 p.
[25] A Guide to the Project Management Body of Knowledge (PMBOK® Guide). Six Edition. USA: PMI, 2017.
[26] Zhukovska V.M., Seraphim N.V. Theoretical aspects of research of personnel risks at the enterprise. Bulletin of NUVGP. 2010. Vol. 1 (41). P. 92-99.
[27] Zhemchugov A.M., Zhemchugov M.K. Person and organization. The two main goals of man are unity and the struggle of opposites. Problems of Economics and Management. 2012. Vol. 8 (12). P. 18-34.
[28] Stout L.W. Human Resource Management; [translation from english.]. M.: Dobraya knyha, 2006. 536 p.
[29] Zhukovska V.M. Prevention of social and behavioral risks of personnel at the trade enterprise. Problems of the economy. 2014. Vol. 2. P. 366-372. Access mode: http://nbuv.gov.ua/UJRN/Pekon_2014_2_53.
[30] Danchenko O.B. Practical aspects of business process reengineering. K.: University of Economics and Law "KROK", 2017. 238 p.

Application of Information Technologies in the Transport Enterprise Project Management

Iryna Kis[1], Olena Bakulich[1] and Andrii Bieliatynskyi[2]

[1] *National Transport University, Kyiv, Ukraine*
[2] *North Minzu University, Yinchuan, NinXia,P.R. China*

Abstract

The work focuses on the need of using information systems and technologies to ensure the efficiency of the enterprises economic activities and their projects management. The classification of information systems and an overview of the software products which belong to certain directions of the project management system are given. The interrelation of the fields of projects management knowledge and information technologies is given for the forming of the comprehensive information system. It aims to solve the problems of management of the enterprise economic activities and their projects.

Keywords

Project, information system, IT in project management, risk management

1. Introduction

The different aspects and issues which refer to the efficiency of management of the enterprises economic activities and their projects are the subject of scientists and experts researches [1; 2].

The project management as a methodology in general and as an individual partial tool, in particular, is popularized in various areas of human activity and still continues to be widely used. The integrated project management in organizations [3], project management of innovative potential and development [4] and other themes are proposed and substantiated. The use of project management is due to a systematic, integrated approach implemented in the methodology, which involves the coverage and formalization of the most important project implementation processes. This is reflected in the international standards, namely PMBOK PMI [5], P2M [6], ICB IPMA [7], ISO 21500 [8], PRINCE2 [9].

For example, the risk management is one of the fields of projects management knowledge, which are used in the management of economic activities by business entities to achieve the goals. It is often used by directors, risk and other managers separately in the enterprise economic activities management system to solve certain tasks that are not always related to the implementation of projects. The numerous scientists' publications are devoted to the issues of risk management of economic activity and individual projects [10 – 13].

This is due to their active development, total digitalization of all spheres of human life, especially the economic sphere, and the transformation of business processes through the switchover to the Industry 4.0 [14 – 17].

The information systems and technologies, their use in the enterprises and projects management, expediency and efficiency, criterions for selecting and further development are actively studied by the scientists of various fields [18 – 29]. The scientists note that "the enterprises must carefully choose the right technology to improve all business management processes" [18]. They substantiate the expediency of using information technologies to achieve the strategic management goals [21]. The scientists also pay attention to the need to do clear categorization of technologies according to the enterprise's goals [18]. It is advisable not only to get acquainted

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: arinakiss.23@gmail.com (I.Kis); bakulich.elena@gmail.com (O.Bakulich); 1586118851@qq.com (A.Bieliatynskyi)
ORCID: 0000-0002-8386-8379 (I.Kis); 0000-0002-8386-8379 (O.Bakulich); 0000-0002-2158-512X (A.Bieliatynskyi)

with the main software products of the project management, but also with the specific, but namely with those that can be used in relation to a particular process (like the project team management, etc.).

2. Main part

An important aspect of the enterprises economic activity is the understanding of the way to achieve their goals. A lot of processes are implemented in order to achieve the result. For example, this is about the use of the strategic and operational management, development of the innovative policies of enterprise operation, introduction of the project management methodology, etc. The information systems and technologies are the traditional components of these types of management which are indicated previously.

The issues of strategic and operational digitalization of the enterprises economic activity are researched by different scientists, in particular Kochkodan V.B. [19]. This is the urgent need for the enterprise to operate successfully in the today's market conditions. As it's noted in [20], in 1982 Hank Lucas and John Turner noticed that the information technology can be used to achieve strategic management goals in three fundamentally different ways [21]. Firstly, they can be used to achieve greater efficiency in existing operations, such as reduction of the variable expenses (reduction of the marginal costs) by automation of the routine activities or improvement of the customer service through the better use of information. Then they can be used to improve the strategic planning process by improving support systems analysis policy. Finally, the technology can be used to open new markets by developing new products or services which are put to the technologies or directly include them [20; 21].

The information technology is traditionally considered using three approaches, namely: conceptual, which allows to determine the substantive aspect of the technology; logical, with the description of information or mathematical models' construction; and physical, which provides a description of the implementation by the software and hardware. Traditionally, using a logical approach to the description of the information technology, we will have four levels, namely: 1) information technology; 2) information process; 3) information procedure; 4) information operation (Fig. 1).

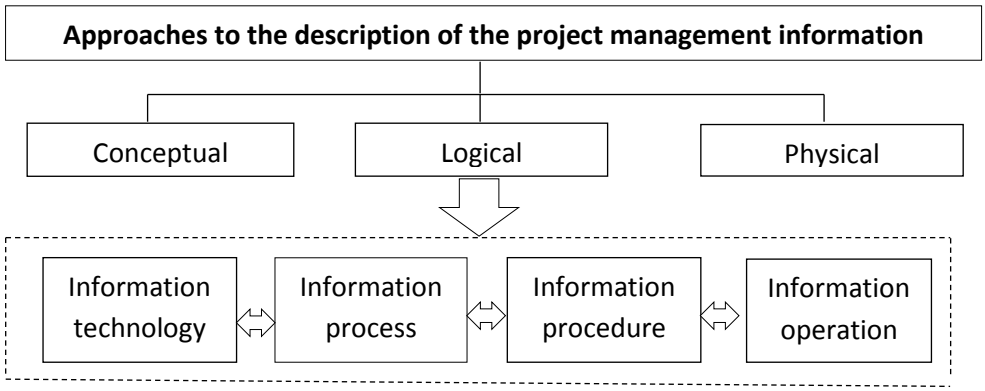


Figure 1: Approaches to the description of the project management information

Figure 1 gives the opportunity to navigate in the specifics of information technologies and software products using, which, in an integrated manner, make up the information system applied at the enterprise. It should be noted that different information systems can be used to ensure the processes of the enterprises economic activities and their projects implementation. For example, Supply Chain Management systems are aimed at organizing of interaction with suppliers, Customer Relationships Management systems – with customers, Business Process Management systems – to manage the business processes of the organization, Enterprise Resources Planning systems – for the resource management, Google Analytics systems – for the analytics management and others.

According to [14], among scientists there are supporters of the idea that ERP-systems will remain the "core" of corporate information systems even in the future and will play an important role in the IT-architecture of the enterprise 4.0, because [15 – 17]:

- ERP remains an important application for both horizontal and vertical integration;
- ERP integrates in terms of data with Internet data, sensors, robotic workplaces;

- ERP in terms of data becomes the basis for the development of great data, business analysis and artificial intelligence;
- ERP can be expanded in the field of production, logistics and communication with the customer.

Exploring the project management direction, we will consider different options of basic and special information technologies (Fig. 2). For example, special information technologies, which are used to manage project risks, are becoming more and more widespread now.

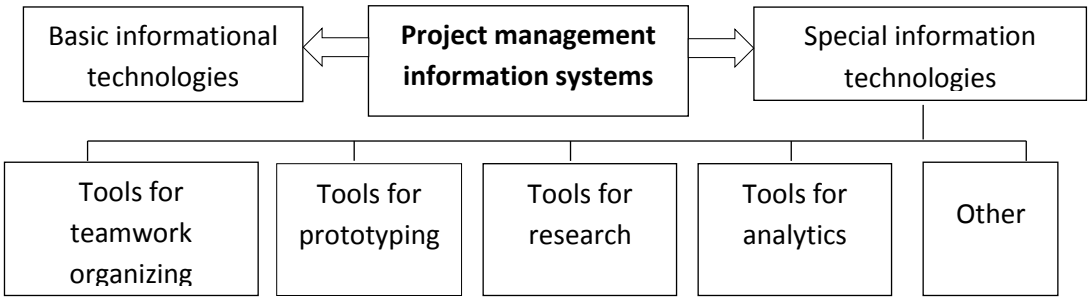


Figure 2: Classification of project management information systems

Among the basic well-known information systems in the project management field, which are popular with users, experts name such as Microsoft Office Project (Microsoft Office Project Standart, Microsoft Office Project Professional, Microsoft Office Project Server, Microsoft Office Project Web Access), and also SureTrak Project Manager, Primavera Project Planner (3P), Primavera Project Planner for the enterprise of the Primavera company. Open Plan (Open Plan Proffessional and «Open Plan Desktop) and Spider Project (Spider Project Pro, Spider Project Desktop Plus, Spider Project Desktop) are popular software products [23]. It is important that today simpler software products are gaining popularity. They have limited functionality but give an opportunity to effectively implement small and simple projects, especially those that carried out within the enterprise or organization. Such software products include, for example, Bitrix24 and Jira Core [23].

Among the software products used by project managers, we can also single out, for example, tools for analytics (Amplitude, Mixpanel, Tableau, Google Analytics, Yandex.Metrica, App Annie, Adjust), research, prototyping, teamwork [30].

Amplitude is a tool for product analytics, which allows you to collect all product data, make an analyze through the visualization of information in the form of graphs. Mixpanel is tool for analyzing the consumers behavior. It is a technology that allows to track consumer interaction with the brand. Tableau is a tool for data analysis and visualization, which allows to collect information from the multiple sources, process and visualize it using graphs. Google Analytics is a tool for analyzing the users behavior on the site. It allows to analyze the effectiveness of the site, that is the user interaction with the site. In essence, a similar tool is Yandex.Metrica, with which you can analyze the users activities on the site. With App Annie, a mobile application data analysis tool, you can explore the state of the market and competitors. The Adjust tool gives the ability to determine average marketing metrics in the similar applications.

The tools for research are OptimalWorkshop (a tool for audience research); BrandMentions (brand reputation research); UserTesting (interviews); UserInterviews (audience research); EnjoySurvey (automated survey service); Trint (transcriber); Uxcrowd (testing and transcription); Google Optimize (site interface testing); Z-Score (table and calculator of Z points); Selects Statistics (calculation of statistical significance); Evanmiller (A/B testing); UXPressia (creation of CJM (customer journey maps)).

The tools for prototyping are Figma; Invision; Sketch; Lookback.

The tools for teamwork organizing are Miro (board for group work); Lucidspark (board for group work); Notion (working area); Trello (task management in the project management system).

Our national scientists, such as Tesla Yury, offer their own software development PrimaNad. PrimaNad is a system which implements resource management functions in the automated mode both at the level of projects and at the level of enterprises [31].

