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NEURO PROJECT MANAGEMENT

Monograph

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This monograph describes the results of the authors' research on the methodology of neuro project management – a new direction of neuroscience that combines such scientific fields as medicine, psychology, neuroeconomics and management. Combining theoretical concepts and accumulated practical knowledge, this monograph presents the possibilities of using neural technologies in project management for effective labor organization and innovative sustainable development. This book is intended for undergraduate and graduate students studying management and economics at the University, for graduate students and scientists engaged in neuroscience, as well as for project managers who want to learn more about the psychophysiological and biological features of the formation of project thinking.

Keywords:.

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CONTENT

INTRODUCTION

Questions of neurobiological and neurocognitive research are important for neuroscientists, psychologists, and those who think about how to organize society, the work of employees, and the education system in the country. The most important thing that we tried to convey in this book is the idea that project activity and project management activities form a special thinking in the human brain – project-thinking – characterized by special properties and functions. The authors stressed the need to increase the number of people with project thinking in senior positions of large companies, as well as at the level of government to achieve global strategic goals and sustainable innovative development. Special attention is given to technologies for recognizing brain activity.

The research was carried out with the financial support of the RFBR in the framework of scientific project no.20-014-002.

The monograph consists of four chapters. The first Chapter explains the necessity and importance of studying neuroscience in connection with the results of research in various countries. The basic concepts and concept of neuro project management as a separate direction of neuro Sciences are defined, the methodology, philosophy, object, and subject of research are described. The functions and influence of the project Manager on the project itself and on the team are also presented. A study describing the relationship between the processes and levels of brain activity of the project Manager was conducted.

The second Chapter represents the results of the research conducted by the method of expert survey at 128 enterprises in Russia. The study allowed to justify the combination of new competencies of the manager and participants of flexible teams. The update applies to both professional and behavioral and contextual competencies. Special attention is paid to such competencies as: team and shared leadership, thinking and values, emotional intelligence, customer focus, cross-functionality, adaptability, and communication skills in a flexible environment. The Chapter substantiates the concept of competence flexibility, which is considered from the point of view of the speed and quality of updating competencies and the response of members of the flexible team to changes in the factors of the project environment.

The third chapter focuses on a summary of different techniques created to understand the brain at the level of individual neurons and synapses. A detailed review of different tools and equipment for neuroimaging modalities is provided. One of the aims was to illustrate their advantages and disadvantages by findings of recent studies from the wide variety of practical applications. Neuroimaging techniques considerably expand our understanding of the neural basis of cognitive processes contributing to educational practice, developmental changes, and social cognition and interaction.

The forth Chapter focuses on the development of methods for managing innovative projects at an early stage of the innovation process; involving various participants: scientists, business, venture industry to create and manage a steady stream of breakthrough innovative projects. It became obvious that the formation of a joint "boiler of innovation" on the basis of a university with interdisciplinary knowledge and a culture of cooperation can provide a steady stream of innovative ideas, technologies, and often innovative products of a high degree of maturity.

Chapter 1
NEURO PROJECT MANAGEMENT: NEW PHILOSOPHY AND SCIENTIFIC DIRECTION

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Abstract. *Neuroscience has boomed in recent decades. Research fields are diversifying and technological development has brought about some revolutionary research tools. New discoveries are quickly hitting the press and neuroscience-based knowledge is being applied to a variety of industries, from education and medicine to business and marketing. The workings of the brain have long been a realm of philosophy. Yet, researchers around the world have trodden the path towards deciphering brain function in unprecedented ways either by tackling the most diverse fields of research or through bold technological innovation. The field of Neuroscience has expanded in every direction. However, a unifying, detailed depiction of how the brain is organized will only emerge by stitching knowledge together and elucidating how function at multiple scales is integrated to give rise to cognition and behavior.*

Today, a large amount of practically tested knowledge has been accumulated concerning the peculiarities of the brain's perceptrons, team interaction, and people management. Technologies have been created and successfully implemented in China that allow managers to make management decisions based on the received neural signals of the employees' brains. This article contains basic principles of neuro project management that describe it as a new and absolutely separate branch of neuro sciences.

Introduction

One of the leading factors that determine technological progress and have a decisive impact on all aspects of society is the development of Neuroscience and Neurotechnology *(Piradov, Illarioshkin, Tanashyan, 2017)*. Neurosciences are a wide range of Sciences, the core of which are branches related to the brain (Fig. 1).

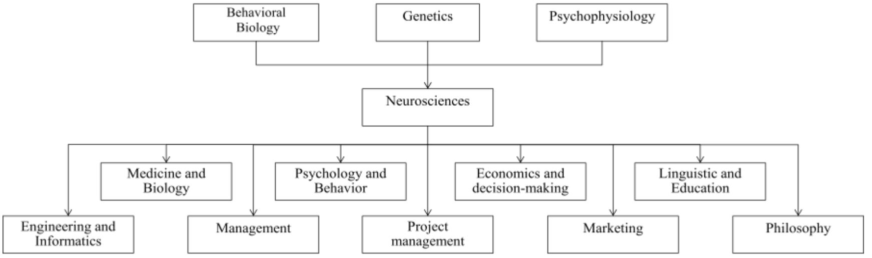


Fig. 1 – Neurosciences diagram

Analyzing a wide range of international articles from different scientific directions – Genetics and Neurodevelopment, Cellular Neurobiology and Neuroimmunology, Synaptic Physiology and Transmission, Neural Circuits and Networks, Neuroanatomy, Cognitive Neuroscience, and Behavioral Neuroscience – foundations of Neuroscience can be determined as Behavioral Biology, Genetics, Psychophysiology. Now there are many scientific areas where Neurotechnology has got its application.

The global research « Brain science. Mapping the Landscape of Brain and Neuroscience Research» made in 2009-2013 years showed that more than half (59.5%) of the 1.73 million active brain and neuroscience researches were classified as multidisciplinary *(Brain science. Mapping the Landscape of Brain and Neuroscience Research, 2014).* Researchers published most often in the areas of medicine, biochemistry, and genetics and molecular biology, but the fields of engineering and computer science were also included among the top 20 disciplines in which active brain and neuroscience researchers published. These findings reflect a state of flux in the area of brain and neuroscience research, where researchers continuously push across disciplinary boundaries to make innovative discoveries.

Neuroeconomics is an interdisciplinary field that seeks to explain human decision making, the ability to process multiple alternatives and to follow a course of action. It studies how economic behavior can shape our understanding of the brain, and how neuroscientific discoveries can constrain and guide models of economics *(Center for Neuroeconomics Study at Duke University, 2014).* It combines research from neuroscience, experimental and behavioral economics, and cognitive and social psychology *(Levallois, C. et al., 2012).*

Neuromanagement uses cognitive neuroscience, among other life science fields, and technology to analyze economic and managerial issues. It focuses on exploring human brain activities and mental processes when people are faced with typical problems of economics and management. This research provides insight into human decision-making and other general social behavior. The main research areas include decision neuroscience, neuroeconomics, neuromarketing, neuro-industrial engineering, and neuro-information systems. Neuromanagement was first proposed in 2006 by Professor Qingguo Ma, the director of Neuromanagement Laboratory of Zhejiang University.

Neuromarketing derives from research on neural features of consumer behavior. Using neural activity to interpret consumer behavior provides insight into the neural mechanism underlying different consumer decision-making behavior. Marketing experts can then determine what will encourage different consumers to make a purchase and produce appropriate marketing strategy, including general marketing, branding and how these relate to customer loyalty. Neuromarketing research is mainly composed of neuro-consumer behavior, neuro-marketing strategy and neuro-advertising.

Neuro project management (NPM) is a branch of neuroscience that reveals specific patterns of project thinking formation, as well as features of neural processes in the professional activities of project managers. It belongs to an interdisciplinary field of knowledge and covers such related fields of knowledge as: cognitive neuroscience; pedagogy/andragogy; medicine; psychology; engineering; neuroethics; neurophysiology; project management.

International aspect of Neuroscience development

The brain research and neuroscience offer a new source of information for strategic assessment and the development of policy and funding strategies at the national and international levels.

In 2000 the "Decade of the brain" - a complex of research works in the field of neuroscience, carried out in 1990-2000 in many countries of the world - has come to an end. Perhaps the main achievement of the completed "Decade of the brain" is the birth of a new idea about the functionality of this organ: researchers have found that the brain has much more variability and plasticity than previously thought. Even in adulthood, it is capable of self-renewal -reactivation of molecules that stimulate the process of neurogenesis - a fact that completely refutes the age - old neurological dogmas. The ability of certain areas of the mature brain to produce new nerve cells is of great importance to both practitioners, neuroscientists and developers of new drugs.

It is possible that the study of this phenomenon will make a revolution in the treatment of certain mental disorders, in the andragogical processes, in the process of work and self-realization of the individual. The hypothesis that prozac and other serotonin reuptake inhibitors in the synapse can influence the emotional sphere of the psyche by initiating neurogenesis is being tested experimentally. If scientists figure out the mechanisms of this process and learn how to adjust the connections between nerve cells, new, more effective drugs against depression can be created.

The brain is not only able to form new nerve cells, but also to change its "wiring diagram". Plasticity is shown as the ability to morphological and functional changes that lead to modification of the reactivity of individual nerve cells and neural networks. Understanding the mechanisms of neural plasticity will help scientists determine the limits of therapeutic possibilities for various brain and spinal cord lesions. In addition, brain plasticity is at the heart of adaptive behavior, self-learning, and memory.

Although the "Decade of the brain" did not provide answers to fundamental questions related to the activity of the brain, intensive international research conducted throughout the 1990s allowed scientists to take a new look at some aspects of its functioning and ways to improve its performance.

Russian Federation. Psychophysiology had started to develop more than 100 years ago and in 1904 the Russian scientist Ivan Petrovich Pavlov got the first Nobel prize in the field of Physiology "in recognition of his work on the physiology of digestion, through which knowledge on vital aspects of the subject has been transformed and enlarged" which is now considered to be the first Nobel prize related to neuroscience.

Important results were obtained during the "Decade of the brain" in the largest neurological center in Russia as well – in the research Institute of Neurology of the Russian Academy of medical Sciences. The complex of research works in the field of neuroscience was based on a conceptual principle, a systematic approach, and the principles of evidence-based medicine. It was conducted in four main areas: vascular diseases of the brain; neurogenetics; neuroinfections; critical conditions in neurology *(Vereshchagin, 2001).*

The study of the brain is assigned by the Government of the Russian Federation to the list of Priority scientific tasks *(Piradov, Illarioshkin, Tanashyan, 2017).* In 2016 the Federal project “Neuronet” in the field of neuro-communication was approved by the President of Russia. Its main task is the development of human-machine communication tools based on advanced development in Neurotechnology and increasing the productivity of human-machine systems, the productivity of mental and thought processes *(Ostrovsky, 2016).*

China. In 1934, the first neurophysiology laboratory was established at the Beijing medical College and in 1957 a similar laboratory was established in Shanghai, and 20 years ago in 1999, the Institute of Neurosciences (ION) of the Chinese Academy of Sciences was established in Shanghai. However, Chinese scientists are forced to admit that stable support for basic scientific research became available only in the 1980s, and only in the last decade has the quality, rather than the number, of publications come to be considered a merit.

The Chinese society of neuroscience was founded in 1995. Then came a phase of rapid expansion fueled by economic growth: science funding in China rose sharply in the first decade of the new century, with annual increases typically around 20% (although the 2011 figure is more modest at 12.5%) *(Gross, 2011).* Thus, the Institute of Neurosciences of the Chinese Academy of Sciences today serves as the flagship of a rapidly growing research community that is now widely recognized by observers both inside and outside the country.

In 2016 the China Brain Project - a 15-year project, approved by the Chinese National People's Congress as part of the 13th Five-Year Plan (2016–2020) – was launched *(Zhu, Cao, Dong, 2013).* It is one of four pilot programs of the Innovation of Science and Technology Forward 2030 program, targeted at research into the neural basis of cognitive function. Additional goals include improving diagnosis and prevention of brain diseases and driving information technology and artificial intelligence projects that are inspired by the brain. The China Brain Project prioritizes brain-inspired AI over other approaches.

USA. It is no accident in 2013 that the United States have launched an unprecedented ten-year program for the study of the brain – “BRAIN Initiative” (Brain Research through Advancing Innovative Neurotechnologies) and Human Brain Project, with an annual amount of funding in the hundreds of millions of us dollars. Similar programs have been adopted in China (Brainnetome), Switzerland (Blue Brain) and a number of other technologically advanced countries *(The White House, 2013).*

The BRAIN Initiative was launched as a Presidential Grand Challenge with the goal of attaining a comprehensive understanding of the brain at multiple levels. It is supporting transdisciplinary research to develop theories of brain function; develop new imaging and treatment technologies; develop tools and standards for data collection, analysis, and integration; and build multi-scale models that relate changes in brain activity directly to cognition and behavior.

In addition, nowadays, the USA has the largest number of scientific journals related to Neurosciences – 215. For comparison, United Kingdom has 102, Germany – 51, Netherlands – 50, Switzerland – 49 *(Russian information-analytical portal eLIBRARY).*

Europe. In 2013, the European Commission approved €1 billion in funding for the large ten-year scientific research project Human Brain Project (HBP) *(Human Brain Project, 2013), (The Human Brain Project, 2012),* a collaboration across 24 countries and 112 institutions. The dual goals of the HBP are to develop and deploy new information and communication technology (ICT) platforms for collecting and integrating brain research data, and then use that data to create a computational model of the human brain.

The Project is divided into 12 Subprojects. These are some of them:

– Human Brain Organisation (understanding the structure of the human brain, and its electrical and chemical functions);

– Systems and Cognitive Neuroscience (understanding how the brain performs its systems-level and cognitive functional activities);

– Brain Simulation Platform (developing data-driven reconstructions of brain tissue and simulation capabilities to explore these reconstructions);

– Neuromorphic Computing Platform (developing and applying brain-inspired computing technology.

Japan. The global network of neuroscience research also extends into Asia, with two Japanese institutions recently joining the HBP: the Okinawa Institute of Science and Technology (OIST) which is developing the Brain Simulation Platform, software that will link specific electrophysiological events and biochemical reactions in neurons in a spatial simulation and the RIKEN Brain Science Institute (BSI) which was founded in 1997 to promote innovative, collaborative brain research that brings together the disciplines of medicine, biology, physics, computer science, and psychology. As a partner institution within the HBP, RIKEN researchers are identifying the brain structures that determine specific mental capabilities and are involved in integrating information.

In addition, Japan's ten-year brain project—Brain/MINDS (Brain Mapping by Integrated Neurotechnologies for Disease Studies) —that was launched in May 2014, will develop the marmoset experimental model to accelerate the understanding of human mental disorders. The program is divided into three groups focusing on structural and functional brain mapping, development of new technologies for brain analysis, and improving the analysis of clinical data such as human patients' brain scans for biomarkers of brain diseases.

African countries. There are limited data on the contribution of the African continent to neuroscience research and publications. Recent Neuroscience research in Africa showed that Neuroscience represents 9.1% of the total medical publications in this region *(Foad, A. et al., 2016).* Saudi Arabia ranks first in the share of scientific journals in the field of neuro Sciences from the total number of scientific journals in this country. For comparison:

1. Saudi Arabia - 8.70%
2. Switzerland – 4.47%
3. Ireland – 4.08%

In 1993 the Society of Neuroscientists of Africa (SONA) *(Society of Neuroscientists of Africa)* was founded to promote research, teaching and advocacy in Neuroscience in Africa and hold an International conference every two years. It is the umbrella organisation for the regional and national neuroscience societies and groups in Africa, and an affiliate of the International Brain Research Organisation (IBRO).

India. India today presents a "unique window to observe how rapid social and lifestyle changes impact disease burden and progression in developing countries, especially aging-related disorders" *(Padma, 2008).* But only in 2014 the Centre for Brain Research (CBR) at the Indian Institute of Science in Bengaluru, Karnataka was founded. It is a pioneering research institution that conducts clinical neuroscience studies focused on brain disorders among the Indian population. CBR's first project addresses aging-related brain disorders.

CBR fills a white space in the field of brain research by conducting long-term studies to better understand the factors that cause and protect against dementia (diseases and conditions characterized by a decline in memory, language, problem-solving and other thinking skills that affect a person's ability to perform everyday activities) in the Indian population. CBR emphasizes a collaborative approach through a public-private partnership within India and by partnering with local and global research institutions. It aspires to build the first India-specific reference genome, which will help scientists across disciplines, not just in brain research.

Neuro project management

NPM, like any science, has a fundamental composition that includes the subject, object, methodology, philosophy, collected data and empirical material.

The subject of NPM are:

1) regularities and methods of project vision formation of project managers and project team members;

2) laws and principles underlying the professional activity of project managers;

3) methodology of mental and cognitive activity in project and program management;

4) specific requirements (knowledge, skills, personal qualities, physiological, psychological and social) that the project Manager must meet;

5) behavioral relationship that develop within project teams.

The object of NPM research is the mental, cognitive and behavioral activities of project managers and their team members, without which it is impossible to achieve the goals set and respect the interests of various parties.

The actual data and empirical material of NPM can be obtained through:

– experience (accumulated and studied data + own accumulated experience);
– experiment (diagnostic and formative experiments).

If the main goal of any science is to get the truth, then the philosophy of science is one of the most important areas for humanity to use its intelligence, in which the discussion of the question «How is it possible to achieve the truth?» The philosophy of NPM can be represented by a variety of concepts that offer models and methods of research to identify the role and significance of NPM, which allows to distinguish it from other activities.

The NPM philosophy is based on the hypothesis of project thinking as a special type of mindset and approach to seeing the situation and solving problems. Projects appear to be emotionally perceived as though they are composed of two opposing forces or elements which were not as dichotomistic as good and bad. Rather, these forces are more complementary or completing aspects of the one phenomenon such as in the concept of Yin – Yang. The experience of managing a project can be described in terms of a duality between thrill and excitement, even fear and personal satisfaction.

The NPM methodology can be described as a set of methods, techniques, and procedures for scientific research of neural processes within the framework of project activities.

Executive activity is contrasted with managerial activity. Its starting principle is the implementation of certain norms. It is preceded by a consistent process of understanding the content of the norm, its correlation with the needs of management, the forecast of the feasibility of requirements with existing abilities, etc. Since it is the Manager who is the proponent, the performer is left to try on their capabilities and desires with a ready-made idea of the method of activity.

A prerequisite for project activity is reflection or self-learning, which preserves past experience, and creates it based on the results obtained – the analysis of lessons learned. At whatever level of development of the project activity there are difficulties, no matter how visible or hidden they are, but only the fixity of the difficulty motivates a reflexive exit.

Implementation of project activities involves the implementation of a complex set of activities that are closely related to each other, but are dispersed in time and space *(Medvedev, 2019).* Project thinking is methodological in nature. Having identified the methodological grounds, a person reveals for himself the content and semantic framework of possible actions and their consequences. The methodology involves a process of meaningful selection of the central positions and leading ideas that we use, the principles that we are guided by.

Project thinking is, first of all, the ability to get fundamentally new information for yourself, learn together with other people new types of activity, and develop certain personal characteristics. This is a special state of openness of consciousness to the new, unknown. Projective consciousness, on the one hand, is focused on extracting knowledge from experience, from reflection on this experience and the actions of the subject within it, and on the other – is able to generate on the basis of knowledge obtained by experience, certain images that perform a leading function relative to the future states of objects (Table 1).

Table 1

Project Manager functions and his impact on the project

Project Manager functions	Impact on the project
Ideological	Defines the general conceptual approaches and position in the project activities
Research	Provides independent acquisition of knowledge necessary for developing strategies and tactics for project implementation, facilitates work with sources of information, gives the opportunity to independently go beyond the known knowledge, creates prerequisites for continuing education
Organizing	Helps to organize information on a single conceptual basis, in a single logic; stores and transmits it to others
Integrating	Allows to generalize and synthesize data from different areas, providing access to a new level of understanding of theoretical and practical problems

Prognostic	Provides a forward-looking view of the design situation, the difficulties and contradictions that may arise in the project activities
Regulatory	Helps to develop goals and principles of project activities, determines the focus and sustainability of actions
Transformative	Makes it possible to correct his actions in the project, allows to consciously improve the design process
Heuristic	Ensures that new issues/ problems / questions are raised
Evaluative	Allows to develop criteria and indicators for evaluating project products

Being an effective tool for establishing actual boundaries of knowledge (skills, systems of relations), reflection simultaneously becomes a universal means of going beyond these boundaries. First, you need to make a stop, interrupt the previous course of thought or activity. In this case, the results of reflection open up the possibility of redesigning the methods of action on new grounds.

The reason for reflection in project management is the object of joint activity with others (network or teamwork), the self in the reflection of others, the system of relations. Group reflection opens up wide opportunities not only for solving project tasks, but also for self-knowledge. In group project work, the aggregate opinion acts as a kind of mirror that helps the individual to go beyond their limits by creating prerequisites for the formation of a new attitude, position, and evaluation in relation to "themselves in the project". As the members of the group speak their opinions about each other's personal characteristics and manifestations, new functional possibilities open up in regulating the dynamics of behavior and personal development.

Along with the listed properties, the project type of thinking is characterized by discipline, the ability to structure, the ability to see connections within the object and its environment, and follow the logic of building standardized thinking procedures.

The same principle of reflection or self-learning is used in the basis of artificial neural networks - ANN) – mathematical models built on the principle of organization and functioning of biological neural networks-networks of nerve cells of a living organism. This concept arose when studying the processes occurring in the brain, and when trying to model these processes.

ANN is a system of connected and interacting simple processors (artificial neurons), each of them periodically receives and sends signals to other processors. And yet, when connected to a large enough network with controlled interaction, these individually simple processors together are able to perform quite complex tasks.

From the point of view of artificial intelligence, ANN is the basis of the philosophical current of connectionism and the main direction in the structural approach to the study of the possibility of building (modeling) natural intelligence using computer algorithms.

Neural networks are not programmed, they are trained. Technically, training consists in finding the coefficients of connections (connectors) between neurons. During training, the neural network is able to identify complex dependencies between input and output data, as well as perform generalization. This means that if training is successful, the network will be able to return the correct result based on data that was missing from the training sample, as well as incomplete and/or “noisy”, partially distorted data.

Brain and mind

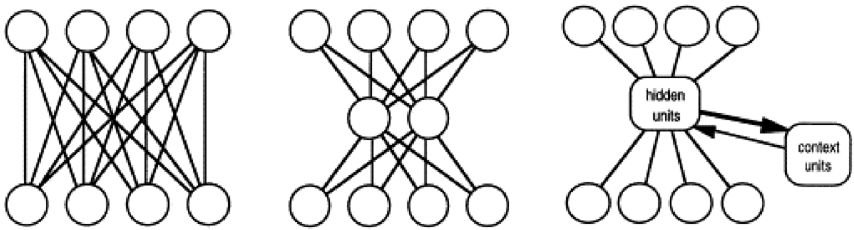
Project management is one of the most applied management concepts in companies all around the world *(Obradović et al., 2013).* Important skills in project management are ability of teamwork and the leadership ability. Among different types of intellect project manager should have half of them: analytical, creative, emotional, interpersonal, practical, social, verbal intellect.