Today, the use of enterprises project management methodology is spreading in various fields, including transport. So we believe that it is worth to review the recommendations for the use and selection of project management information system. It is necessary to provide flexibility of the choice and the ability to use not only basic information technology, but also special, or both basic and special as needed. An approach to the selection of a particular project management information system was proposed in the work [23]. It is based on three criteria, namely the skills/abilities of the project manager, the functionality of the system and its cost. In

our opinion, today the selection criteria should include knowledge spheres of project management methodology, namely project integration, content, timing, cost, quality, resources (human and other), communications, risks, purchases and interested parties' management [5].

Considering a wide range of special software products, not only the use of basic and professional information systems can be effective. By the way, they do not always cover all the tasks that need to be solved during the project. That's why it is a need to use special information systems that can meet the requirements of the project information and analytical support (Fig. 3).

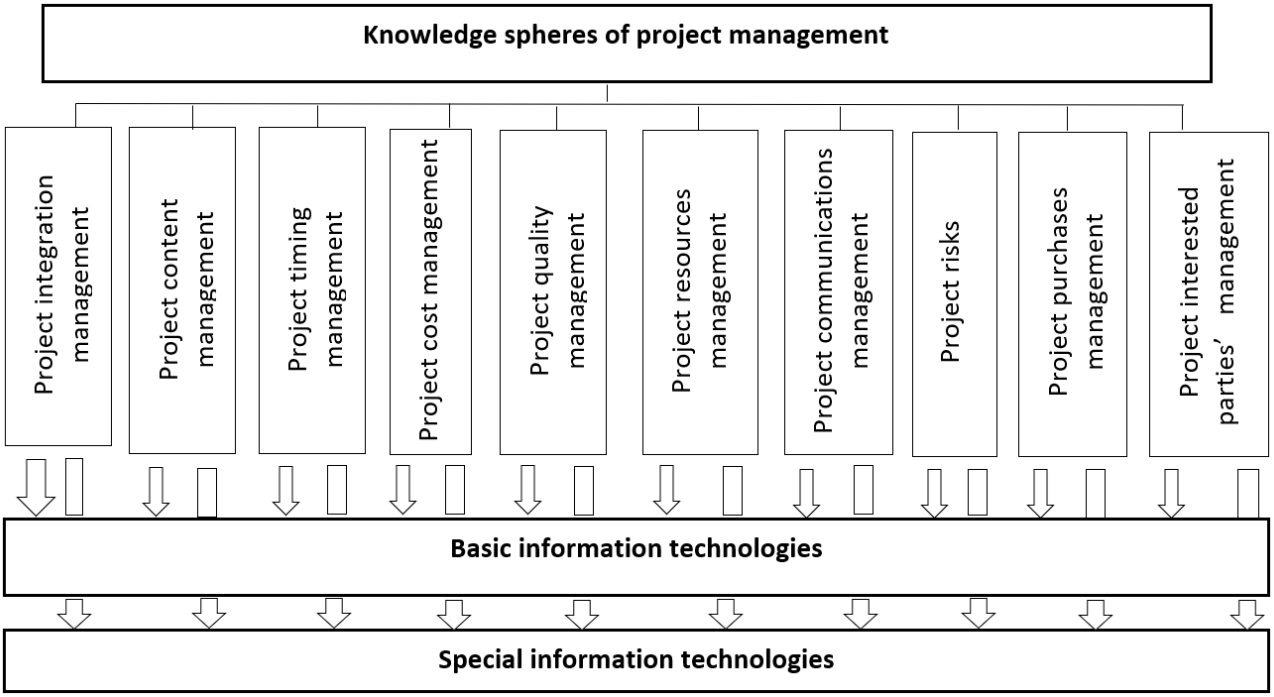


Figure 3: Interconnection of the knowledge spheres of project management with the respective information technologies.

3. Conclusions

Such factors as development of the information systems and technologies, enterprises activity in the Industry 4.0 conditions and total digitalization determine the relevance of the systems and technologies research in the economic activities and projects management. The main aim of the informational technologies use is the effectiveness of the enterprises economic activity and good project results. An important aspect of the information systems and technologies use is the choice of them through the increase of the both basic and special software products in the economic activities and projects management sphere. For the project management effectiveness, it is advisable to clearly define the need to use a certain type of software package or a set of software products aimed at solving certain tasks.

4. References

[1] Zanora, V.O., Voitko, S.V. Enterprise management: technological costs planning, risk management, motivation, management decisions making. Kyiv, 2017.

[2] Danchenko, O.B., Zanora, V.O. Project Management: Risk and Change Management in Decision Making Processes. Cherkasy, 2019.

[3] Zanora, V.O., Lepskyy V.V. Integrated management of project-oriented organizations: methodological basis. European Journal of Economics and Management Sciences. №2, (2017): 24–26. doi: 10.20534/EJEMS-17-2-24-26.

[4] Zanora, V. Project management of enterprise innovative potential and development. Economics. Management. Innovations. Vol.2, (2019). URL: http://nbuv.gov.ua/UJRN/eui_2019_2_6. doi: 10.35433/ISSN2410-3748-2019-2(25)-4.

[5] A Guide to the Project Management Body of Knowledge (PMBOK® Guide). Six Edition. USA : PMI, 2017.
[6] A Guidebook of Program & Project Management for Enterprise Innovation Japan : Project Management Association of Japan (PMAJ), 2017.
[7] IPMA I. C. B. IPMA Competence Baseline Version 3.The Netherlands: Nijkerk, 2006.
[8] ISO 21500 : 2012 Guidance on project management. 36 p. URL : https://www.iso.org/standard/50003.html (accessed: 07/02/2020).
[9] PRINCE2. 6th Edition. URL: www.prince2.com.
[10] Wilhams, T. L. An integrated approach to risk management. Risk management. №6, (1996): 22–27.
[11] Stulz, M. R. Risk Management Failures: What Are They and When Do They Happen? Journal of Applied Corporate Finance. Vol. 20, №4, (2008): 39–49.
[12] Langdalen, H., Abrahamsen, E. B., Selvik, J. T. On the importance of systems thinking when using the ALARP principle for risk management. Reliability Engineering & System Safety. Vol. 204, (2020). doi: 10.1016/j.ress.2020.107222.
[13] Bakulich, O. O., Kis, I. R., Zanora, V. O. Trends in environmental risk management of transport projects. Proceedings of Scientific Works of Cherkasy State Technological University. Series Economic Sciences. №56, (2020): 62–69. doi: 10.24025/2306-4420.0.56.2020.201674.
[14] Josef Basl. (2018). Analysis of Industry 4.0. Readiness Indexes and Maturity Models and Proposal of the Dimension for Enterprise Information Systems. 12th International Conference on Research and Practical Issues of Enterprise Information Systems (CONFENIS), Poznan, 57–68, doi: 10.1007/978-3-319-99040-8_5.
[15] Industry 4.0: Building the digital enterprise, Global Industry 4.0 survey, Price Waterhouse Coopers, 2016.
[16] Muller, J. M., Kiel, D., Voigt, K. What Drive the Implementation of Industry 4.0? The Role of Opportunity and Challenges in the Context of Sustainability. Journal of Sustainability. №10, (2018). doi: 10.3390/su10010247.
[17] Stojkovic, Z., Veza, I., Bosnjak, I. (2016). A Concept of Information System Implementation (CRM and ERP) within Industry 4.0. Proceedings of the 26th DAAAM International Symposium on Intelligent Manufacturing and Automation, Vienna, 0912–0919. doi: 10.2507/26th.daaam.proceedings.
[18] Rokia Bouzidi, Fahima Nader, Rachid Chalal. (2017). Towards a classification of information technologies. In proceedings of the International Conference on Computing for Engineering and Sciences (ICCES '17). NY, 24–28. doi: 10.1145/3129186.3129191.
[19] Kochkodan, V. B. Research of influence of modern information technologies on the work efficiency increase of O&G enterprises. Scientific Bulletin of Ivano-Frankivsk National Technical University of Oil and Gas (Series: Economics and Management in the Oil and Gas Industry), №1(19), (2019): 31–39. doi: 10.31471/2409-0948-2019-1(19)-31-39.
[20] Jon Turner and Kenneth Laudon. (1988). Information technology and management strategy. Information Systems Area. New York, URL: https://www.researchgate.net/publication/228141782_Information_Technology_and_Management_Strategy. (accessed: 05/04/2020).
[21] Lucas, H. C. and Turner, J. A. A corporate strategy for the control of information processing. Sloan Management Review, №24(3), (1982): 25–36.
[22] Fushtikj, V., Rashkovska, M. and Petrova, N. (2017). The impact of information technology to the project management effectiveness in the companies in Republic of Macedonia. 17th International Conference on Smart Technologies (IEEE EUROCON 2017), 110–113. doi: 10.1109/EUROCON.2017.8011087.
[23] Zanora, V., Zachosova, N., Danylyuk, S. Management of sociocultural projects in the educational environment: informational technologies and grounds for their selection. Project management and development of production, №2(70), (2019): 41–49.
[24] Castro, J., Kolp, M., Mylopoulos, J. Towards requirements-driven information systems engineering: the Tropos project. Information systems. №27, (2002): 365–389. URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.399.455&rep=rep1&type=pdf.
[25] Laudon, K.C., Laudon, J.P. Management information systems: managing the digital firm. New Jersey,
[26] 2012. URL: https://repository.dinus.ac.id/docs/ajar/Kenneth_C._Laudon,Jane_P_._Laudon_--_Management_Information_System_12th_Edition_.pdf.
[27] Pawlak, Z. Information systems theoretical foundations. Information systems, Vol. 6, is. 3, (1981): 205–218. doi: 10.1016/0306-4379(81)90023-5.

[28] David Romero, François Vernadat. Enterprise information systems state of the art: Past, present and future trends. Computers in Industry. Vol. 79, (2016): 3–13. doi: 10.1016/j.compind.2016.03.001.
[29] Ɓlvaro Rocha, Hojjat Adeli, Luнs Paulo Reis, Sandra Costanzo, Irena Orovic, Fernando Moreira. Trends and Innovations in Information Systems and Technologies: Volume 2. Springer International Publishing, 2020.
[30] Khristova, A., Bashynska, I. The use of modern information technology project management. Economic journal Odesa polytechnic university. №1(1), (2017): 88–92.
[31] 30 free tools for a product manager. URL: https://skillsetter.io/blog/product-tools.
[32] Teslia, Yu.M., Biloshchytskyi, A.O., Teslia, N.Iu. Information technology of management projects on a base erpp (enterprise resources planning in project) and ape (administrated projects of the enterprise) systems. Management of Development of Complex Systems. №1, (2010): 16–20

Identification and Analysis of Information Risks in Digitalization Projects

Vitalii Kharuta[1], Valentin Tkachenko[2], Inga Semko[2] and Alexander Semko[2]

[1] *National Transport University, Kyiv, Ukraine*
[2] *Cherkasy State Technological University, Cherkasy, Ukraine*

Abstract

In this work, the authors identified the information risks of digitalization projects, their qualitative and quantitative analysis by the method of expert assessment, which allows to identify the objects of risk that are most prone to the occurrence of risky events and to identify the highest risks that turn a probable potential threat into a number of dangerous. The methods used in the identification process are marked, and the main factors that cause the emergence of risk situations are identified.