There are two ways to think of intelligence: first, we can see it as the ability to interact with the world, to solve problems by trial and error. Alternatively, intelligence can be thought of as verbal logical reasoning inside our mind *(Bocanegra et al., 2019).*

Mind is a set of cognitive faculties including consciousness, perception, thinking, judgment, and memory. The mind is the faculty of a human being's reasoning and thoughts. It holds the power of imagination, recognition, and appreciation, and is responsible for processing feelings and emotions, resulting in attitudes and actions. The most straightforward scientific evidence of a strong relationship between the physical brain matter and the mind is the impact physical alterations to the brain have on the mind, such as with traumatic brain injury and psychoactive drug use. The relationship between mind and brain involves a number of scientific questions, including understanding the relationship between mental activity and brain activity, the exact mechanisms by which drugs influence cognition, and the neural correlates of consciousness.

One of the theoretical approaches to explain how mind emerges from the brain is - connectionism. The goal of this approach is to construct an abstract model of the neural processes taking place in the brain. The main components of connectionism: knowledge is distributed, information is processed in parallel, inactive knowledge is nowhere. More realistic models of the brain include recurrent connections that are necessary in order to explain such cognitive features as short term memory.

The Rethinking Innateness approach represents one particular use of connectionism that is aimed at eliminating innate domain-specific representations and symbol-manipulation (Fig. 2).



a. 2-layer pattern associator b. Single feedforward network c. Single recurrent network

Fig. 2 - Sketches of some network architectures used in Rethinking Innateness. Input units are drawn on the bottom of each figure, output units on the top. Not all connections are shown. The ovals labeled as ‘hidden units’ and ‘context units’ contain multiple nodes. *(Marcus, 1998)*

Project manager is self-serving. He does not serve the individual or organisation. Network interaction is a key process while developing or implementing a projet. The reality of the complex human social system is that people`s behaviour is driven by the interaction of the individual agents (humans and organisational entities), not by one person. But how does the brain functions during project management activity? (Fig.3)

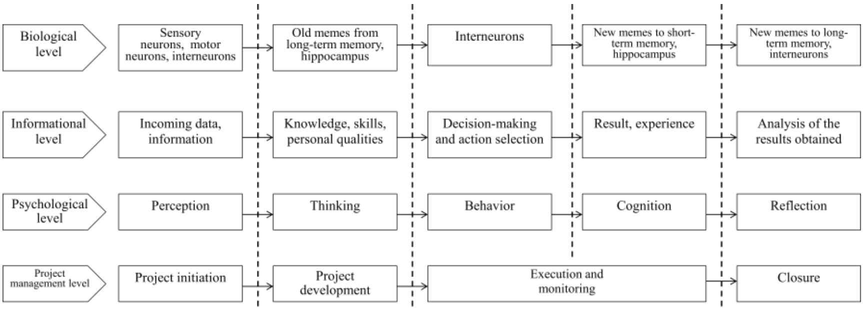


Fig. 3 – Levels and processes of brain activity of a project manager

Psychologists and neuroscientists generally agree that the hippocampus plays an important role in the formation of new memories about experienced events (episodic or autobiographical memory). Different types of memory are stored in different regions of the brain. Long-term memory is typically divided up into two major headings: explicit memory and implicit memory. Various researchers have proposed that stimuli are coded in short-term memory using transmitter depletion. According to this hypothesis, a stimulus activates a spatial pattern of activity across neurons in a brain region. As these neurons fire, the available neurotransmitters in their store are depleted and this pattern of depletion is iconic, representing stimulus information and functions as a memory trace. The memory trace decays over time as a consequence of neurotransmitter reuptake mechanisms that restore neurotransmitters to the levels that existed prior to stimulus presentation.

However, not all researchers agree that short-term and long-term memory are separate systems. The Unitary Model proposes that short term memory consists of temporary activations of long term representation *(Cowan, Nelson, 2008).*

Emotions and behaviours have a biological foundation *(Furnham, 2012)*. As the environment becomes more and more complex, successful behavioural strategies become more and more elaborate. Today humans exist in a biological environment, a complex social/cultural environment, an ever increasing virtual environment, and our behaviour to satisfy various physical and physiological ‘thirsts’ is extraordinarily complex too.

Memes can be considered to be recipes or instruction manuals for doing something cultural *(Stephen, 2009)*; behaviours, words, or sounds that are copied from person to person. Furthermore, memes can be considered to be a data structure, made of information, which resides in the structure of the human brain, and behaves as a virtual machine as they cause us to do things we could not do without them. Memes such as ideologies replicate principally by producing a physiological and socio-physiological (broadly affective and emotional) stimulus in humans which in turn impels behavior.

Memes are thinking tools and primarily among them is language as words are a type of meme that can be pronounced. Words can be made of technique. That is to say that when we learn a new word a recipe for action is learnt. When we learn the word Gantt chart or cost benefit analysis, what do we learn? We might learn a new technique and in a sense remake and reattribute the structure of our brain.

In the neocortex (making up about 80% of the human brain), approximately 20–30% of neurons are interneurons. The interaction between interneurons allow the brain to perform complex functions such as learning, and decision-making.

Learning and memory are cognitive functions but they are not “the function” of cognition. The sole function of cognition is to reproduce/replicate biologically and to reproduce behaviors that support reproduction. Viewing cognitive skills as part of a whole evolving “memetic system” allows us a framework in which to examine how these processes interact together to allow humans to function as single and social cognitive units *(McNamara, 2011).*

Utilizing modern communication devices such as mobile phone applications, social networking sites, closer work with social and evolutionary scientists, one can envisage longitudinal (ranging from hours to weeks) neuroimaging experiments measuring changes in connectivity between brain regions as a component process to cultural evolution.

Conclusion

The President of Russia Vladimir Putin has often talked "about the need to introduce modern administrative technologies to solve specific tasks, about the need for dissemination of best practices, alignment mechanisms, training and engaging people with project thinking" *(Khalimon et al., 2019).* Now it is clear what kind of project thinking he was talking about. The project manager must be able to create and model a multi-factor space of interaction between people in the course of achieving the desired goals. It needs to have a certain style of thinking, the ability to properly perceive the project situation, to see the prospects for its development, to grasp the multi-factor space of interaction of various processes that form the "body" of the project.

It can be concluded that the NPM concept is based on the following principles:

1) focus on project: nothing is more important than the project that the team runs until it is completed;

2) connectionism within the team and beyond in terms of constant communication with participants, choosing a convenient form and types of interaction;

3) the highest professionalism based on scientific organization of project activities and continuous improvement in the management and subject area;

4) responsibility to team members and external parties.

The last two principles are consistent with the Japanese culture of shokunin’s work: the Manager must not only know his skills perfectly, but also have a special social consciousness and attitude. Shokunin undertakes to work as well as he can for the good of the people.

5) harmony inside and outside of the project Manager: stable physical, psychological, emotional state of the project Manager and his team members; motivation of team members and compliance of personal interests with the project goals.

Modern project management delivers cultural survival benefits to individuals and corporations, and its various behaviours and concepts are encoded genetically and memetically across our genes and culture. The memetic framework for project management contributes to the field by providing a means to debunk the 'sacred cows' of project management; it brings new understandings of how the various ideals, tools and concepts of project management deliver benefits, and to whom; and it provides an agenda for evidence based practice and the democratisation of work where project management is inculcated into the various work domains such as Health, Art, Agriculture, Commerce, etc, rather than a standalone discipline.

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Chapter 2
PROFESSIONAL COMPETENCIES OF A FLEXIBLE PROJECT TEAM MANAGER AND THE TEAM'S MEMBERS

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Abstract. *In conditions of high dynamics and uncertainty of the environment in which many projects of modern enterprises are implemented, the demand for flexible project management increases. For such management, it is necessary to form and develop flexible teams with a certain set of professional competencies. The classic competencies of the project manager and team members should be supplemented with new competencies that allow them to achieve the best results in a flexible management environment. To test this scientific hypothesis, a study was conducted to determine the most significant competencies of participants in flexible teams and their managers. The results of the research conducted by the method of expert survey at 128 enterprises in Russia are presented. The study allowed to justify the combination of new competencies of the manager and participants of flexible teams. The update applies to both professional and behavioral and contextual competencies. Special attention is paid to such competencies as: team and shared leadership, thinking and values, emotional intelligence, customer focus, cross-functionality, adaptability, and communication skills in a flexible environment. The research substantiates the concept of competence flexibility, which is considered from the point of view of the speed and quality of updating competencies and the response of members of the flexible team to changes in the factors of the project environment.*

Many contemporary projects are implemented under conditions of high dynamics and uncertainty of the environment. Under the circumstances there is a growing demand for flexible project management, which, in turn, requires that flexible teams with a certain set of professional competencies be created and developed. Classical competencies of a project manager and her/his team members should be completed with new competencies enabling attainment of the best results under flexible management conditions. These competencies include not only team cross-functionality, adaptability, and team leadership but also other competencies in human resource project neuro-management. Flexible management as a reaction to enhanced dynamics and uncertainty of the environment creates a need for using resources and opportunities of emotional intelligence, team cognitive processes, neuro-technologies, neuro-systems and artificial intelligence. Efficient use of these human and technological resources should enable a flexible team to implement projects within a shorter timeframe, quickly adapt to changing project tasks, make multi-variant project decisions, remain highly-efficient under increased stress conditions linked to a large number of changes and uncertainty of project implementation circumstances.

Despite evident demand in flexible project management and flexible teams with the relevant set of new and professional competencies on the part of organization, for the moment this demand has not been met yet. The reason for this is that practitioners and researchers do not specifically understand what competencies a flexible project team in general, and all its members in particular should possess and how these competencies could be developed.

Our research focuses on resolving this matter. The purpose of this research is to substantiate competencies of managers and project team members for working under conditions of flexible project management.

To achieve this goal, we should propose a theoretical and methodological basis for this research, conduct empirical research, draw conclusions and create a set of competencies for a flexible project team.

To propose a theoretical and methodological foundation, we should consider extant research. To start with, it stands to reason that professional competencies are well researched into in contemporary science. For example, such universally acknowledged authors in the field of the competency approach to human resource management as D. McClelland, R. Boyatzis, R. Mills, S. L. M. Spenser, S. M. Spenser, S. Whiddett, S. Hollyforde, provide a definition for competencies, describe their structure and types. Our research is based on an understanding of professional competencies as a combination of knowledge, skills, capabilities, motivation, personal qualities an employee demonstrates which empower her/him to do their job in line with what is required [3, 4, 5, 14, 17].

For the purpose of our research it is also important to consider scientific approaches to project management methodology, flexible methodologies of project management, professional competencies of a project manager and those involved in project implementation. Thus, project management matters, including human resource project management matters are studied by Polkovnikov A.V., Dubovik M.F., Tovb A.S., Tsipes G.L., Razu M.L., Yakutin Yu.V., Razu B.M., Bronnikova T.M., Titiv S.A., Larson E., Obradovica V., Cicvaric Kostica S., Mitrovica Z. et al. We have borrowed from the research implemented by these scholars the idea that project team human resource quality is important for the project success. To ensure high quality, professional management of a project team is required. This management should take into account project activity specificities [2, 6, 7, 11, 12, 13, 15, 18, 19].

Due to the increase in the degree of uncertainty and unpredictability of the project environment, a flexible approach to project management has recently come to the forefront. In particular, description of flexible project management methodologies is provided in the research of such authors as Mike Cohn, Robert S. Martin, James W. Newkirk, Robert S. Koss and others. This research does not reveal which competencies human resources engaged in projects with flexible methodologies should possess. But what is valuable for the purpose of our study is a description of the specificity of a flexible project team activity. This relates to team cross-functionality, its need to constantly exchange information on the current project state, the changes which have occurred in the project and adjustment of further actions on the part of the project team members [8, 9, 10].

Professional standards in the field of project management include description of professional competencies of a project manager. For example, the International Competence Baseline (ICB) standard, representing international requirements for competencies of specialists in the field of project management, describes a set of competencies of a project manager. These competencies are considered classical and relevant for all projects, regardless of their type and conditions under which they are implemented.

In terms of our research it is important to highlight how competencies are grouped in the abovementioned standard, i.e. behavioral, contextual, and technical competencies are distinguished [19]. In particular, we are interested in revealing which competency groups are in demand the most in the context of flexible project management. It is also important to disclose if the competencies identified in professional standards are sufficient for flexible project management.

The following summarizes our review of scientific research on the subject:

– there is a steady trend of increasing uncertainty, poor predictability and high dynamics of project environment factors. This drives the need for flexibility in project management;

– project team activity under flexible management conditions differs from project team activity under normal conditions;

– activity specificities impose special requirements on human resources of flexible projects and, in particular, on competencies of these human resources;

– traditional competencies of project managers and those who implement projects are not sufficient for efficient flexible project management.

At the same time, scientific research analysis demonstrates that for the moment there is no exact definition of flexible teams and flexible competencies needed for working on projects under conditions of flexibility. There are no detailed explanations as to which professional competencies are required for working in flexible teams. Based on these findings, we have proposed interpretations of the concepts of a flexible team and flexible competencies.

As previously noted, contemporary conditions characterized by increased dynamics and uncertainty of the environment predetermine the objective need for transitioning to flexible project management, which, in turn, requires development of flexible project teams and flexible competencies of these project teams (Figure 1).

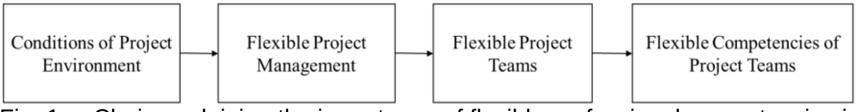

Fig. 1. – Chain explaining the importance of flexible professional competencies in line with contemporary project environment conditions

Flexibility as a scientific term means maneuverability, adaptability, ability to respond to change. Economic systems flexibility is their ability to get restructured within the shortest possible timeframe at a minimum cost. Project management flexibility is a parameter characterizing a management system property which manifests itself in the ability to get quickly restructured and functionally changed, adapted to a changing environment within the shortest (or specified) timeframe with minimal (or optimal) cost.

This definition shows that an important property of flexibility is not restructuring as such. It is restructuring with respect to time parameters and costs. A project management system can adapt well to a changing environment, but if it takes a long time and/or if different resource costs are high this system cannot be recognized as a flexible one.

Flexible management uses flexible methodologies which originated in the IT industry but are currently used in many other sectors of the economy. Flexible methodologies are understood as a set of principles, criteria, methods and methodological tools used to implement and develop project management and human resource management. Concepts of a flexible project, flexible team, flexible human resources and their competencies originate in flexible methodologies.

Human resource management flexibility is a management ability to update qualitative and quantitative parameters of team members, their competencies and behavior through changes in technologies and tools used to work with these resources to ensure adaptation in line dynamic factors of the project and organizational environment.

In practice, human resource management system flexibility can manifest itself though the variability of interconnections of project team members with each other and with other project participants, various options for uniting people in micro groups and changes in the configuration and structure of the project team, replaceability of team members and replaceability of the project team work technologies, variability of project communications, establishment of additional mechanisms and feedback technologies with the project team as a reaction to the changes taking place in the project, development of new models of behavior of the project team members in addition to established normative behavior models. Considering human resource flexibility and project management, it stands to recognize that flexibility manifests itself in the following notions: mobility, plasticity, fluidity, variability, lability, a wide range of behavioral reactions, non-standard decisions and cognitive ability. All these attributes are characteristic of a flexible team and flexible competencies.

A flexible project team is a team which uses its potential and resources to shift to new work conditions, produce an altered innovative product or service, adopt new technologies of project work under the influence of environment factor dynamics within a short period of time and at a minimum cost without stopping the team's current project work.

Flexible professional competencies are a combination of project team human resource knowledge, skills, competencies, motivation, values and personal characteristics which can be easily and quickly adapted to external conditions, developed, matched and restructured. In other words, these are those competencies which are important in terms of endowing a team with flexibility and ensuring the team's efficient work under flexible project management conditions.

Empirical research was implemented for the purpose of substantiating a set of flexible professional competencies.

The main research hypothesis was as follows: classical competencies of a manager and its team members should be completed by new competencies which should enable the manager and its team to attain best results under flexible management conditions.

The following research method was chosen: expert interviews with members of project teams working under flexible project management conditions. Expert interviews were held in 128 organizations operating in the following markets: IT, construction, manufacturing, sales, finance, services (training, consulting) in Russia.

Overall, 128 experts (managers and project team members working under flexible management conditions) were interviewed.

Research comprised three stages:

- 2016 – 32 organizations;
- 2018 – 32 organizations;
- 2019 – 64 organizations.

A relatively small research sample is conditioned by the fact that flexible project management is not sufficiently developed in organizations in Russia. Therefore, there are not so many experts available who could provide professional assessment.

Now we can consider research results and findings in more detail.

Conclusion 1. Experts have confirmed that contemporary project activity conditions are characterized by a high level of dynamics and uncertainty, which brings flexible project management to the forefront. This is illustrated by the experts' answers to the following question: "Do you agree that today projects are often implemented under conditions of quick and unexpected environmental change, uncertainty and dynamics of stakeholders' (customer's, consumers', partners') interests?". In 2016 56% (vs. 66% in 2018 and 75% in 2019) of experts agreed that these conditions prevailed (Figure 2). Therefore, we could highlight a trend towards the spread of these conditions.

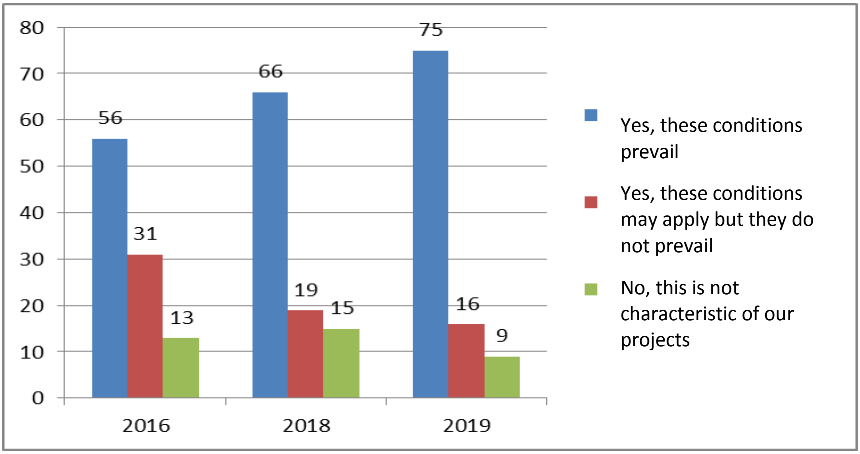

Fig. 2. Experts' answers to the following question: "Do you agree that today projects are often implemented under conditions of quick and unexpected environmental change, uncertainty and dynamics of stakeholders' (customer's, consumers', partners') interests?" (in % of those who replied to the question)

Conclusion 2. Experts believe that there is a growing need in flexible project management. Data in Table 1 illustrates this. As we can see, today project success is largely determined by the ability of the project team and its manager to flexibly adapt to changes in the project. Success also depends on risk and uncertainty management. Moreover, the abovementioned factors, according to experts, should be developed yet further and significance of these factors is increasing. From the point of view of our study it stands to reason that experts highlight the importance of the project manager and project team competencies as success factors.

Table 1

Answers to the question: "Which project success factors should be developed in your organization?"

Sample Answers	Response Rate (%)		
	2016	2018	2019
Well-planned processes in the project itself and its management	44	44	50
Competencies of the project manager and project team	57	56	69
Project management culture in the company, project activity values and norms	29	53	56
Sufficient time and resources	14	22	13

Project team's and project manager's flexibility to adapt to project change	57	69	70
Correctly identified customer preferences and expectations and orientation towards them	57	63	56
Risk and uncertainty management	44	75	77
Project manager and team member leadership	29	41	44
Motivation and engagement of the project team members	44	53	53

Conclusion 3. Experts have confirmed our suggestion that flexible project management requires flexible teams and flexible competencies of the project team members. Figure 3 shows that the organization has a strong need for teams capable of quick and high-quality adaptation, reconstruction of their competencies and work methods in line with the changing environment factors. Besides that, the need in flexible teams grew in 2019 vs. 2016.

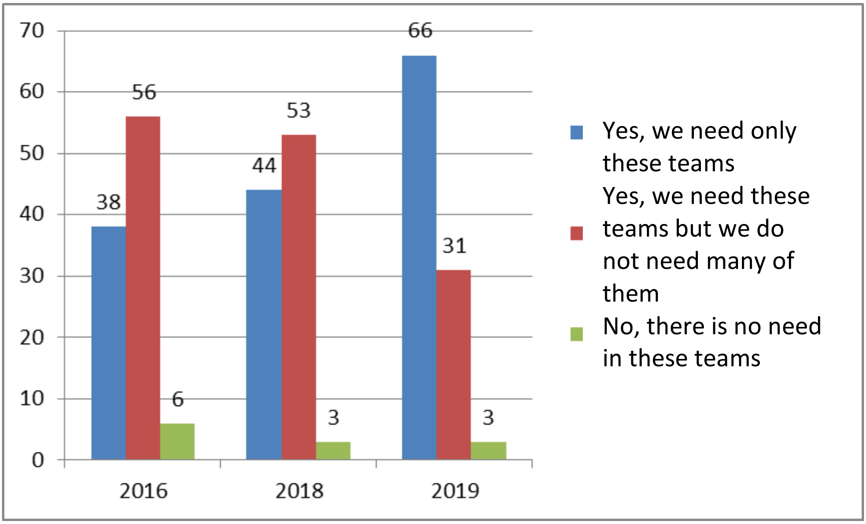

Fig. 3. – Answers to the following question: «Does your organization need flexible project teams, i.e. teams capable of quick and high-quality adaptation and restructuring of its competencies and methods of work in line with the changing environment factors?" (in % of those who replied to the question)

It is important to mention growing requirements not only for the competencies of a manger but also for those of her/his project team members. Answers to the following question demonstrate it: "Do the requirements for the project manager and those for the members of the project team differ under stable conditions and under conditions of a rapidly changing and uncertain environment?” (for the period of 2019):

– no, the requirements do not depend on the environment and conditions – 8 %;

– yes, there is a change mostly in terms of the requirements for the project manager – 19 %;

– yes, requirements for the project manager and her/his team members are changing – 73 %.

Thus, flexible conditions impose special requirements on the competencies of the entire project team.

Conclusion 4. Experts have confirmed that flexible teams require certain competencies which include not only traditional competencies but also new competencies which have not yet been fully described in different professional standards and scientific project management literature.

These competencies will be described further in the present paper. In order to understand why the need for certain competences arises, we can summarize specificities of flexible team activity.

As mentioned earlier, flexible teams have become in demand as a result of an introduction of a flexible approach and flexible methodologies to project management. Flexible methodologies are based on unforeseen changes constantly occurring during project implementation and a lack of advance planning. In particular, the customer of a project may not have a ready-made product sample, her/his preferences may change, therefore, those implementing the project should take this situation into account, act flexibly and adaptively. Flexible planning is applied under the circumstances. A flexible organizational structure (including project roles and their interaction) of the project is created. A special infrastructure is implemented. It flexibly responds to customer requests and changing requirements during product development and its service.

The main advantage is achievement of flexibility in the product creation process, i.e. the ability for real-time transformation. Process orientation flexibility and product creation process implementation flexibility are both possible. Process orientation flexibility assumes that the process allows the following:

1) change of priorities and private goals while maintaining a common goal;

2) tasks review;

3) adjustment of the combination and the content of the functions performed;

4) change in direction in the event of deviation from established guidelines.

Process implementation flexibility assumes that the process can change the following:

1) forms and methods of implementation;

2) composition and sequence of stages;

3) such parameters as duration, intervals between stages, speed, intensity etc.