Keywords

Information risks, identification, quantitative and qualitative analysis, digitalization projects

1. Introduction

The information space requires special attention, study and constant monitoring, as the intensive introduction of modern industry technologies using artificial intelligence (AI), introduction of cyberphysical systems and neurotechnologies, dissemination of automatic identification services, collection and processing of global databases (big data), cloud services (cloud computing), smart devices and industrial facilities (smart everything), development of social networks, various platforms, services of the digital Internet environment "sharpens" the issue of information security [1, 2, 3].

Most corporate information systems were once designed without the necessary level of information security, which makes them vulnerable to information risks.

Thus, the identification and analysis of information risks is the main task of risk management for the successful implementation of projects, including digitalization projects, and strategic management of the enterprise [4, 5].

2. Main part

Understanding today's realities in implementation of digitalization projects, it is obvious that it is almost impossible to manage all possible information risks, because of its large financial and human costs. To date, most information risks have been identified and described, but digitalization "creates" new, as yet unknown risks. Therefore, the issue of risk identification is quite relevant and one of the prerequisites for a successful response to risks is to determine their priority in the project.

At the stage of risk identification, the areas of business processes of the enterprise most prone to information risks are identified, there is also a determination of risk factors and adverse internal and external environments

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: kharuta_vitaliy@ukr.net (V.Kharuta); tkachvf@gmail.com (V.Tkachenko); semkoinga77@gmail.com (I.Semko); alexsemko7@gmail.com (A.Semko)
ORCID: 0000-0002-8897-7558 (V.Kharuta); 0000-0001-6290-2286 (V.Tkachenko); 0000-0002-6251-5830 (I.Semko); 0000-0002-4309-3556 (A.Semko)


in accordance with the object of risk of the enterprise, that is, e.i. a process of identifying, recognizing and registering risks (the main components of risk identification).

Identification of information risks at each stage of the digitalization project allows to analyze the risks at the initial stages of technical and economic justification of the project.

Risk identification is an extremely important step in risk management: risk that has not been identified cannot be further analyzed; risk that has been identified rather superficially can lead to errors in risk assessment.

The process of identifying information risks involves the analysis of a number of elements on which the identification will be considered full-fledged: causes and sources of risks, the probability of occurrence of risky events, the severity of probable risks, the consequences of risky events.

It is appropriate to remember about the classification of risks, which is an integral part of risk management. Having determined to which group of risks the investigated risks belong, it is possible to speak already about partial identification with the following description of the reasons of risk event occurrence.

In [1] the classification of information risk groups according to separate criteria was carried out. This paper will identify and analyze certain risks, which according to the authors are the most common among the information risks of digitalization projects.

Causal links between the main components of risk identification are considered in two ways:

- risk identification through analysis of the causes of risk events with subsequent determination of their consequences (what can happen and what it will lead to);
- due to the consequences that have already occurred or may occur in the future with the determination of the cause of these events (what consequences should be avoided and what to strive for, what events these consequences can cause) Fig. 1 [6, 7].

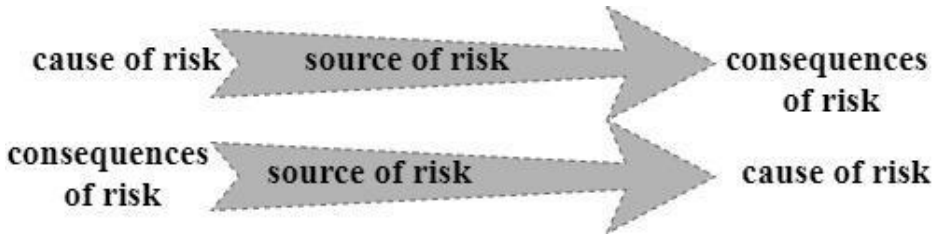


Figure 1: Causal links between the main components of risk identification

The following tools are used to identify information risks:

- methods of questionnaires and surveys;
- expert assessments;
- benchmarking;
- analysis of statistical data;
- analysis of the nature, consequences and criticality of failures;
- operational safety analysis and critical control points;
- method of brainstorming;
- risk ranking and filtering;
- system analysis;
- error tree analysis;
- scenario analysis;
- system design methods, etc. [9, 10, 11].

The following is a description of some methods. Expert risk assessment has its positive (relative simplicity for forecasting) and negative (subjectivity of experts' opinions and limited judgments) moments.

Statistical methodology can be used for risk analysis, but it also has its advantages (there is a significant amount of analytical and statistical information on the necessary elements of the analyzed system for a certain period of time) and disadvantages (information about this risk may not be available in the database) [11, 12, 13].

Brainstorming is quite fast and facilitates the interaction of team members, but it is possible to deviate from the real risks, or the dominance of the opinion of one team member [14].

Analysis method of nature, consequences and criticality of failures is widely used for failure modes associated with hardware and software tools and procedures, but can only be used to identify individual failure modes, not their combinations [15].

The logical course in the identification of information risks is the use of several methods that take into account not only the features and specification of risks, but also the uniqueness of digitalization projects themselves. The result of information risk identification is a risk register.

Table 1 presents a description of the most common information risks specific to digitalization projects [1, 16].

Thus, the risks are described and identified. The next stage, which precedes the stage of tools development to reduce information risks, risk analysis.

Table 3

Identification of information risks in digitalization projects

№	Name of information risk	Description of information risk
1	Making changes	Repeated changes to the project documentation, while this factor is absent in consulting projects
2	Problems with artificial intelligence	New AI technologies are used incorrectly or provoke unexpected system failures
3	Failure (non-working condition) of technical tools	Network congestion due to accidents or natural disasters
4	Errors in models, information processing algorithms, programs	Inefficiency of the system in managing changes and configurations
5	Unavailability of the service	Lack of support from an IT provider
6	Loss of software, information databases	Unauthorized access, Inability of IT audit to detect security issues
7	Copyright infringement	
8	Infringement of confidentiality	
9	Incomplete information	Automation of erroneous decisions due to poor data
10	Inaccuracy of information	
11	Destruction of information	Unauthorized access Loss of IT resources User computer literacy
12	Dissemination of fake information	Infringement of the rules of professional ethics
13	Innovations	The decision to innovate in IT solutions is made before the basic requirements are formulated

Analysis of information risks of digitalization projects is nothing but a process of comprehensive assessment of project security by quantitative and qualitative indicators.

Qualitative risk analysis aims to identify areas and types of risks, as well as to identify factors that affect the level of justification of various possible countermeasures.

Quantitative analysis makes it possible to quantify the size of information risks and the project as a whole [17, 18, 19].

The method of expert assessment was used to analyze information risks, taking into account the results of risk identification, which allows to determine the objects of risk that are most prone to the occurrence of risk events (Table 2).

Table 2

Quantitative analysis of information risks in digitalization projects

№	Name of information risk	Probability of occurrence (0 ÷ 1)	Impact on project implementation (0 ÷ 1)
1	Making changes	0.4	0.5
2	Problems with artificial intelligence	0.4	0.7
3	Failure (non-working condition) of technical tools	0.4	0.8
4	Errors in models, information processing algorithms, programs	0.5	0.9
5	Unavailability of the service	0.4	0.6
6	Loss of software, information databases	0.7	0.9
7	Copyright infringement	0.4	0.5
8	Infringement of confidentiality	0.8	0.9
9	Incomplete information	0.5	0.9
10	Inaccuracy of information	0.5	0.9
11	Destruction of information	0.8	0.8
12	Dissemination of fake information	0.5	0.5
13	Innovations	0.4	0.7

The weight of each information risk is determined using the probability matrix (Table 3).

Table 3

Matrix of probability and impact of information risks in digitalization projects

Average probability of occurrence (0 ÷ 1)	Average impact on project implementation (0 ÷ 1)				
	0.1	0.3	0.5	0.7	0.9
0.8 – 1.0					3
0.6 – 0.8					4, 6, 11
0.4 – 0.6			12	13	9, 10
0.2 – 0.4			1, 7	2, 5	8
0.0 – 0.2					

high risk area
moderate risk zone
low risk area

In accordance to Table 3, it is possible to formulate conclusions about the types of information risks:

- high risks – 3, 4, 6, 8, 9, 10, 11, 13;
- moderate risks – 1, 2, 5, 7, 12.

Thus, high information risks are risks that are related to the vulnerability of information. The group of moderate risks includes the risks of more mechanical (engineering) mistakes, errors. Among the studied information risks, none were considered low. This indicates the importance and necessity of information security in digitalization projects, the end product of which is information.

The reliability of the analysis depends on the completeness and quality of information on the risks to be studied in detail. The IT market offers the use of special software products in the tasks of threat modeling and risk assessment, such as OWASP Threat Dragon; CAIRIS; Mozilla Seaspon, Microsoft Threat Modeling Tool; RiskWatch; vsRis and others. These programs simplify information risk analysis processes, saving time and reducing costs.

Qualitative evaluation results are used to form a relationship between the probability and consequences of an event for key risks [1], i.e. set the highest risks, which turn a probable potential threat into a number of dangerous ones and therefore at the next stage will require additional protective measures and tools to reduce information risks in digitalization projects.

3. Conclusions

Thus, in the process of risk identification it is necessary to identify probable areas of information risks for the project and assess the degree of impact of these risks on the project. It should be noted that the issue of assessment and management of a significant part of information risks is well researched and described in the literature, and the rapid development of information security tools allowed to reduce the number of technical security. But the number of risky events caused by the information component still remains large. The information factor remains a "weak link", so along with the technical protection, organizational aspect, staffing, risk management should be given priority: systematic identification and assessment of risks - will guarantee results' achievement.

4. References

[1] Lanskih E.V., Danchenko O.B., Semko O.V. Information in digital format. *Bulletin of Cherkasy State Technological University*. Cherkasy: ChDTU, 2020. Vol. 3. P. 58-66.

[2] Danchenko E.B., Elbaruni J.E. The problems of projects for the implementation of management of management information system. *Project, Program, Portfolio Management. P3M*: Abstracts of the 4th International Scientific and Practical Conferences [at 2v.]. Vol. 1. Odesa: Balan V.O., 2019. P. 29-31.

[3] Kravchenko O.V., Danchenko E.B., Marunych V.S., Bedrii D.I. Estimation of the Effect of External Information on Participants of Web-Communities by IT-Tools under Conditions of Behavioral Economy. *PROBLEMELE ENERGETICII REGIONALE*. 2019, no. 1-1 (40). pp. 45-59; DOI: 10.5281/zenodo.3239144.

[4] Danchenko E.B. Maklev I.A. Project risk management with introduction of project office in organization. *International Workshop "Prediction and decision making under uncertainties (PDMU-2004)*. Abstracts. Ternopil, Ukraine, 2004, pp. 12-14.

[5] Seek Ali M.A., Teslenko P., Bedrii D., Kyiko S. Risk management of the construction project based on a value-oriented approach. *The scientific heritage.* Budapest, 2020. Vol. 1, no. 52 (52). P. 35-39.

[6] Fedulova I.V. Identification of risks for warehouse management. *Science journal Intellect XXI*, 2016. no. 4. P. 29-45.