When the above criteria of flexibility are achieved, the project becomes flexible and requires a flexible team. In particular, self-organizing teams operate in flexible projects. Practice shows that only self-organizing teams are able to flexibly respond to change. The matter is that splitting the product production process into short stages and frequently changing requirements leads to the fact that it is technically impossible to fully support project paperwork. Under the circumstances the team would spend more time trying to meet all the necessary requirements than creating a product. Since there is little paperwork, team members should communicate more often to solve everyday project tasks. Therefore, the team should be self-organizing to cope with the operational task workflow.

Thus, flexible technologies emphasize direct contact between all team members. Most flexible teams work at the same office. These teams include not only their main participants but also the customer or her/his authorized representative. Product users can also be part of these teama. This methodology is distinguished by regular (often daily) meetings, during which results of the previous stages are discussed and future tasks are outlined. This enables managers to control the product development process, adjusting its direction, if necessary. Prioritizing direct communication, flexible technologies reduce the amount of paperwork as compared to other direct contact methods.

Flexible methodologies are based on the following principle: all employees participating in product production should be involved in the process of rethinking her/his tasks and the common cause. Everyone can stop this production process and introduce their proposals. The team is cross-functional, it should comprise professionals of different specializations and roles. But all of them are interconnected and work, as a rule, in one room in line with the principle of “everyone doing everything”. Conflict of team member roles and their corresponding interests is overcome via flexible methodologies. Everyone is highly engaged through unification around a common goal, which consists in providing the customer with a high-quality product.

Flexible technologies require changes not only in the design culture within a team but also in the business culture of the entire organization. This culture becomes innovative, emotionally and technologically engaging employees in the production of a high-quality product, developing and supporting team and individual leadership. The thinking paradigm should also shift from the habit of executing someone's orders to the habit of collaboration.

After describing the specificities of the flexible team activity, it becomes clear why the experts have emphasized certain professional competencies of flexible team members.

In particular, experts' answers presented in Table 2 highlight the importance of the following competencies for flexile projects and flexible teams: engagement and motivation of team members, flexibility and adaptability to new conditions, leadership, resilience to stress, learning agility and the ability to quickly rebuild their competencies. Special importance is attached to the group of communication competencies: collaboration and the ability to reach agreement, tolerance to other standpoints, ability to work with professionals with different profiles. Experts believe that these competencies are not sufficiently developed, and flexible team members should bring them to the next level.

Table 2

Answers to the following question: "Which competencies are important for innovative projects with flexible teams and flexible management methods? Which of these competencies should your human resources develop?" (for 2019, in %)

Competencies	Important	Should be Developed
Creativity, open-mindedness	56	33
Leadership	61	33
Teamwork, ability to become part of a team	77	42
Communication capabilities, tolerance to other standpoints	77	56
Collaboration and ability to reach agreement	86	23
Ability to work with professionals with different profiles	70	33
Resilience to stress	70	33
Flexibility, adaptability	77	45
Engagement, motivation, loyalty	100	56
Learning agility and ability to transfer knowledge	61	23
Self-criticism	56	25

Our research highlighted the following matter: is it enough to develop classical competencies or do we need new competencies which are not mentioned in professional project management standards? To answer this question, we used in-depth interviews when conducting research in 2019. The subject of research was revealing new, previously not so relevant competencies. Research results are provided in Table 3.

Among important competencies ensuing and sustaining flexibility we could mention the following relatively new professional competencies:

– different leadership types and forms with a focus on team and shared leadership;

– team ability to organize itself, motivate itself and operate cross-functionally;

– communication competencies under stress, crisis conditions, when decisions should be taken quickly, and the level of uncertainty is high;

– customer orientation in relations between team members and collaboration with the customer and partners.

Table 3

Combination of classical and new or more specific classical competencies of a flexible team manager and its members

Classical Competencies	New or More Specific Classical Competencies
Leadership of the project manager	Team and shared leadership, leadership among leaders, transformational leadership
Project team management competencies	Self-organization and self-leadership at the team level (leadership substitutes), cross functional flexible team management
Communication competencies	Special communication competencies under stress, crisis conditions, when decisions should be taken quickly and the level of uncertainty is high, in cross functional environments
Motivation, values, reasoning	Emotional intelligence, customer orientation as a value and motivation, team self-motivation, value management, neuro systems of the person and the team
Competencies in the field of change management	Self-adaptation to the change, speed and cost-effectiveness of adaptation to the environment, self-regulation of stress, adaptation based on neuro science
Competencies in the field of risk management	Competencies in the field of self-regulation of social, psychological and other risks
Competencies in the field of knowledge management	Competencies in the field of quick and effective self-education team development through a knowledge base (lessons learned, neuro technologies etc.)

Special attention could be given to the competencies linked to intelligence and neuro management. Our research shows that nowadays the following is required for working in flexible teams: well-developed emotional intelligence, ability to think and make decisions not only at the team level but also at the individual level under conditions of multitasking and uncertainty, skills in the field of quick thought and behavioral reactions to the changing project environment factors, developed cognitive ability in the context of a quick switch to new functions and project roles, developed adaptive abilities and efficient responses to stress through the use of neuroscience techniques, learning agility and quick knowledge modification with the help of neuro-technologies.

As previously noted, neuro-systems and technologies in people and team management are under research at the moment. They are often linked to managing dynamic objects acting in enhanced dynamics of the environment, uncertainty, information complexity and, consequently, high crisis and stress factors. These conditions are often observed in terms of flexible projects. Therefore, we consider it reasonable to assume that neuro project management issues could be considered promising from the standpoint of scientific research and implementation in practice. Neuro project management matters may be considered emerging as a stand-alone neuro science field and as an area stimulating project team flexibility development. In particular, in our opinion, the following areas should be developed:

– neuro-technologies for project team work organization, including work organization in flexible teams under a higher level of stress, dynamics, uncertainty etc.;

– making management decisions in flexible project teams based on neuro sciences;

– development of flexible competencies of project team members with the help of different technologies, including neuro technology;

– knowledge management, creating knowledge bases based on gained experience, example and data base-driven training and development of project teams, machine learning, training with the help of neuro management methods;

– management of the life quality of managers and team members under flexible conditions (increased stress, multi-subject and multi-functional activity, increased demand in adaptive capability etc.)

Nevertheless, these suggestions require additional research. One of our research results is the following hypothesis which should be tested in terms of further research: neuro technologies and systems include a group of significant methods/practices aimed at developing flexibility of a project manager and project team members; neuro project management promotes flexibility.

Conclusion 5. The experts' answers provide grounds for the following conclusion: the major part of the required flexible competencies may be classified as behavioral in accordance with the ICB IPMA standard. Thus, experts believe that a flexible team requires the following:

- behavioral competencies (determine 40% of flexible team success based off the experts' opinion) – alignment, negotiation, leadership, engagement and motivation, combination of result and people orientation etc.;
- technical competencies (25% of flexible team success) – team management while taking into consideration its cross-functionality and flexibility, change management, risk and uncertainty management, stakeholder management;
- contextual competencies (35% of flexible team success) – flexible technologies of product development, flexible human resource management, managing the combination of project, program and project portfolio sustainability and flexibility (new emerging competency).

Conclusion 6. Methods and methodologies of flexible competency assessment and development should be brought to the next level.

This is conditioned by the fact that project human resources are not often ready to work under conditions of uncertainty, they lack flexible competencies to this end (Table 4).

Table 4

Answers to the question: "Please, assess to what extent human resources of your company are ready to work on projects distinguished by novelty, unpredictability, increased risk and uncertainty, lack of defined action algorithms"

Sample Answers	Response Rate (%)		
	2016	2018	2019
Fully Ready	14	16	14
Partly ready, but important qualities development is needed	72	56	67
Not so ready, because it is difficult to get ready for these conditions in advance	14	28	19

In conclusion, we have implemented research enabling us to substantiate a set of new competencies of a flexible team manager and the team's members. Professional, behavioral and contextual competencies are reinvented. Special attention is given to such competencies as team and individual leadership, values, emotional intelligence, customer orientation, cross-functionality, adaptability, communication competencies under flexible conditions. Special focus is on those competencies which are linked to brainwork and cognitive processes in flexible team activity. Consequently, we may conclude that new competencies of a flexible project team should be developed. Neuro-science and neuro-management methods would play an important part in it. It is necessary to analyze and conduct research in possibilities of applying neuro-technologies in project management in view of efficient organization of the activity performed by a flexible team.

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Chapter 3
MODERN METHODS AND TECHNOLOGIES FOR STUDYING NEURAL ACTIVITY OF THE BRAIN

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Abstract. *By the end of the XX century, magnetic resonance imaging (MRI) and X-ray computed tomography (CT) were firmly established in clinical practice, revolutionizing approaches to the diagnosis of diseases in almost all areas of medicine. This fully applies to neurology, which, thanks to MRI and CT, has been enriched by the unique experience of clinical and neuroimaging comparisons [Vereshchagin, Bragina, et al., 1986]. The appearance of high-field MR-tomographs and ultra-fast pulse sequences opened up new diagnostic possibilities for neuroimaging in assessing the speed of diffusion processes, local and main blood flow, cerebrospinal fluid flow, etc. [Kornienko, Pronin, 2006]. The further evolution of neuroimaging went along the way of increasing the speed of obtaining images from MRI and CT scanners, creating new technologies for recording data, and algorithms for processing them. Currently, the widespread use of high-field magnetic resonance and multispiral X-ray computed tomographs allows not only to study structural changes in the Central nervous system, but also to evaluate the cerebral metabolism, blood flow and functional state of certain parts of the brain. Such techniques as perfusion MRI (CT), diffusion-weighted and diffusion-tensor MRI, voxel MRI morphometry, MR spectroscopy, functional MRI, etc., which were recently considered the latest promising directions in neurorentgenology, are now widely used in a variety of fundamental and applied research. Thanks to this, neuroimaging has become an independent complex discipline that largely determines the prospects for the development of all neuroscience.*

Introduction

Understanding the brain at multiple scales requires the integration of anatomy and physiology with cognitive and systems neuroscience to flesh out the neural mechanisms underlying cognition—e.g., in object recognition, visuomotor control, episodic memory, sleep, wakefulness, and consciousness. To this end, researchers combine experimental studies in rodents and humans, integrate data in computational models and simulations of large-scale neuronal networks, and simplify and apply these models to control physical robots or simulated agents in order to capture essential features of animal and human behavior. Neuroscientists working on the cellular or molecular level exchange results with researchers working in cognitive and systems as well as theoretical neuroscience to cast neurobiological principles into new theories and formal models, which then prompt simulation studies and the development of neuromorphic computing systems. There is still no comprehensive theory describing information processing in the brain, but important building blocks can be won through these approaches and may constitute the basis for such a theory in the future.

Methods of neuroscience: functional near - infrared spectroscopy.

In recent years, in the field of medical physics and biomedical engineering, a number of new methods of brain imaging have emerged, which have allowed scientists to obtain much more accurate data on the structure and organization of the human brain, both healthy and in a number of diseases. One of these methods is functional near - infrared spectroscopy (fNIRS). This is a non-invasive, relatively cheap and simple brain imaging method that allows you to measure the level of blood oxygenation by hemoglobin in various areas of the brain (Fig. 1). This method has insignificant exclusion criteria and high environmental validity [*Sitnikova, 2016*].