[7] Danchenko E.B Shendryk V.V., Hrabina K.V. Opportunity Management overview in terms of the Risk Management in the software development industry standards. Project Management: Stan and Perspectives: Materials XV NPK. Mikolaiv, NUK, 2019. 108p.

[8] Krygina E.G., Kleimenova N.L., Yakovleva A.Yu. Identification of key risks in the company's activities. Innovative economy: prospects for development and improvement, 2017. No. 8 (26). p. 44-49.

[9] Fedulova I.V. Identification of state donations. *Visnik KNTEU*, 2017. No. 4. P. 89-103.

[10] ISO / IEC 31010: 2009 Risk management - Risk assessment techniques (IDT), 2009.

[11] Bedrii D.I. Stagnation of the statistical method for assessing the risks of science projects. Project management in the development of the suspension: X international conference, 17-18 May 2013 p. Kyiv: KNUBA, 2013. P. 17-18.

[12] Bedrii D. Integrated anti-risk management of conflicts of a scientific project in a behavioral economics. Scientific Journal of Astana IT University. Astana, September 2020. Vol. 3. P. 4-14. DOI: 10.37943/AITU.2020.15.62.001.

[13] Bedrii D. Development of a model of integrated risk and conflict management of scientific project stakeholders under conditions of behavioral economy. Technology audit and production reserves. Kharkiv, 2020. Vol. 3, no. 2 (53). P. 9-14. DOI: 10.15587/2706-5448.2020.207086.

[14] Yushchenko N.L. The development of methods for identifying risks in complex projects for the modernization of thermal jerels and thermal fences. The state of the region. Series: Economics and education, 2020. No. 6 (117). P. 36-42.

[15] Khabibulin M. Risk management. Management. No. 1 (33), 2015. 18p.

[16] Denchik O.R., Bedrii D.I., Savchenko S.O. Analysis of risky projects in the agro-industrial complex. *Bulletin of Cherkasy State Technological University*. Cherkasy: ChDTU, 2017. No. 1.P. 100-109.
[17] Danchenko E.B., Elbaruni J.E. A SYSTEMATIC APPROACH TO RISK MANAGEMENT OF PROJECTS. Project management in the development of the suspension. Topic: "Project management in the minds of the transition to behavioral economics": theses of additional ideas. Kyiv: KNUBA, 2020. P. 52-55.
[18] Dictionnaire-guide for project management / Bushuєv S.D. Ukrainian Association for Project Management. Kyiv: Vidavnichy dim "Business Ukraine", 2001. 640p.
[19] Arkhipov O., Skiba A. Information technologies: methods and methods of preliminaries, models of measures and methods of identification. Zakhist information, vol. 15, no. 4, p. 366-375, zhovten-breast, 2013.

A Mathematical Model of Risk Management in IT-audit Projects

Mateusz Dasal[1], Oksana Savina[2], Viktor Melenchuk[3] and Victor Alba[4]

[1] *Czenstochowa Institute of Humanistics and Social Science, Department of Humanistics and Social Sciences in Pharmacy Medical University, Wrocław, Poland*
[2] *National University of Shipbuilding, Mykolaiv, Ukraine*
[3] *Military Academy, Odesa, Ukraine*
[4] *«KROK» University, Kyiv, Ukraine*

Abstract

Ensuring the quality of enterprise management without reliable information systems and effective IT control measures is impossible. An urgent task today is skillful and effective risk management of IT audit projects. Theses of stages of anti-risk management of IT audit projects are defined in the abstracts and the mathematical model of anti-risk management of IT audit projects is developed.

Keywords

IT audit projects; IT audit project management; project risks; risk management of IT-audit projects

1. Introduction

In a relatively short period of time, the field of information technology (IT) from the ordinary, has become one of the main drivers of the world economy. The number of IT specialists in the country is growing rapidly: from 89 thousand professionals in 2015 to 190 thousand in 2019 [1]. The main share of the global IT market is in the United States (36.8%), followed by China (11.3%) and the United Kingdom (5.8%). According to the Top Lead directory, Ukraine is competing with Romania and Poland in terms of market size, significantly behind India and China.

Ukraine is attractive for the development of IT business among countries with developed economies. First, the labor markets in Poland and Romania are already significantly "overheated". Secondly, taxation is very profitable in Ukraine. Third, competence and cultural proximity place Ukrainian developers far above Indian ones. Today, Ukrainians can create, promote and sell IT products in global markets. They are interested not only in creating a product, but also in its active development. The Ukrainian IT industry is now successfully competing in the global market and is a reliable source of foreign exchange earnings. For productive and efficient operation of IT enterprises requires constant monitoring and control of the real state of the IT infrastructure. Therefore, an IT audit is introduced to assess the state of the information and / or financial system of the enterprise. Conducting an IT audit is a starting point and allows to objectively assess the current relevance of the IT infrastructure, compliance with business requirements, the use of resources, both financial and human, as well as to draw conclusions about changes or upgrades to this system [2].

V. Rudnytsky, O. Pugachenko, S. Kanygin, R. Us, S. Golov, B. Usach, V. Zhuk, Yu. Prozorov, V. Galkin, M. Bilukha, I. Platonova, A. Kuzminsky, N. Dorosh and others are engaged in research of audit development. I. Platonova [3], N. Kuzhelny, E. Petryk [4], F. Butynets [5], G. Davydov dedicate their research to the issues of development, organization of audit and point to a certain completion of the formation of the national audit system. O. Redko analyzes the performance of the audit services market, N.I. Dorosh researches the organization of audit activity and pays attention to quality control of the audit services market, I. Pilipenko believes that it is

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: mateusz.dasal@umed.wroc.pl (M.Dasal); oksanasavina14@gmail.com (O.Savina); viktor.melenchuk1976@i.ua (V.Melenchuk); wannaup@gmail.com (V.Alba)
ORCID: 0000-0003-4804-3766 (M.Dasal); 0000-0001-5717-4923 (O.Savina); 0000-0003-1236-6731 (V.Melenchuk); 0000-0003-0633-1188 (V.Alba)

necessary to improve the regulatory framework governing audit activities. The author [3] distinguishes the audit by the nature of the audit: confirmatory, system-oriented and risk-based audit, or risk-oriented, and in the source [6] there are: investment, external, internal and special types of audit (environmental, energy audit, project audit and information security audit).

Some theoretical and applied aspects of problem solving in the activities of project-oriented IT enterprises are presented in the works of A.A. Biloshchytsky., S.D. Bushuyev, N.S. Bushuyeva, R.A. Druzhinin, I.V. Kononenko, O.M. Medvedeva, D.A. Novikov, V.A. Rach, Archibald, I.A. Babayev, V.Yu. Bykov, E.H. Reshke, H. Tanak, Yu.M. Tesla, S.V. Tsyutsyura, H. Schelle, S.K. Chernov, O.S.Voitenko, N.Yu. Yegorchenkova, Z.P. Stashevsky, Yu.O. Borzov and others.

The author [7] notes that the information support of internal audit at an industrial enterprise is the main condition for effective prevention and timely detection and elimination of errors, whereas it provides verification, modeling and analysis of data to establish its completeness, quality, legality and reliability, and increasing the efficiency of financial and economic activities at the enterprise during the internal audit is possible precisely due to the effective information support for the provision of relevant information and control functions in the relevant accounting system. Assessment of economic security of investment projects for enterprise informatization was carried out by the authors [8], the role of audit in detecting fraudulent actions with financial statements - noted in [9].

Problems of staff motivation in the IT sphere, basic and modern theories of motivation are presented by the authors [10]. Projects in the field of IT through the prism of soft projects are considered by Medvedeva O.M. in [11], features of personnel management in the IT field in [12], where the basic requirements for knowledge and skills of HR-manager and IT-recruiter are given, the sources of search for qualified specialists for IT companies are considered, the functionality of HRM-systems is characterized. The method of evaluating the team of IT-project executors in which it is proposed to consider the task of appointing employees to work on a new IT-project as a kind of clustering task, proposed in [13]. Integrated application of emotional intelligence and KANBAN method in IT project management is described in the source [14].

The impact of internal audit principles on the control environment: economic and social consequences have been studied by the author [15] and proved that the whole set of methods and techniques, used in the internal audit process provide unity and logic methodological principles, and compliance with organizational principles allows to choose the best options for streamlining the structure and operation of the internal audit department.

Models and mechanisms of planning the content of educational projects of higher educational institutions of the State Service of Ukraine for Emergencies and monitoring of the formation process of personnel competence for IT-projects of the State Service of Ukraine for Emergencies on Information Security based on the competency approach according to customer requirements proposed in the source [16], and the mathematical model of the educational project of the State Service of Ukraine for Emergencies of specialist' training in the field of information security is considered in [17].

IT audit is a key component to ensure the quality of enterprise management, without reliable information systems and effective IT control measures, it is not able to properly perform operations / transactions and summarize reliable financial statements, which, in turn, affects the level of achievement of its objectives and goals.

Based on the sources [18-19], the IT audit project (ITAP) is a set of interrelated measures to verify the accounting data of the financial statements of the IT company and conducting IT infrastructure assessments aimed at creating a unique product: independent opinion of the auditor, his findings, evidence, conclusions and recommendations on all essential aspects and in accordance with applicable laws, regulations (standards) or other rules, and in accordance with the requirements of users in terms of time and resource limitations.

Such a comprehensive inspection allows to determine the capabilities and shortcomings of the existing information infrastructure at the enterprise, its compliance with the requirements and expectations of management, makes it possible to assess the likely development of business and communication processes in the enterprise [20]. Modernization or modification of existing systems or functioning solutions can be carried out only if there is a full body of data on the current state of the company's IT management.

Tasks, principles, stages and features of ITAP, as well as the characteristics of its product are pre-defined by the authors in the sources [18, 21].

According to sources [18, 22-23], ITAP management is a process of management and coordination of human, material and financial resources during the project life cycle by applying modern management methods and techniques to achieve the results defined in the project in terms of composition and scope of work; cost, time, quality and satisfaction of project stakeholders. ITAP management is based on a systems approach. It is

implemented by the project team. And at the same time methods of project analysis are used as a component in the project management process.

Risk management is currently used as the main method of combating deviations and uncertainties in the project. A large number of works and developments are devoted to this issue. Among them are works of Ukrainian scientists (S.D. Bushuyev, N.S. Bushuyeva, Yu.M. Tesla, S.K. Chernov, K.V. Koshkin, E.A. Druzhinin, O.B. Danchenko, Yu.M. Kharitonov, I.B. Semko, D.I. Bedriy, K.P. Kolotyrina, O.Yu. Savina) and foreign scientists (Drucker Peter F., J.M. Keynes, G. Simon, Tovba A.S., Tsipes G.L., Shapiro V.D. etc.)

Risk-oriented IT audit, according to [24] - is an activity carried out in the interests of management, which collects audit evidence and assesses the degree of their compliance with the agreed audit criteria in order to form an independent expert assessment of the actual level of IT risks and develop recommendations aimed at minimizing them.

According to the analysis of recent publications and research, the degree of study of the problem by domestic and foreign scientists can not be considered sufficient, and the problem of forming a holistic ITAP management methodology, taking into account its specifics, requires further research.

2. Main part

ITAPs have specific risks that synthesize components of organizational risks, IT risks, and risks posed by stakeholders. Based on the source [18], it can be argued that a significant part of the deviations and uncertainties that lead to an increase in time and cost are directly related to project stakeholders. Each of the stakeholders has the opportunity to influence the project in the best way, or hinder its implementation. However, sometimes even with positive guidelines and goals, they can create wrong or unnecessary actions at the moment and thus cause threats. But, sometimes the opposite happens, when high-risk projects lead to increased opportunities and chances of high efficiency and success of the project. Opposites of opportunity-threat complement each other: opportunities create threats, and threats create opportunities, and, only in a balanced harmonious ratio can achieve the correct and effective result [18] precisely through risk management.

The essence of the model is that ITAP risk management is comprehensive by minimizing the risks of IT audit by applying risk management to key project stakeholders by project management office managers and top managers, which ultimately allows to increase the efficiency of the company by reducing the cost of projects, time for their implementation, and improving the quality of such projects, and leads to ensuring the fulfillment of company's strategic goals.

Each stakeholder group has its influence on the project implementation, and the impact can be positive (chance), negative (threatening) or neutral [25]. The positive impact of stakeholders on the project is useful as it helps to implement the project. However, it can also have negative consequences. Negative impact, in general, is not useful during project implementation. However, sometimes the opposite can happen. Neutral influence, in the general case, does not affect the implementation of the project in any way, however, sometimes it can be changed by external factors, and then from neutral to become either positive or negative. It is important for the project manager and the project team not to miss the growth of neutral influence into negative, or to make efforts to change the neutral position to a positive one. Due to their opposite possibilities and threats, being antipolar, they oppose each other and limit each other. When one side is in excess, the other is deficient. When one side is weakened, the other is strengthened. To ensure the effective management of project stakeholders, it is necessary to balance their risks: increase the opportunities for positive influence of stakeholders and reduce the chances of threats, maintaining a stable state of the system, within three categories that correspond to the "magic" triangle of project management goals: time, cost, quality, that is possible by combining the techniques of opportunity management (chance management) and threats (risk management) [25].

ITAP risk management is based on the management of stakeholders in wind energy projects, which is described in the source [26], and supplemented by taking into account the positive and negative consequences of organizational risks and IT risks inherent in these projects. As a result, it allows in-depth study of ITAP, identification of high risks, to further reduce them and make reasonable management decisions, which contributes to the achievement of ITAP goals.

The stages of ITAP risk management are presented in Fig. 1.

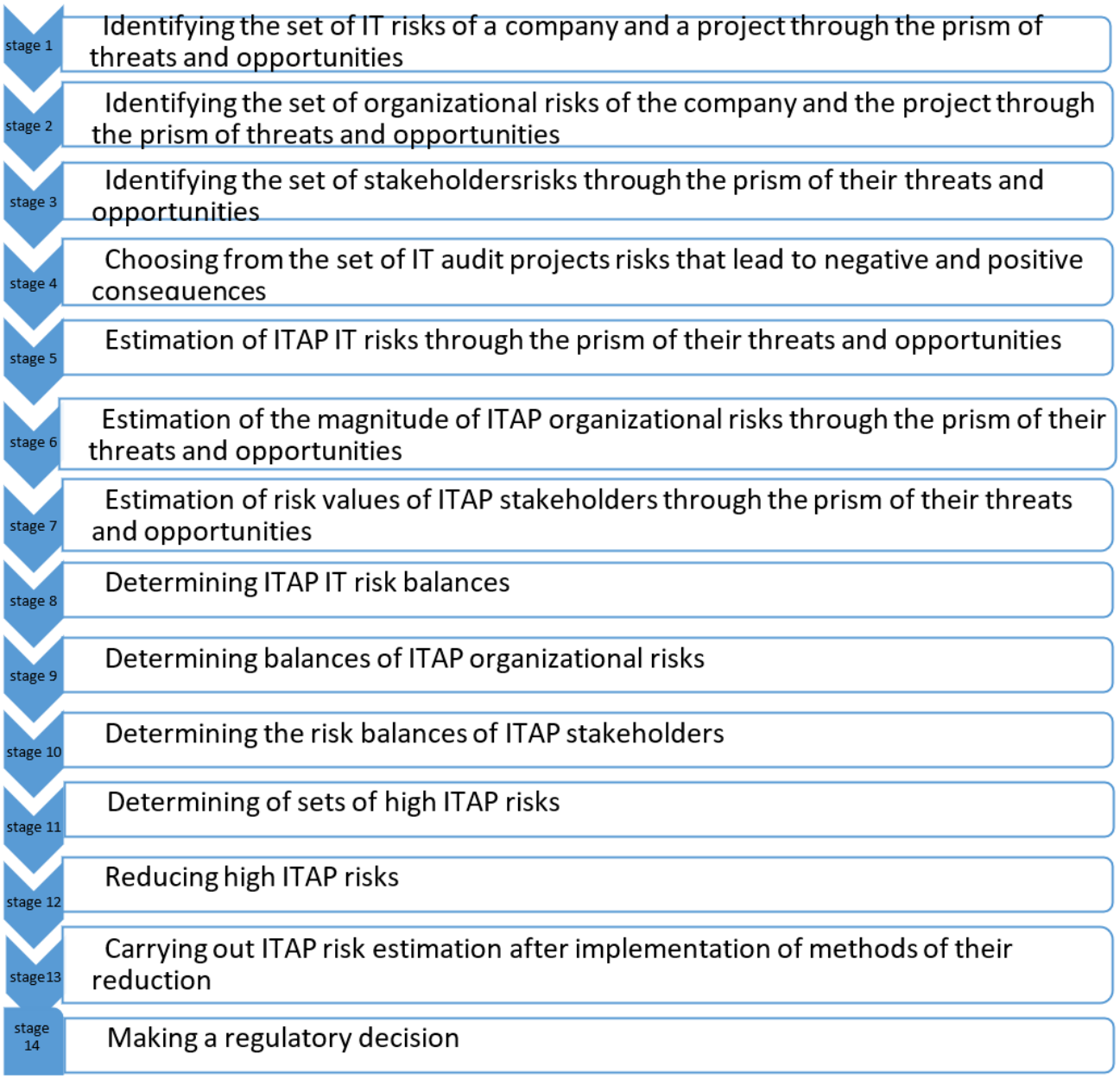


Figure 1: ITAP risk management process

Based on the features of ITAP, the specifics of their management, based on proposed conceptual model and risk management ITAP and based on the mathematical model of risk management of stakeholders of wind energy projects, described in [26], we will develop a mathematical model of ITAP risk management.

We use the mathematical apparatus, in particular: methods of set theory, systems analysis, risk balances, etc., to describe possible states of the ITAP risk interaction system.

First, the company's IT risks, organizational risks and project stakeholders are identified through the prism of threats and opportunities, and three sets are obtained:

The set of IT risks of the company $\{ITR\}$:

$$ITR=\{ITR_1;\dots\ ITR_w;\dots.;\ ITR_x\}$$

$$where\ \ x-quantity\ of\ IT\ risks\ of\ the\ company, w-IT\ risk\ number, (x=\underline{1;w}).$$

Set of organizational risks of the company $\{OR\}$:

$$OR=\{OR_1;\dots\ OR_y;\dots.;\ OR_z\}$$

$where\ \ z - quantity\ of\ organizational\ risks, y - organizational\ risk\ number, (y = \underline{1; z})$.

Set of stakeholders of the company $\{RS\}$:

$$RS=\{RS_1; \dots\ RS_r; \dots.; RS_c\}$$

$$where\ \ c - quantity\ of\ company\ stakeholders, r - stakeholder\ number, (r = \underline{1; c}).$$

Of the three sets of risks (IT risks of the company $\{ITR\}$, organizational risks $\{OR\}$ and projects stakeholders $\{RS\}$) we choose the risks inherent in ITAP and we receive set of ITAP risks $\{R_{ITAP}\}$:

$$R_{ITAP}=\{R^{IT}\} \cap \{R^{O}\} \cap \{S\}$$

where R^{IT} – set of IT risks, R^{O} – set of organizational risks, S – set of ITAP stakeholders.

We will estimate the magnitude of these risks.

Set of ITAP IT risks $\{R^{IT}\}$:

$$R^{IT} = \{R_1^{IT}; \dots; R_a^{IT}; \dots; R_b^{IT}\},$$

$$where\ \ b - the\ quantity\ of\ ITAP\ IT\ risks, a - IT\ risk\ number, (a = \underline{1; b}).$$

Set of organizational risks $\{R^{O}\}$:

$$R^{O} = \{R_1^{O}; \dots; R_e^{O}; \dots; R_f^{O}\},$$

$$where\ \ f - quantity\ of\ organizational\ risks, e - organizational\ risk\ number, (e = \underline{1; f}).$$

Set of ITAP stakeholders, S $(Stakholders)$:

$S = \{S_1; \dots; S_k; \dots; S_l\}$,

$$where\ \ l - the\ quantity\ ITAP\ stakeholders, k - stakeholder\ number, (k = \underline{1; l}).$$

Based on the conceptual model of risk balance (opportunities and threats) of stakeholders of wind energy projects [25], to ensure effective risk management it is necessary to balance them: increase the opportunities for positive impact and reduce the chances of threats. Therefore, it is first necessary to identify opportunities and threats for certain sets of ITAP risks.

The set of ITAP IT risk opportunities is denoted as C^{IT} (Chance):

$$C^{IT} = \{C_{a1}^{IT}; \dots; C_{ag}^{IT}; \dots; C_{ah}^{IT}\},$$

$where\ C_{ag}^{IT}$ – possibility of a-th IT risk; h – $quantity$ of opportunities for IT risks, $g - the\ number\ of\ the\ possibility\ of\ the\ a - th\ IT\ risk, \ (g = \underline{1; h})$.

The possibility of the a-th IT risk C_{ag}^{IT} can be written by the formula:

$$C_{ag}^{IT} = \sum_{g=1}^{h} P_{ag} \cdot V_{ag}, \qquad (1)$$

where P_{ag} – the probability of a-th opportunity of IT risk; V_{ag} – gain from the a-th opportunity, UAH, h – $quantity$ of IT risk opportunities.

The set of ITAP IT risk threats is denoted as D^{IT} (Danger):

$$D^{IT} = \{D_{a1}^{IT}; \dots; D_{ap}^{IT}; \dots; D_{aq}^{IT}\},$$

$where\ D_{ap}^{IT}$ – threat of a-th IT risk, q – $quantity$ of threats, p – a number of a-th IT risk threat, $\left(p = \underline{1; q}\right)$.

Threats of the a-th ITAP IT risk D_{ap}^{IT} are defined by the formula:

$$D_{ap}^{IT} = \sum_{p=1}^{q} P_{ap} \cdot V_{ap,} \quad (2)$$

where P_{ap} – the probability of the *p*-th threat; V_{ap} – losses from the *p*-th threat, грн., q – $quantity$ of ITAP IT risk threats.