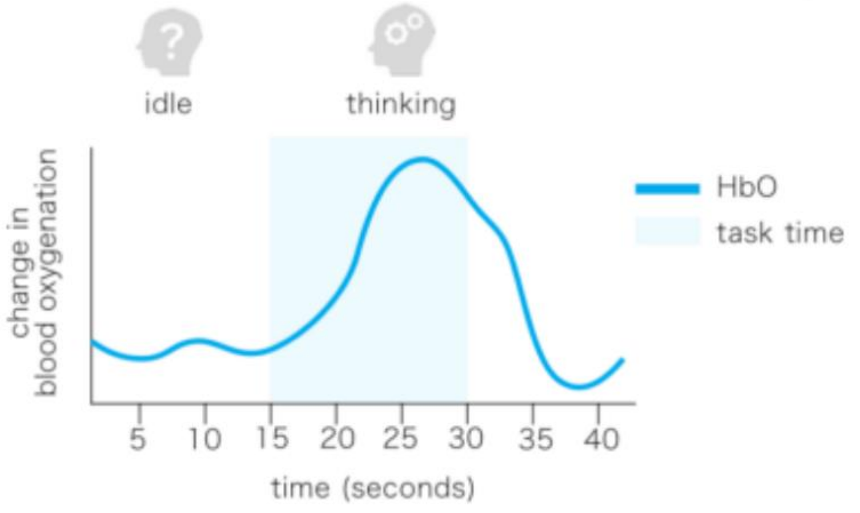

Figure 1. How blood oxygenation changes as measured from a fNIRS sensor

The application of neuroimaging tools (e.g., fNIRS) is pivotal to better understand the influence of physical-activity-induced mechanisms on cognitive performance. Based on the advantages of fNIRS, this neuroimaging method is a promising tool to shed light on physical-activity-induced functional brain changes (e.g., changes in cortical hemodynamics during cognitive testing) [*Herold et al., 2018*].

However, the introduction of fNIRS technique in neuroscience has considerably expanded our understanding of the neural basis of cognitive processes contributing to educational practice, developmental changes, and social cognition and interaction. To come closer to more standardized protocols, the systematic research should summarize the methodological details of studies applying fNIRS to investigate the influence of physical activity on cognitive performance and underlying neurobiological processes (e.g., cortical hemodynamics).

Methods of neuroscience: diffuse optical tomography.

The logical extension of fNIRS is diffuse optical tomography (DOT). It allows using infrared radiation to measure the optical absorption (light absorption) of hemoglobin, based on its absorption spectrum depending on oxygen saturation (Fig. 2).

DOT is a brain imaging technique that allows to create three-dimensional images [*Lee, Cooper, Topun, 2017*]. Its main advantage over other methods is the ability to track the dynamics of blood flow in brain tissues at different depths, while excluding changes in oxygen saturation in other tissues, such as the skull or scalp. In addition, since DOT uses infrared radiation, it is harmless in contrast to, for example, computed tomography, in which the image is formed from layer-by-layer x-rays.

No method is perfect, and DOT is no exception. To date, there are several problems that researchers have to solve when working with DOT. Due to the size and weight of optical fibers, their maximum number is limited, especially when working with children [*Lee, Cooper, Topun, 2017*]. Therefore, researchers have to choose between placing them all over the head at a great distance from each other and focusing on one area for a more thorough study of it. In addition, head movements can affect the quality of the study – they cause short-term high-amplitude bursts of intensity. The main factor that does not allow improving the results of DOT is still a limited number of optical fibers.

However, the technology is rapidly developing and the fibers may no longer be needed. But the advantages of the method are still much more than the disadvantages. Further improvements in technology will make research equipment cheaper and more compact.

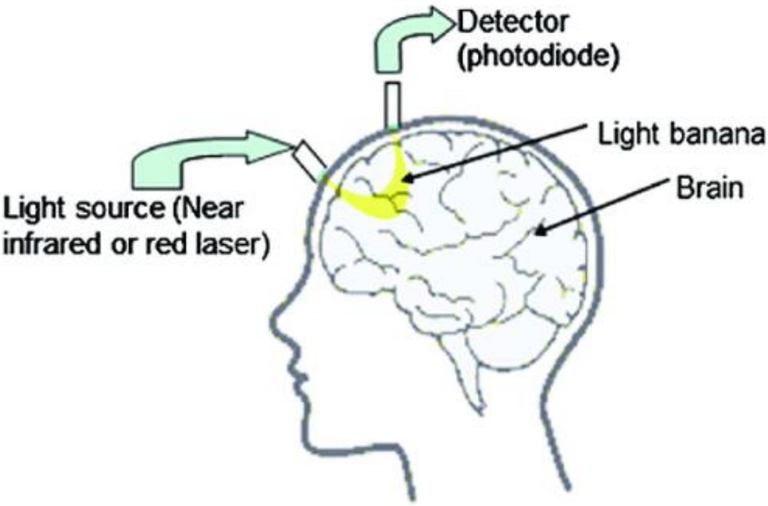

Figure 2. Principles of the diffuse optical tomography [Source: *Tsytsarev et al., 2012*]

Methods of neuroscience: optogenetics.

For years, neuroscientists have wanted to understand how behavior and cognitive activity are related to neural circuit activity. To explore these questions, researchers initially used a time-consuming and imprecise pharmacological methods of electrical stimulation for the control of neuronal activity. However, when there are different classes of neurons communicating through extensive, complex networks and fast electrical signals, it is necessary to identify a method with high spatial and high temporal resolution for precise control of individual neurons and cause-effect decoding of the activity function of neural circuits.

In 1979, Francis Crick proposed a new solution: using light to control a neuron (*Boyden et al. 2005*). Derived from this very idea and with the efforts of many other scientists, the revolutionary technique of optogenetics was born.

Optogenetics, a genetic method for activating or inhibiting individual neurons with light, was invented in 2005 by Karl Deisseroth and Edward Boyden (Boyden et al. 2005). Notably, the development of optogenetics began with the discovery of Peter Gegemann, who successfully expressed the depolarizing blue light opsin, the rhodopsin-2 (ChR2) channel, in cell culture (*Nagel et al. 2003*).

Building on these findings, Deisseroth and Boyden virally expressed ChR2 in neurons, they demonstrated for the first time that neurons can be activated by blue light (*Boyden et al. 2005*).

Optogenetics has benefited many scientific fields by allowing scientists to monitor the activity of various cell types with millisecond accuracy. A big advantage for neuroscientists is that optogenetics has been adapted for use on rodents, primates (Fig. 3), free-living nematodes, Drosophila, and Danio-rerio to study neural correlations of cognitive activity and behavior.

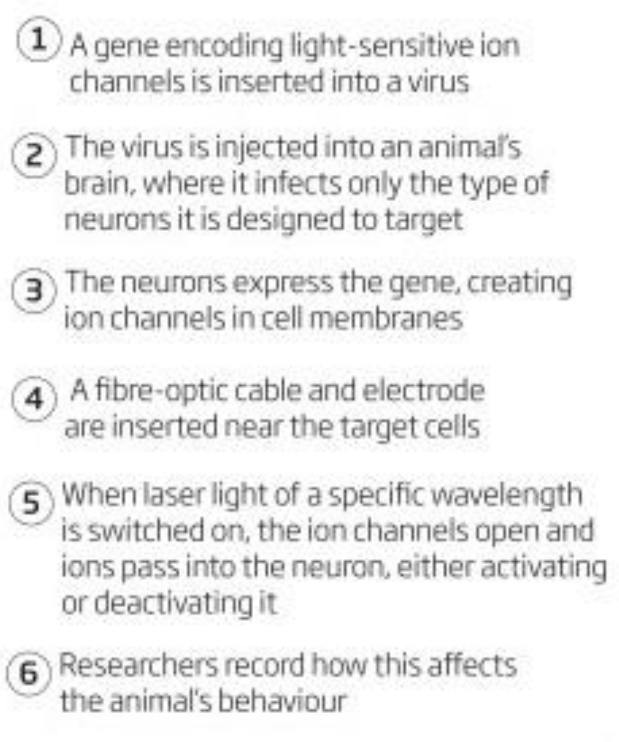

Figure 3. Six steps in optogenetics. Stages of the experiment [Source: *Burrell, 2016*]

Methods of neuroscience: magnetic resonance imaging.

Magnetic resonance imaging (MRI) is a method for obtaining images of human internal organs based on the phenomenon of nuclear magnetic resonance (NMR).

The human body contains a large number of protons-the nuclei of the hydrogen atom: in the composition of water, in each molecule of organic matter-proteins, fats, carbohydrates, small molecules… A proton is one of the few atoms that has its own magnetic moment or direction vector. In the absence of an external powerful magnetic field, the magnetic moments of protons are randomly oriented, that is, the arrows of the vectors are directed in different directions.

If an atom is put in a strong permanent magnetic field, everything changes. The magnetic moment of hydrogen nuclei is oriented either co-directionally to the direction of the magnetic field, or in the opposite direction. In the second case, the energy of the state will be slightly higher. If you now affect these atoms with electromagnetic radiation of a resonant frequency (fortunately for us, this is the frequency of radio waves, which is absolutely safe for humans), then some of the protons will change their magnetic moment to the opposite. And after disabling the external magnetic field, they will return to their original position, releasing energy in the form of electromagnetic radiation, which is recorded by the tomography (Fig.4).

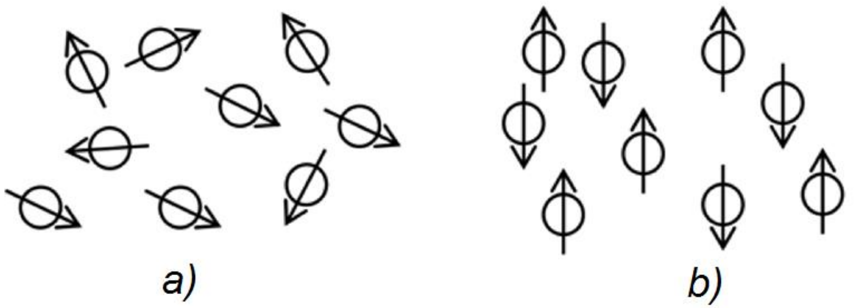

Figure 4. Orientation of the magnetic moments of the nuclei
a) in the absence of an external magnetic field
b) in the presence of an external magnetic field

In addition to the study of large objects-humans and animals, there are other ways for researchers to use magnetic resonance. For example, MR-microscopy, which is perhaps the most powerful tool for studying the brain at the molecular level.

Methods of neuroscience: functional magnetic resonance imaging.

MRI gives the researcher a lot of information about the anatomical structure of an organ, tissue, or other object that falls within the field of view. However, there is not enough data on functional activity to form a complete picture of the processes taking place. And for this purpose, there is a BOLD-functional magnetic resonance imaging (BOLD-blood oxygenation level dependent contrast, or contrast, depending on the degree of oxygen saturation of the blood).

Functional magnetic resonance imaging (fMRI) is a powerful, non-invasive tool that visualizes brain activity. The related techniques of event-related (task-based) fMRI, resting-state fMRI (rs-fMRI), and real-time fMRI (rt-fMRI) are widely used in research. This important subfield of translational neuroscience—particularly when combined with other approaches—is contributing to the diagnosis and treatment of neurobehavioral problems and psychiatric disorders.

In one important area of translational research, the development of biomarkers for diagnosis and prognosis, scientists are integrating fMRI findings with new technological approaches. The most promising new approaches, driven by advances in molecular biology and bioinformatics, come from fields where scientists are mapping the entire complement of an important biological entity—including genes (genomics), proteins (proteomics), or metabolites (metabalomics). These studies attempt to integrate all that is known about the biology of an entire system, including how all the components interact with each other and the environment to determine health and disease (*Petrella et al., 2008*). Although identifying the totality of these biological entities requires substantial groundwork, the payoff in terms of understanding individual vulnerability to diseases is expected to be enormous.

BOLD-fMRI is one of the most applicable and well-known ways to determine brain activity. Activation leads to increased local blood flow with changes in the relative concentration of oxygenated (oxygen-rich) and deoxygenated (oxygen-poor) hemoglobin in the local bloodstream.

Deoxygenated blood is a paramagnetic (a substance that can be magnetized) and leads to a drop in the MRI signal level. If there is more oxygenated blood in the brain area – the MRI signal level increases. Thus, oxygen in the blood serves as an endogenous contrast agent.

To activate the work of neurons in certain areas of the cortex, there are special activating tasks. Task design is usually of two types: "block" and "event-related". Each type assumes the presence of two alternating phases – active state and rest. In clinical fMRI, "block" tasks are more often used. When performing such exercises, the subject alternates between the so - called ON - (active state) and OFF - (rest state) periods of equal or unequal duration. For example, when determining the area of the cortex responsible for hand movements, tasks consist of alternating finger movements and periods of inactivity, lasting on average about 20 seconds. The actions are repeated several times to increase the accuracy of the fMRI result. In the case of an "event-related" task, the subject performs one short action (for example, swallowing or clenching his fist), followed by a period of rest, while the actions, in contrast to the block design, alternate unevenly and inconsistently.

In practice, BOLD-fMRI is used for preoperative planning of resection (removal) of tumors, diagnostics of vascular malformations, and operations for severe forms of epilepsy and other brain lesions. During brain surgery, it is important to remove the lesion as accurately as possible, while at the same time avoiding unnecessary damage to neighboring functionally important areas of the brain.

The method is very effective in the study of degenerative diseases, such as Alzheimer's and Parkinson's, especially in the early stages. It does not involve the use of ionizing radiation and radiopaque substances, in addition, it is non-invasive. Therefore, it can be considered quite safe for patients who need long-term and regular fMRI examinations. FMRI can be used to study the mechanisms of formation of epileptic attacks and avoids the removal of the functional cortex in patients with intractable frontal lobe epilepsy. Monitoring the recovery of the brain after strokes, studying the effects of medications or other therapies, monitoring and controlling the treatment of psychiatric diseases – this is not a complete list of possible applications of fMRI.

In addition, there is also rest fMRI, in which complex data processing allows you to see the brain networks that function at rest.

Methods of neuroscience: electroencephalography.

Electroencephalography (EEG) is a method of studying the brain, with which you can "read" its electrical activity and present the results as a graphic image (Fig. 5).

The brain is a very complex structure, it constantly has complex oscillatory electrical processes that can be registered by placing electrodes on the surface of the brain substance, if the cranial box is missing (electrocorticography) or on the scalp. In the nuclei of the thalamus, which is located in the midbrain, there are special generators of action potentials that send impulses along the thalamocortical fibers to the neurons of the cortex. However, the rhythm of activity can also be determined by the activity of neural networks in the cortex itself.

Figure 5. Example of an EEG of a patient

Impulses coming from the thalamus are received by the dendrites of the pyramidal cells of the cortex and cause an electrical response in them in the form of a postsynaptic potential (in other words, the membrane of the "receiving side" is excited). Here, local extracellular currents appear, which spread and "flow" in the area of superimposing electrodes.

Some researchers say that the EEG does not generally reflect the activity of the brain as a whole, as is commonly believed, but only the activity of the first layer of the cortex, which consists of closely intertwined dendrites of cortical neurons. The main task of electroencephalography at present is to assess the functional activity of the brain, while anatomical defects can be detected by a variety of other methods. The role of EEG in the study of epilepsy is particularly important. The role of EEG research in the field of functional disorders has increased: emotional, cognitive, neurotic and behavioral disorders, and psychiatric diseases. For a very long time, EEG is used in sleep research – in somnology.

The latest methods of processing EEG data allow you to create absolutely fantastic ways to use EEG – the so-called "brain-computer interfaces". In the future, this method will allow you to control various devices literally "by the power of thought".

Methods of neuroscience: magnetoencephalography.

Nerve cells actively generate and conduct weak electrical impulses, and this is directly related to the process of processing the information received by the brain. Because of this work, an electromagnetic field is formed, which, of course, has an important component – the magnetic field.

The contribution of each individual neuron is small, but being at a particular site in a large number (for example, 50,000-100,000 neurons), they are able to create a field that can already be detected by highly sensitive magnetometers. The activity of this field differs in healthy brain cells and in abnormalities, for example, during an epilepsy attack or post-stroke condition, so it must be studied. And this is what magnetoencephalography does.

The effect of the method itself can be imagined as a huge stethoscope (in the form of magnetometers and gradiometers), which is able to detect the magnetic "rhythms" of the brain. The MEG method is non-invasive and non-contact. The device is a "helmet", which is "put" on top of the patient's head. In fact, it is a scanner that has many shielded sensors or sensors that read the magnetic fields of the brain. MEG uses magnetometers and/or gradiometers as sensors. Magnetometers pick up the signal and are more sensitive to the fields of deeper parts of the brain, but they are also good at “catching” extraneous noise. Gradiometers filter this noise better, but, as you might guess, they are also slightly less sensitive to the brain's magnetic field.

The MEG method is used both in scientific research of brain activity and in medicine to monitor the condition of patients. There is always background activity in the brain, but there is also activity caused by external influences. Scientists are interested in exploring what stimuli and how it changes. It is also interesting to understand how the child's brain develops and learns, what processes occur when a person grows up and when they age.

Methods of neuroscience: transcranial magnetic stimulation.

Using magnetoencephalography for medical and scientific purposes, it became possible to study the activity of neurons. But there is also a method of transcranial magnetic stimulation (TMS), which, unlike magnetoencephalography, does not register magnetic fields, but generates them itself.

In fact, there is a generator that is located at a close distance to the person's head. It affects small areas of the brain with an alternating magnetic field, causing depolarization or hyperpolarization in neurons. Depending on the frequency with which the pulses are generated, the stimulation has a retarding or exciting effect. TMS is used in science to understand which parts of the brain are responsible for what, how they interact with each other, and in medicine – directly for the diagnosis and treatment of diseases of the nervous system. Basically, they study and stimulate the brain, but TMS is also used for other structures of the nervous system, such as the spinal cord and peripheral nerves.

One of the most important and relevant areas of stimulation use is in the treatment of depression. As a result, often the symptoms of depression weaken or disappear altogether, although the effect sometimes does not last long.

In addition to depression, TMS is used for demyelinating diseases, spinal cord injuries, trying to improve the condition of patients after a stroke, migraines, Parkinson's disease.

Methods of neuroscience: positron emission tomography.

Medicine knows a lot of cases when apparently healthy people were found to have advanced malignancies, either involving a variety of regional lymph nodes, or even with metastases to other organ systems. At the same time, people previously could even be examined by x-rays or CT scans. Very accurately, brain tumors – for example, gliomas – are seen by MRI. But sometimes in order to find the tumor process at an early stage of development, it is not enough even ultra-accurate "photos" of internal organs. In addition, you really want to see the activity of the brain-and functional magnetic resonance imaging may not be enough. And then positron emission tomography or just PET comes into play.

The main physical principle in PET is the annihilation of matter and antimatter. We need a short-lived isotope that decays by beta (+) decay, emitting a positron discovered in 1932 in cosmic rays, an antiparticle to an electron. We make an organic molecule labeled with an atom of this isotope – a so-called radiopharmaceutical that is injected into the body. In the body, the atom decays, the positron collides with the first atom on its way, interacts with the electron. They annihilate by emitting two energetic photons-gamma quanta.

In neuroimaging, glucose is most often chosen as a biologically active compound, which is labeled with the isotope fluoro-18 with a half-life of just over 109 minutes. Our brain takes up only two percent of our body weight, but consumes 20% of all energy. And it takes energy from glucose. PET is also used in the diagnosis of Parkinson's disease, and then a radiopharmaceutical based on levodopa is synthesized.

After that, the radiopharmaceutical should be delivered as quickly as possible to the diagnostic center, where it will already be introduced to the patient and the registration procedure will be performed. Large PET centers have their own cyclotrons, which makes the situation easier, but there are countries where radiopharmaceuticals are made centrally, and then airlifted to medical centers.

The duration of the procedure takes about one and a half to two hours. A little more than half an hour is allocated for the distribution of the drug to the tissues, and then the person is put on the couch of the scanning device and a picture of the metabolic activity of the tissues is visualized. The affected organs capture the drug most strongly, and more energy is released in their zone, so they begin to glow in the image, thus marking the problem. In order to achieve special accuracy, a CT scan is performed during PET, and the images are superimposed on a color image of the metabolism, allowing you to see the site of the lesion as clearly as possible and already form a treatment strategy.

If we examine the activity of the brain (Fig. 6), PET provides better resolution and a smaller time delay than fMRI. Mass application of this method in neuroscience prevents only one thing: it is very expensive.

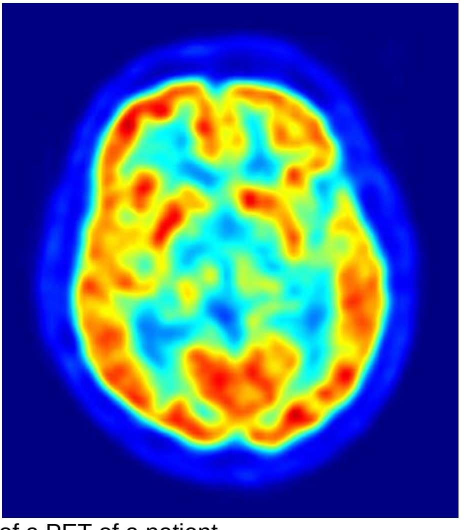

Figure 6. Example of a PET of a patient

PET has several main advantages: first, the method allows you to examine all the organs at once, while having a radiation dose comparable to CT. Second, it "sees" the slightest changes in tissue metabolism long before an organic focus is formed. This is not possible with a conventional x-ray, ultrasound, or even MRI. Third, positron emission tomography can determine the size of even minor metastases up to a few millimeters in diameter, clarify their localization, and track the effectiveness of the prescribed treatment. By the way, the accuracy of standard CT ranges from 80%, while the accuracy of PET reaches 90-95% with the same safety and painlessness.

But there are disadvantages. First, the need for fast delivery of radiopharmaceuticals. Of course, the half-life of 18F does not mean that after 109 minutes you will have nothing left, but, nevertheless, the activity of the drug during this time is reduced by half. Well, in addition, the method is very expensive, because the RFP is prepared for each individual patient just before the procedure. PET-CT of the brain in Russia costs more than 40,000 rubles. Do not think that in other countries it is cheaper, on the contrary: the recommended price in the UK is about 700 pounds, in Canada – 1200 canadian dollars.

In addition to neuroscience and Oncology, positron emission tomography can detect disorders in the blood supply, so it can be used to diagnose heart ischemia, as well as using it to find old myocardial infarctions in the foci of reduced blood flow. PET is also productive in clinical neurology: it perfectly determines the foci of increased activity in epilepsy, which makes it possible to clarify the scope of surgical intervention, as well as to find at an early stage and make a differential diagnosis between different neurodegenerative diseases.

Conclusion

In order to understand the brain at the level of individual neurons and synapses, scientists often build computer models of neuronal circuits or particular brain regions. However, while some regions, such as the visual cortex, have been the focus of many such studies, other areas of the brain are largely ignored, and a comprehensive model that can simulate activity across the entire brain does not yet exist. In order to create whole-brain models, the researchers have been developing different tools and equipment during the last 70 years.

Current imaging technology forces a choice between portability and high image resolution. Large, “bolted-to-the-floor” equipment, such as those used for magnetic resonance imaging (MRI), magnetoencephalography (MEG), and traditional PET, provides high-resolution images but requires the participant to remain completely still. Others, such as electroencephalography (EEG) and near-infrared spectroscopy (NIRS), work with a moving subject, but they have very low spatial resolution and do not reveal structures deep within the brain, such as the hippocampus (used in memory and navigation) and the amygdala (important for emotion). New technology allows researchers to characterize the differences between healthy and diseased neurons like never before. Using human cells from patients with neurological disorders and healthy controls, the new strategy will help identify what goes wrong in different diseases. Different cell types in the brain vary in subtle ways, and understanding these differences might explain why some cells become diseased and how to make drugs that can correct the problem. However, for ethical reasons, studying human brain cells has always been difficult and expensive and some researches are still of top secret.