The set of possibilities of organizational risks is denoted as C^O:

$$C^O = \{C_{e1}^O; \dots; C_{es}^O; \dots; C_{et}^O\},$$

$where\ C_{es}^O$ – possibility of *e*-th organizational risk; t – $quantity$ of opportunities for organizational risk, $s - number\ of\ e-th\ organizational\ risk,\ (s = \underline{1; t})$.

Possibility of e-th organizational risk C_{es}^O can be written by the formula:

$$C_{es}^O = \sum_{s=1}^{t} P_{es} \cdot V_{es}, \quad (3)$$

where P_{es} – the probability of the s-th opportunity of e-th organizational risk; V_{es} – gain from the *s*-th opportunity, UAH, t – $quantity$ of opportunities for organizational risk.

The set of threats of ITAP organizational risk is denoted as D^O:

$$D^O = \{D_{e1}^O; \dots; D_{eu}^O; \dots; D_{ev}^O\},$$

$where\ D_{eu}^O$– threat of *e*-th organizational risk, v – $quantity$ of threats, u – threat number of the *e*-th organizational risk, $(u = \underline{1; v})$.

Threats of *e*-th organizational riskD_{eu}^O can be defined by the formula:

$$D_{eu}^O = \sum_{u=1}^{v} P_{eu} \cdot V_{eu,} \quad (4)$$

where P_{eu} – the probability of the *u*-th threat; V_{eu} – losses from the *u*-th threat, UAH, v – $quantity$ of organizational risk threats.

The set of opportunities of ITAP stakeholders is denoted as *C*:

$$\mathrm{C}_k = \{\mathrm{C}_{k1}; \dots; \mathrm{C}_{ki;\dots}; \mathrm{C}_{kn}\},$$

$where\ C_{ki}$ – opportunity of the k-th ITAP stakeholder; n – $quantity$ of opportunities for the stakeholder, $i - opportunity\ number\ of\ the\ k-th\ stakeholder,\ (i = \underline{1; n})$.

Opportunity of the k-th ITAP stakeholder C_{ki} can be written by the formula:

$$C_{ki} = \sum_{i=1}^{n} P_{ki} \cdot V_{ki}, \quad (5)$$

where P_{ki} – the probability of the *i*-th opportunity of an ITAP stakeholder; V_{ki} – gain from the *i*-th opportunity, UAH, n – $quantity$ of opportunities for the stakeholder.

The set of threats of ITAP stakeholders is denoted as *D*:

$$D_k = \{D_{k1}; \dots; D_{kj;\dots}; D_{km}\},$$

$where\ D_{kj}$ – threat of the *k*-th ITAP stakeholder, m – quantity of stakeholder threats, j – threat number of the k-th stakeholder, $(j = \underline{1; m})$.

Threats of the k-th ITAP stakeholder D_{kj} can be defined by the formula:

$$D_{kj} = \sum_{j=1}^{m} P_{kj} \cdot V_{kj,} \quad (6)$$

where P_{kj} –probability of the *j*-th threat; V_{kj} – losses from the *j*-th threat, UAH, *m* – quantity of stakeholder threats.

The set of balances of risks (opportunities and threats) is denoted as BR (Balance of risk).

Then, a set of ITAP IT risk balances:

$$BR^{IT} = \{BR_1^{IT}; \dots BR_a^{IT}; \dots; BR_b^{IT}\},$$

where BR_a^{IT} – balance of the *a*-th IT risk, *b* – quantity of IT risks, *a* – IT risk number, $(a = \underline{1; b})$.

Based on a conceptual model of risk balance (opportunities and threats) of stakeholders of wind energy projects [25] the value of the balance of the *a*-th IT risk BR_a^{IT} can be defined by the formula:

$$BR_a^{IT} = \sum_{g=1}^{h} C_{ag}^{IT} + \sum_{p=1}^{q} D_{ap}^{IT}, \quad (7)$$

Based on formula (1) and formula (2), the value of the balance of the *a*-th IT risk BR_a^{IT} will acquire such a form:

$$BR_a^{IT} = \sum_{g=1}^{h} P_{ag} \cdot V_{ag} + \sum_{p=1}^{q} P_{ap} \cdot V_{ap} \quad (8)$$

Set of balances of organizational risks of the company:

$$BR^{O} = \{BR_1^{O}; \dots BR_e^{O}; \dots; BR_f^{O}\},$$

where BR_e^{O} – balance of *e*-th organizational risk, *f* – quantity of organizational risks, *e* – organizational risk number, $(e = \underline{1; f})$.

Balance value of *e*-th organizational risk BR_e^{O} can be defined by the formula:

$$BR_e^{O} = \sum_{s=1}^{t} C_{es}^{O} + \sum_{u=1}^{v} D_{eu}^{O} \quad (9)$$

Based on formula (3) and formula (4), balance value of *e*-th organizational risk BR_e^{O} will acquire such a form:

$$BR_e^{O} = \sum_{s=1}^{t} P_{es} \cdot V_{es} + \sum_{u=1}^{v} P_{eu} \cdot V_{eu} \quad (10)$$

The set of risk balances (opportunities and threats) of ITAP stakeholders is denoted as BR:

$$BR = \{BR_1; \dots; BR_k; \dots; BR_l\},$$

where BR_k – risk balance for the *k*-th ITAP stakeholder, *l* – quantity of ITAP stakeholders, *k* – stakeholder number, $(k = \underline{1; l})$.

The value of the risk balance BR_k for the *k*-th ITAP stakeholder can be written by the formula:

$$BR_k = \sum_{i=1}^{n} C_{ki} + \sum_{j=1}^{m} D_{kj}, \quad (11)$$

Based on formula (5) and formula (6), value of the risk balance BR_k for the *k*-th ITAP stakeholder will acquire such a form:

$$BR_k = \sum_{i=1}^{n} P_{ki} \cdot V_{ki} + \sum_{j=1}^{m} P_{kj} \cdot V_{kj} \quad (12)$$

Given the possible states of the system of interaction of opportunities and threats at source [25], the value of the risk balance (BR) can take value:

$$BR_k = \{BR < 0, if\ C < D\ BR = 0, if\ C = D\ BR > 0, if\ C > D \quad (13)$$

where C – the total amount of opportunities for the corresponding risk, and D – the total amount of threats of the corresponding risk.

According to the conceptual model of risk balance (opportunities and threats) [25] on risk balances, we will divide IT risks, organizational risks and all ITAP stakeholders into three groups:

if $BR < 0$ – threatening, in which high threats and low opportunities;

if $BR = 0$ – harmonized, in which opportunities and threats are in balance;

if $BR > 0$ – chances, which have high opportunities and low threats.

Based on the results obtained, we can determine, respectively, three sets for each type of ITAP risk.

The set of IT risks, $\{R^{IT}\}$, can be defined by the formula:

$$R^{IT} = \{R^{IT}{}_D\} \cup \{R^{IT}{}_G\} \cup \{R^{IT}{}_C\},$$

where $R^{IT}{}_D$ – set of threatening IT risks; $R^{IT}{}_G$ – set of harmonized IT risks; $R^{IT}{}_C$ – set of chance IT risks.

The set of organizational risks, $\{R^{O}\}$, can be defined by the formula:

$$R^{O} = \{R^{O}{}_D\} \cup \{R^{O}{}_G\} \cup \{R^{O}{}_C\},$$

where $R^{O}{}_D$ – set of threatening organizational risks; $R^{O}{}_G$ – set of harmonized organizational risks; $R^{O}{}_C$ – set of chance organizational risks.

The set of ITAP stakeholders, S, can be defined by the formula:

$$S = \{S_D\} \cup \{S_G\} \cup \{S_C\},$$

where S_D – set of threatening ITAP stakeholders; S_G – set of harmonized ITAP stakeholders; S_C – set of chance ITAP stakeholders.

Then, the total set of high (threatening) ITAP risks $\{R_{ITAP}^{high}\}$ will look like this:

$$R_{ITAP}^{high} = \{R_D^{IT}\} \cup \{R_D^{O}\} \cup \{S_D\}$$

where $\{R_D^{IT}\}$ – set of threatening IT risks; $\{R_D^{O}\}$ – set of threatening organizational risks, $\{S_D\}$ – set of threatening ITAP stakeholders.

For each threatening set, we can conduct additional assessments of opportunities and threats within the set or for each stakeholder individually, which allows to investigate in depth indicators of components of risk (opportunities and threats) and expands limits of the accepted administrative decisions.

Chance risks need to be kept and encouraged, harmonized risks can be used to increase the component capacity, and threatening risks need to be reduced to an acceptable level.

3. Conclusions

In the process of managing IT audit projects, management faces the question of the feasibility and effectiveness of their implementation, to solve which requires adapted to the IT sphere models, methods and mechanisms and clear algorithms for their use. The article identifies the stages of ITAP risk management, the

mathematical model of such management is described which allows to estimate their possibilities and threats, to define sizes of balances of risks, to carry out a rating assessment of risks of ITAP and stakeholders on these balances and to form sets of threatening, harmonized and chance risks, and identify the set of high ITAP risks. Further research should focus on the impact of risk balances on the effectiveness of ITAP management within three categories that correspond to the "magic" triangle of project management goals: time, cost, quality.

4. References

[1] IT in Ukraine: where we are moving: website. URL: https://dou.ua/lenta/columns/future-of-it-ukraine/ (access date 12.11.2020).

[2] Pugachenko O.B. Features of audit of information systems and technologies / O.B. Pugachenko // Scientific works of Kirovograd National Technical University. Economic sciences. – Kirovograd, 2009. Vol. 16, part. II. – pp. 223-228.

[3] Platonova I.A. Problems and prospects of audit in Ukraine / I.A. Platonova // Scientific Bulletin of Poltava University of Economics and Trade. – Полтава, 2011. № 4 (49). – pp. 337-341.

[4] Audit: a practical guide / [A. Kuzminsky, N. Kuzhelny, E. Petrik and others] ; ed. A. N. Kuzminsky. – K. : Uchetinform, 2008. – 283 p.

[5] Butinets F. F. Audit: state and trends in Ukraine and the world: a monograph / F. F. Butinets, N.M. Malyuga, N.I. Petrenko. – Zhytomyr: ZSTU, 2004. – 564 p.

[6] Information technologies. URL : https://uk.wikipedia.org/wiki/%D0%86%D0%BD%D1%84%D0%BE%D1%80%D0%BC%D0%B0%D1%86%D1%96%D0%B9%D0%BD%D1%96_%D1%82%D0%B5%D1%85%D0%BD%D0%BE%D0%BB%D0%BE%D0%B3%D1%96%D1%97 (access date 12.11.2020).

[7] Datsenko G.V. Conceptual principles of information support of internal audit of industrial enterprises. Scientific Bulletin of Uzhhorod National University. Series: International Economic Relations and the World Economy. 2020. Vip. 33, part. 1. pp. 45-48. DOI: https://doi.org/10.32782/2413-9971/2020-33-8.

[8] Makarova M. V., Bilousko T. M. Assessment of economic security of investment projects for enterprise informatization. Project management and production development: zb.nauk.pr. Luhansk: published by SNU. V.Dalya, 2011. № 1 (37). 160-168.

[9] Chenash V. S. Rusin O. I. The role of audit in detecting fraudulent actions with financial statements. Scientific Bulletin of Uzhhorod National University. Series: International Economic Relations and the World Economy. 2016. Vip. 7, part. 3. 50-53.

[10] Zadorozhnyuk N. O., Alekseenko S.O., Zhanko K.O. Motivation of staff in the IT field. Black Sea Economic Studies. 2018. Vip. 35. 66-70.

[11] Medvedeva E. M. IT projects as a kind of soft projects. Project management and production development: zb.nauk.pr. Luhansk: published by SNU. V. Dalya. 2015. №2 (54). 112-124.

[12] Orlova O. M. Features of personnel management in the IT sphere. Scientific Bulletin of Uzhhorod National University. Series: International Economic Relations and the World Economy. 2017. Vip. 11. 117-120.

[13] Vasiltsova N. B., Panferova I. Y. Method of evaluating the team of IT project executors. Bulletin of NTU "KhPI". 2014. № 2 (1045). 116-121.

[14] Titorenko V. S. Complex application of emotional intelligence and KANBAN method in IT project management. Bulletin of Cherkasy State Technological University. Series: Technical Sciences. 2019. №1. 41-47. DOI: 10.24025 / 2306-4412.1.2019.165422

[15] Semenets A. A. Influence of internal audit principles on the control environment: economic and social consequences. Economic space. 2018. №139. 182-198. DOI 10.30838 / P.ES.2224.271018.182.283.

[16] Stashevsky Z. P. Models and mechanisms of formation of competence of personnel of IT-projects: author's ref. dis. … cand. tech. sciences: 05.13.22 / Lviv. LDUBJD, 2015. 21 p.

[17] Stashevsky Z. P. Mathematical model of the educational project of training a specialist in the field of information security. Management of complex systems development. 2014. Vip. 20 (1). 67-73. URL: http://nbuv.gov.ua/UJRN/Urss_2014_20(1)__15.

[18] Alba, V. & Bielova O., & Savina, O. (2020). Features of IT-audit projects and specifics of managing them. Management of Development of Complex Systems, (44), 6-19 [in Ukrainian].

[19] «IT project management» URL : http://dspace.tneu.edu.ua/retrieve/19638/%D0%9B%D0%B5%D0%BA%D1%86%D1%96%D1%97.pdf (access date 12.11.2020).

[20] Audit of IT infrastructure URL: https://www.softcom.ua/ru/it/it-resheniya/it_aydit.php (access date 12.11.2020).
[21] Alba V. O. Features of IT audit projects. Project management: status and prospects: coll. materials of the XVI International. scientific-practical conf. Mykolayiv: Admiral Makarov NUOS, 2020. P. 3–4.
[22] Yaroshenko F.A., Bushuev S.D., Tanaka H. (2011.) Management of innovative projects and programs based on knowledge system P2M: Monograph. Kiev, Ukraine, 263.
[23] Alba V. O, Danchenko O. B, Savina O .Yu. Features of IT audit project management. Materials V International. scientific-practical conf. «Project, Program, Portfolio p3 management». Odesa : ONPU. 2020. P. 10–13.
[24] Basic principles of IT audit. URL: https://www.itexpert.ru/rus/audit/itaudit/. (access date 12.11.2020).
[25] Bakulich, O. O. (2019). Conceptual model of risk balance (chance and dangers) of stakeholders in wind power projects / O. Bakulich, A. Sevostianova // Scientific notes of the University "KROK": Collection of Scientific Publications, 3(55), 143-150.
[26] Sevastianova, A.V. (2019). Mathematical model of anti-risk management of stakeholders in wind power projects. Science and Education a New Dimension: Natural and technical sciences. Budapest, Hungary: 2, 30 – 33.

Risk Management Models of a Project for the Implementation of a Management Information System in the State Institutions

Ruslan Mann[1], Dmytro Bedrii[2], Jalal E. Elbaruni[3] and Safar Hisham[3]

[1] *Cherkasy State Technological University, Cherkasy, Ukraine*
[2] *Odesa National Polytechnic University, Odesa, Ukraine*
[3] *«KROK» University, Kyiv, Ukraine*

Abstract

The paper presents a conceptual model of information risk management of the project of information management system implementation and a formalized mathematical model based on determining the impact of information risks on the state institution, project and environment. The application of these models will allow the project manager and a team to increase the effectiveness of information risk management of the company, project and environment.

Keywords

Project, IT, MIS projects, model, information risks, state institution

1. Introduction

Information society determines the transformation of education system. In recent years, rapid, effective and global communication of knowledge has created a new basis for cooperation and teamwork at both national and international levels. The growing role of information technology (IT) in the development of society requires an active response to the challenges of the information society. Already there are new requirements for the basic qualifications of specialists, as well as their knowledge of introduction consequences of information technology [1, 2].

The combination of education and technology is considered a key element of human progress. Education transfers technology, which in turn is the basis of education. Therefore, it is obvious that information technology has changed the methods, goals and potential of education [3].

The project management methodology has shown its effectiveness in all areas of human activity, including information technology [4].

In [5] the authors proposed the model of levels for local community competencies in energy efficiency projects. The model consists of three levels – "initial", "in development", "developed". Each level of the model is characterized. The method of assessing the competence level of the local community in energy efficiency projects, as well as the method of developing the competence of the local community in energy efficiency projects is proposed. Perspectives of further research in the chosen direction are outlined.

The authors in [6] proposed information technology for managing stakeholders of art projects based on a value-oriented approach. The sequence of stages of collection, preparation, processing (analysis) and storage of information about the value profile of art projects is presented, in order to make decisions on ensuring effective management of such projects. Effectiveness, with this approach, will be expressed in the degree of stakeholders' satisfaction, namely, in the degree of obtaining the expected value.

In [7] the authors are devoted to the necessity of application, as to the current requirements, acute for power engineering of information technologies. Development and implementation of IT projects at the enterprises of

P_3M-2020: Project, Program, Portfolio management, December 04–05, 2020, Odesa, Ukraine
EMAIL: mannruslan1@gmail.com (R.Mann); dimi7928@gmail.com (D.Bedrii); jalbarouni@gmail.com (J.Elbaruni); hishamsafar@gmail.com (S.Hisham)
ORCID: 0000-0003-3936-2677 (R.Mann); 0000-0002-5462-1588 (D.Bedrii); 0000-0008-2242-2115 (J.Elbaruni); 0000-0002-2492-2815 (S.Hisham)


energy industry create opportunities to optimize the information movement at all stages of technological process, which in turn leads to improved efficiency of all levels of management.

Taking into account the above scientific works, it can be concluded that the introduction of information technology in project management can increase their efficiency and quality and timeliness of their implementation. Therefore, it is proposed to develop models of information risk management projects for the implementation of management information systems of State institutions.

2. Main part

Information risks may arise in the process of implementation of management information systems (MIS) projects and in the organization as a whole. The author proposes a new approach to information risk management, which is proposed to be described using a conceptual model that should provide guidance on where to seek a deeper understanding of the different perspectives on risk management in the project and the organization as a whole.

Information risk management provides procedures and policies, as well as technologies that the organization must use to improve the security of its information [8, 9]. Without a proper risk management procedure, technological vulnerabilities are usually high, and this can negatively affect the availability, integrity and confidentiality of data. Factors that can be sources of risk in the company include unclear roles and responsibilities, weak data protection system and employee confusion.

Although there are different forms of models that help in risk reduction processes, it is necessary to determine the most appropriate model for a particular project. The purpose of the review of different models is to suggest different model formats and to identify those of interest to both researchers and practitioners in the field of information technology. The role of the conceptual model should be to develop an appropriate strategy for information risk management.

The concept proposed by the author provides a better approach to managing information risks associated with the implementation of MIS projects. At the same time, the organization may have different approaches to risk management; this conceptual model involves the identification and analysis of possible risks as a first step. At this stage, it is planned to identify any possible risks of the organization and analyze them to determine the level of severity in terms of impact on the project and the organization as a whole. First of all, it is necessary to deal with the risks that have the greatest impact and allocate more resources to deal with them.

Because an organization has information risk of the project and risk of the company, this conceptual model assumes that organization should give priority to the information risk of the project. The rationale for this is that a project, being a smaller unit within a company or organization, is more vulnerable and is likely to be suppressed by any form of risk. Therefore, the conceptual model assumes the need to address the risks associated with the project first, before addressing the risks associated with the company.

In the process of risk analysis there is a need to identify risks that affect the project either by the company or by the environment. Some of the company's information risks include poor IT structure, artificial intelligence risks, unavailability of services, data loss, and inaccurate decision automation. After that, it is also necessary to identify some common risks. The concept also shows the impact of the environment on a project's success. The environment in which the organization is located affects the implementation of projects. Everything in the company's environment can affect the project in two ways, the first of which is the impact of the environment on the company, and then it is transformed into information risk of the project [10]. In second case, impact of environment directly affects information risks of project. If the environment is compromised, information risks of the project are also compromised. In the process of information risk analysis there is a need to address the identified risks based on their impact and probability. The identified risks must then be classified as high, medium or low depending on their potential impact. Once this is done, project risk minimization strategies need to be considered (Fig. 1).

In some cases, information risk of the project can be equated to information risk of the company. This means that information risks of the project do not affect a particular segment of the company, but the whole. Once the number of such risks has been calculated, it is also necessary to assess whether there are other risks. Risks can be of different types: some are directly related to the company and others are not.

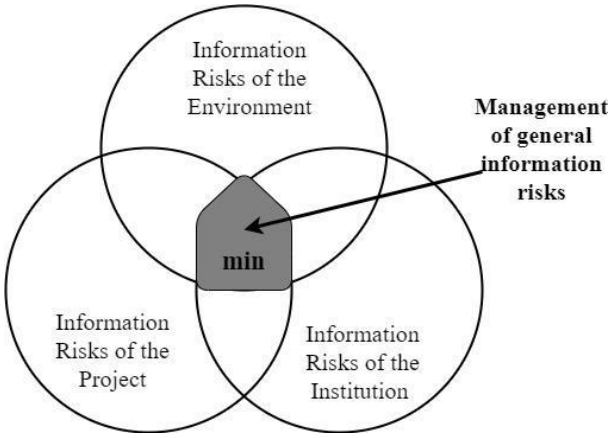


Figure 1: Concept of general information risk management

As shown by the conceptual model in Fig. 2. [11], the MIS implementation project has a direct link to the main database and is therefore more vulnerable than a State institution. Although the impact on the project is the impact on the State institution, it is easier to deal with the information risks associated with the project than with those risks that are directly related to the company. As shown by the arrows, everything that happens with the MIS implementation project is shifted to the whole company. For example, if there is a risk that delays the implementation of the MIS project, these effects will be felt even at the company level. This reflects the kind of relationship that exists between the company and the project. They are intertwined in such a way that when one of them is affected, the effect is felt by both.

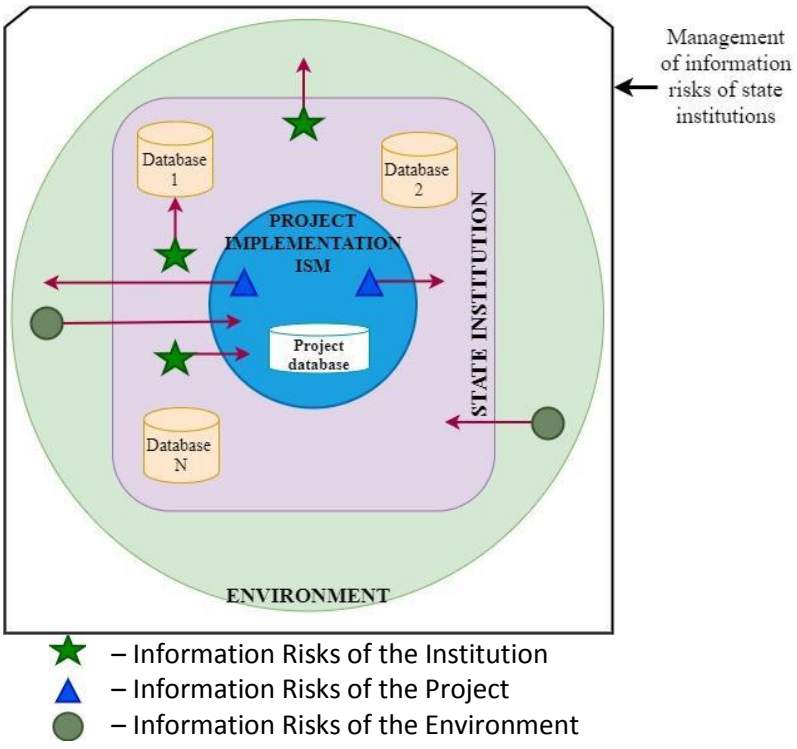


Figure 2: Conceptual model of information risk management of STATE institutions

A detailed analysis is needed here, as there may be some risks that seem insignificant, but if they are not eliminated, they may adversely affect the project. These risks should be assessed based on whether they are directly related to the project or to the company. If they are directly related to the project, they should be resolved as soon as possible to ensure the continued project work [12]. If they are directly related to the company, they also need to be resolved before they affect the information risk of the project and the company as a whole.

If no other risks are identified, a detailed analysis should be performed to ensure that any possible high risks are minimized. As the project progresses, a review should be conducted to ensure that even unforeseen risks are minimized to the highest possible level. As shown in the conceptual model in Fig. 2., the project of management

information system implementation uses the main database and is exposed to risks from different sides. Since the information risk of the project affects both the company and the environment, it is likely that they will receive risks from these environments.

If the risks are not reduced during the implementation of the project, the project may not give the required results. Risk management covers several key processes that should be considered to ensure the success of project risk management [13]. One of the processes is to establish the criteria by which the evaluation is conducted. This process should identify existing vulnerabilities and threats based on their forecasted impact on the project. Once the risks and their magnitude have been identified, it is necessary to select the most appropriate measures to reduce them to a sustainable level or eliminate them completely. Thus, the project can work continuously.

There is also a process of follow-up assessments to determine whether there is a remaining risk and ways to address the residual risk. Residual risk may depart from the environment, the company or the project itself [14]. During the implementation of the project, the project itself may form some risks that need to be resolved, because if they are not resolved in time, they can affect the overall success of the project.

During the implementation of the MIS implementation project, different databases are used, as shown in Fig. 2. There is a project database and other databases that perform smaller tasks. It is important to note that each of these databases is equally important and needs to be properly developed. The risk propensity of one database may eventually affect others, especially in cases where the databases are interconnected [15]. For example, risks such as susceptibility to malware in one database may lead to vulnerabilities in others. The conceptual model shows the project database and databases 1, 2 and N.

The project database has a direct impact on the MIS and information risks of the project. As this is a project database that directly affects the project successor, it should be protected from any forms of risk. Databases 1, 2 and N are also important and related to the company's information risk. Therefore, it is also necessary to ensure that any form of risk that may affect such a database is properly addressed.

Based on the conceptual model of information risk management, can be formalized the mathematical model of risk management in various organizational projects, the implementation of mis has several negative impacts that have simultaneous consequences for different management operations [16, 17, 18]. In the process of implementing MIS in projects, there is a general identification of various risks that may affect how these projects are managed by several employees who will try to conduct successful research on critical issues. This can force the implemented strategies to work on the planned projects regardless of all types of risks that may affect the work of management as a whole [19].

Considering that the most important components of state institution’s failure in the implementation of management information systems are the emergence and likely negative impact of information risks, including information risks of the company, information risks of the project and information risks of the environment, which can be calculated as follows.

Each information risk of the company is calculated by the formula (1):

$$IRC_i = P_i \times V_i, \quad (1)$$

where IRCi – information risks of the company;

Pi – the probability of information risks of the company, 0 ÷ 1;

Vi – loss of company information, кБ;

i – company information risk number, 1 ÷ n;

n – quantity of information risks of the company.

In addition, the target function for each information risk of the company (2):

$$IRC_i \to min. \quad (2)$$

For each information risk of the project, the implementation of management information systems will be calculated according to the formula (3):

$$IRP_j = P_j \times V_j, \quad (3)$$

where IRPj – information risks of the project;

Pj – the probability of information risks of the project, 0 ÷ 1;

Vj – loss of project information, кБ;

j – project information risk number, 1 ÷ m;

m – quantity of information risks of the project.

In addition, the target function for each information risk of the project is the implementation of management information systems (4):

$$IRP_j \to min \quad (4)$$

Each information risk of the environment is calculated by the formula (5):

$$IRE_g = P_g \times V_g, \quad (5)$$

where IREg – information risks of the environment;
Pg – the probability of information risks of the environment, 0 ÷ 1;
Vg – loss of environmental information, кБ;
g – number of information risk of the company's environment, 1 ÷ k;
k – quantity of information risks of the environment.
In addition, the target function for each information risk of the environment (6):

$$IRE_g \to min \quad (6)$$

According to the mathematical model proposed by the author in [64], as well as according to the concept of general information risk management (Fig. 1), it is possible to formalize the general information risk (IR) obtained at the intersection of three sets of information risks, in particular the State institution, the MIS implementation project, and the environment, which can be represented as follows (7) - (10):

$$IR = IRC \cap IRP \cap IRE, \quad (7)$$

where IRC – the set of information risks of the company (8):

$$IRC = \{IRC_1, ..., IRC_i, ..., IRC_n\}, \quad (8)$$

IRP – the set of information risks of the project (9):

$$IRP = \{IRP_1, ..., IRP_j, ..., IRP_m\}, \quad (9)$$

IRE – the set of information risks of the environment (10):

$$IRE = \{IRE_1, ..., IRE_g, ..., IRE_k\}. \quad (10)$$

Therefore, the set of common information risks can be represented as (11):

$$IR = \{IR_1, ..., IR_x, ..., IR_z\}. \quad (11)$$

Moreover, each general information risk can be calculated by the formula (12):

$$IR_x = P_x \times V_x, \quad (12)$$

where IRx – general information risk;
Px – the probability of general information risks, 0 ÷ 1;
Vx – loss of information, кБ;
x – number of general information risk, 1 ÷ z;
z – quantity of general information risks.
In addition, the target function for each overall information risk has the following limitations (13):

$$IR_x \to min. \quad (13)$$

Thus, the author describes a mathematical model for managing information risks that may arise and have an impact on the activities of State institutions that provides projects for the implementation of management information systems

3. Conclusions

Based on the study, the authors proposed a conceptual model of information risk management projects for the implementation of information management systems of State institutions, which is based on the need to identify, assess and manage information risks that arise in the environment, the company and the project in particular. In addition, this study presents a mathematical model of information risk management for the project of management information systems implementation, which allows to calculate the general information risk by determining the impact of information risks of the company, project and environment. The implementation of these models will increase the effectiveness of information risk management to ensure the successful operation of the State institution.

4. References

[1] Graf H. Informationstechnologien und Bildung: Der skandinavische Weg. Zeitschrift für internationale erziehungs und sozialwissenschaftliche Forschung. 1995. Vol. 12, no 2. P. 245–260.

[2] Christensen, R., Knezek, G. Instruments for as-sessing the impact of Technology in Education. Computers in the Schools. 2001. № 18(2/3). P. 5–25.

[3] Sangra A., González-Sanmamed M. The role of information and communication technologies in improving teaching and learning processes in primary and secondary schools. Research in Learning Technology. 2010. Vol. 18. Is. 3. P. 207–220.

[4] A Guide to the Project Management Body of Knowledge. (6 Ed.). Chicago: Project Management Institute, 2017. 756 p.

[5] Bushuev S., Shkuro M. Formation and development methods of managerial competences in it-components of energy efficiency projects for local communities. Project, Program, Portfolio Management. Proceccing of the Fourth International Scientific and Practical Conference 06-07 December 2019. Book 2. Odesa, ONPU, 2019. P. 13-16.

[6] Bas D.V., Danchenko O.B., Teslenko P.O. Information technology of value-oriented management of art projects. Proceccing of the Fourth International Scientific and Practical Conference 06-07 December 2019. Book 1. Odesa, ONPU, 2019. pp. 153-156.

[7] Bedrii D.I., Semko I., Krylov V. IT-projects in power engineering. Project, Program, Portfolio Management. Proceccing of the Fourth International Scientific and Practical Conference 06-07 December 2019. Book 2. Odesa, ONPU, 2019. pp. 16-20.

[8] K. Schwalbe. Information technology project management. Boston, MA: Cengage, 2019.

[9] Danchenko E., Elbaruni J.E. A systematic approach to risk management of projects. Project management in the development of society. Abstracts of the XVII International Scientific and Practical Conference on May 15-16, 2020. Kyiv, 2020. pp. 52-55.

[10] M. Khosrow-Pow. Cases on information technology management in modern organizations. Hershey, PA.: Idea Group Pub, pp. 225-249, 1997.

[11] Danchenko E., Elbaruni J.E. The role of informational risks conceptual model to management information system projects implementation. Project, Program, Portfolio Management. Proceedings of the Fifth International Scientific and Practical Conference December 4-5, 2020. Vol.1. Odesa, 2020. pp. 42-44.

[12] M. Gupta, R. Shaman, J. Walp. Information technology risk management and compliance in modern organizations. Hershey, PA: Business Science Reference, 2018.

[13] J. Slay, A. Koronios. Information technology security and risk management. Milton: Wiley, 2006.

[14] C. Wright. Fundamentals of information risk management auditing: An introduction for managers and auditors. United Kingdom: IT Governance Publishing, 2016.

[15] T. Merna, F. F. Al-Thani. Corporate risk management. England: Wiley, 2008.

[16] A. Mubarak Saleh. Construction Project Scheduling and Control. Wiley, 2016.

[17] O. Savina. Mathematical model of value-oriented portfolio management of high-tech enterprise projects, Natural Technical Sciences, no. 2, pp. 36-39, 2017.

[18] A. Trad. An Applied Mathematical Model for Business Transformation and Enterprise Architecture: The Business Engineering and Risk Management Pattern (BE&RMP). In Empowering Businesses With Collaborative Enterprise Architecture Frameworks. IGI Global, pp. 51-89, 2020.

[19] Y. Zhang, S. Liu, J. Tan, G. Jiang, Q. Zhu. Effects of risks on business process outsourcing projects' performance: The moderating roles of knowledge management capabilities. International journal of project management, vol. 36, no. 4, pp. 627-639, 2018.