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Chapter 4
PROJECT MANAGEMENT AT AN EARLY STAGE OF THE INNOVATION PROCESS

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Abstract. *Today there is an increasing demand for innovation. Companies, venture capital funds, business angels are looking for innovative investment ideas. Universities are seen as one of the sources of such ideas. However, there are many difficulties with project management in which various stakeholders are involved: scientists from the university, venture funds, and companies. Moreover, in the early stages of the innovation process, the risks significantly increase that the project will not be successful. This is enhanced by the fact that each stakeholder in the project has his own interests: a scientist, wants to get new knowledge, business - to earn money and get a return on investment.*

On the other hand, the evolution of the life cycle models of the innovation process changes from linear to non-linear models. And it becomes obvious that the formation of a joint "boiler of innovation" on the basis of a university with interdisciplinary knowledge and a culture of cooperation can provide a steady stream of innovative ideas, technologies, and often innovative products of a high degree of maturity.

The study focuses on the development of methods for managing innovative projects at an early stage of the innovation process; involving various participantsscientists, business, venture industry to create and manage a steady stream of breakthrough innovative projects.

One of the main values of innovations is their influence on the development of the country's economy, primarily through increasing productivity *(Volkov et al., 2011)*.

In turn, the main catalyst for stimulating knowledge-based growth in many countries is universities, because to ensure success in knowledge-based economic development, key positions are needed: creating the highly qualified human capital that industry needs and capitalizing on research through a successful technology transfer for business applications *(Ross DeVol et al., 2017).*

The research should begin with the disclosure of the term "innovation".

In the 30s of the XX century, J. Schumpeter introduced the concept of "innovation" as "a change to introduce and use new types of consumer goods, new production assets, markets and forms of organization in industry" *(Schumpeter, 1982).*

At that time, "innovation" was perceived primarily as an internal process of an organization or system, allowing it to change the production of a competitive product.

However, today an increasing number of companies are tending towards a transition from the traditional, "closed" model of innovation, involving the creation of innovations on their own, to the model of "open" innovations *(Arkhipov, 2012).* According to the definition of G. Chesbrough, introduced in 2003, "The model helps the firm create value throughout the value chain and then positions the firm to capture some portion of that value" *(Chesbrough, 2003).* In the Chesbro model, greater preference is given to external sources as an unlimited number of possible sources against a single resource within the organization. This new paradigm makes it possible to distribute roles in the chain of creating innovation since research is carried out in some organizations and consumed in others, which allows universities to increase the market for their own research.

What technologies exist for managing network projects, or resources of several organizations? Can competent management of such "network" projects lead to a reduction in the time needed to create an innovation?

Changes are also taking place in project management. In the previous stages of the development of the methodology, the main issues were schedule management - we all know network schedules, then risk management and others. Then, project management turned into a tool for implementing the strategic goals of the organization. But, when we talk about managing network projects, the main issue is in the resource management zone. This section may answer the question - is the project possible in principle? But if we look more broadly at the resources of several organizations, we can conclude that the competent management of resources can become a source of projects, and can often contribute to the accelerated development of innovative projects.

Trends:

− The importance is growing not of "direct ownership of resources", but of gaining access to them (example: centers for the collective use of expensive equipment that one company cannot afford to buy, or an industrial collaboration for the release of one product by several manufacturers);

- The amount of information increases exponentially: as a result, vertical hierarchical structures become ineffective, since the first person does not have time to make all decisions, and employees below do not know and do not have time to find out what is in their organization in another department. The result is the purchase of equipment, knowledge, etc., which are already in the organization. It is necessary to move to horizontal integration, which will significantly save resources and not do "double work".
- Globalization and simplification of communications today have led to the fact that, on the one hand, processes can be managed from anywhere in the world, on the other hand, there is still an overproduction of resources. For example, to make a successful business, the company provides several parallel processes: production, customer search, research and development of an improved or new product. At the same time, on a global scale, for almost any product, there is an organization that owns a sales network, and an organization that conducts research in this area. Collaboration greatly simplifies time and reduces resource costs.

Consequently, the implementation of projects for network interaction and the use of distributed centers of production, research, sales, based on the existing structure, rather than creating a new one, becomes relevant. This approach saves time, money, and also reduces the risks of project implementation (since there is not only an idea, but also the presence of end-users who can get feedback on the project being created).

Currently, for a more effective existence and effective development, an organization must use not only internal resources, but also external ones - resources belonging to other interested parties (partners, customers, suppliers, etc.). Consequently, the creation of joint partnerships and collaborations not only saves time and financial costs, but also leads to significant resource savings due to their synergy in general and to minimize risks in the future.

The implementation of such projects does not come from the goal, but from the competent (economical) resource management (with an understanding of the specific situation at every minute). This approach is more flexible, as it easily adapts to changing conditions, but also requires new competencies:

- ability to combine resources;
- ability to organize collaboration projects - for joint resource management;

– multicultural management (as different organizations have their own corporate culture);

– horizontal translation of knowledge (building the Knowledge HUB) - for quick and unhindered management;

– resolving issues with confidence and new mechanisms that simplify sharing, with sole ownership;

– the ability to quickly assess the direction of the path according to the strategies of the main project participants.

Implementation of network interaction projects is becoming an increasingly relevant topic. A similar trend in network interaction is also observed in the conduct of industrial policy - the implementation of projects within the innovation ecosystem is becoming more promising, which in turn also requires synergistic interaction between organizations. However, the implementation of this approach requires intensive research and the development of relevant adaptive models for the effective management of various types of resources when implementing network projects

These and other issues have been closely studied in project management methodologies within the same organizational structure. But the methods studied are poorly suited when we talk about several peer organizations of participants, as well as for large vertically integrated structures.

The study analyzed approaches to the study of “open systems”, starting with a systems approach.

A systematic approach is the direction of the methodology of scientific knowledge, which is based on the consideration of an object as a system: an integrated complex of interconnected elements (I.V. Blauberg, V.N. Sadovsky, E. G. Yudin); aggregates of interacting objects (L. von Bertalanffy); totality of entities and relationships (A.D. Hall, R.I. Fagin, late L. von Bertalanffy).

Closely related to the systems approach and is a concretization of its principles and methods, the general theory of systems. The general theory of systems (systems theory) is the scientific and methodological concept of the study of objects representing systems. The first version of the general theory of systems was put forward by Ludwig von Bertalanffy.

Modern research in the general theory of systems should integrate the achievements accumulated in the areas of the "classical" general theory of systems, cybernetics, systems analysis, operations research, systems engineering and synergetics.

Von Bertalanffy also introduced the concept and explored “open systems” - systems that constantly exchange matter and energy with the environment.

One of the results of the mid-20th century was the development of a number of scientific and technical research areas. For example, cybernetics has arisen as a result of research and development on the automation of anti-aircraft installations. A number of studies continue, such as "system analysis" of the famous American corporation "RAND" (created in 1948) and the British "study of operations", which later joins systems engineering ("system engineering" in the Soviet translation). The integration of these scientific and technical areas into the basic structure of the general theory of systems enriched and diversified its content.

Non-trivial approaches to the study of complex systemic formations are put forward by such a direction of modern science as synergetics, which offers a modern interpretation of such phenomena as self-organization, self-oscillations and co-evolution. Scientists such as Ilya Prigogine and Herman Haken, in their studies, turn to the dynamics of nonequilibrium systems, dissipative structures, and the production of entropy in open systems.

Today, the world is transforming from rigidly structured systems aimed at achieving a specific goal, within the framework of a single set plan, to a more flexible one based on constant monitoring and resource management, taking into account the changes that take place and clarifying the goal during implementation. This approach allows you to experiment, create breakthrough technologies, while analyzing the prospects in the early stages, and not wasting time on the long process of coordination and planning.

Project management models are also changing: from the popular and well-known international standards PMI (Project Management Institute), IPMA (International Project Management Association) to flexible Agile, Scrum management systems. However, the issues of integrated resource-efficient management in the face of uncertainty of objectives (due to the variability of the external environment) are only just beginning to be raised and explored.

It should be noted that the issues of innovative development are given significant attention in the works of a number of foreign and Russian researchers: J.A. Schumpeter, T. Amabile, P. Drucker, G. Mensch, R. Nelson, M. Porter, J. Stiglitz, G.A. Balykhin, S.Yu. Glazyev, S.A. Dyatlov, V.I. Zinchenko, N.I. Ivanova, A.S. Kazantsev, D.S. Lviv, V.D. Markov, L.E. Nikiforova, V.V. Titov, Yu.V. Yakovets.

The issues of innovation project and process management systems are reflected in the works of the following researchers: Frank J. Fabozzi, I. Nonaka, D. Ronggui, W. Sharpe, S. Schmidt, H. Takeuchi, G.S. Altshuler, V.I. Voropaev, O.V. Lavrov, N.K. Moiseeva A.V. Polkovnikov, A.S. Tovb, G.L. Tsipes.

In the above studies, the following concepts can be distinguished, which indicate the possibility of using for the rapid development of your project, company, large-scale organization of resources not only internal but also external, belonging to other persons. This helps not only save time but also on a global scale leads to significant resource savings and the solution to the problem of overproduction.

1. Outsourcing,
2. Open Innovation. Developed in the 60s of the 20th century at the Haas School of Business at the University of California.
3. Crowdsourcing. The term was introduced in 2006.
4. Crowdfunding. It began to develop in the 2000s.
5. Co-creation. Designed and published in 2000 by Harvard Business School Press

The listed concepts working with “external resources” have disadvantages. All of them allow solving an applied problem when a task is formed. And only Co-creation allows you to ensure the search process of the task itself. There is a need to develop modern models of innovative project management at an early stage, where there is great potential, for the formation of initially resourced projects.

The purpose of the research is to develop theoretical and methodological recommendations for managing innovative projects at an early stage. To achieve this goal, the following steps were taken:

Firstly, a comprehensive analysis of the available theoretical and methodological approaches to the study of the evolution of the innovation process. The main research methods and techniques: a critical analysis and generalization of theoretical, methodological and methodological approaches to the development of the life cycle of the innovation process. In particular, the publications of the bibliographic databases of WoS, Scopus were studied. The analysis of Russian studies to address the evolution of the life cycle of the innovation process.

Secondly, the author’s model of the innovation project management system at an early stage of the innovation process is scientifically substantiated based on the generalization and scientific understanding of fragmentary studies that currently exist, the achievements of practice, and specialized professional standards in the field of innovative project management at an early stage. In contrast to existing approaches, the emphasis is not on improving approaches to managing innovative projects, but on the issue of generating initially successful projects based on the existing reserve of resources of various organizations, using the principles of managing network projects.

Thirdly, experimental confirmation of the importance of the reflected principles in the model of the system for managing innovative projects at an early stage in 10 universities of Russia was carried out. This made it possible to assess the importance of shifting the focus of attention from the usual project management during the implementation within a separate organization to network generation formats and the simultaneous selection of projects that can go to more mature stages of the innovation process.

Analysis of the evolution of innovative project management models

In this section, we will consider the evolution of the innovation process. There are a large number of copyright models. In this paper, we will rely on the classification proposed by Roy Roswell *(Rothwell, 1994)*, which identified five generations of the innovation process, analyzing the period 1950-1990, in the form of the following models:

1) technology push;
2) market pull;
3) "coupling", model of innovation
4) integrated model
5) networking process.

First generation (1950s - Mid-1960s): economic growth largely through rapid industrial expansion & new technological opportunities. The first generation, or technology push concept of innovation assumed that "more R&D in" resulted in "more successful new products out".

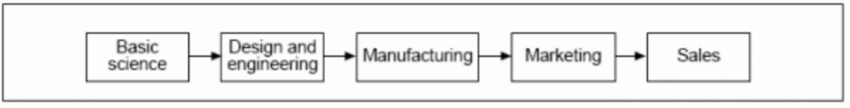

Fig. 1 - The linear technology push model

Third-generation (Early 1970s - Mid-1980s): High rates of inflation and demand saturation (stagflation). Growing structural unemployment. Companies were forced to adopt strategies of consolidation & rationalization, with growing emphasis on scale & experience benefits. Successful innovation process on the basis of a portfolio of wide-ranging and systematic studies covering many sectors and countries ("coupling", model of innovation) (Figure 2)

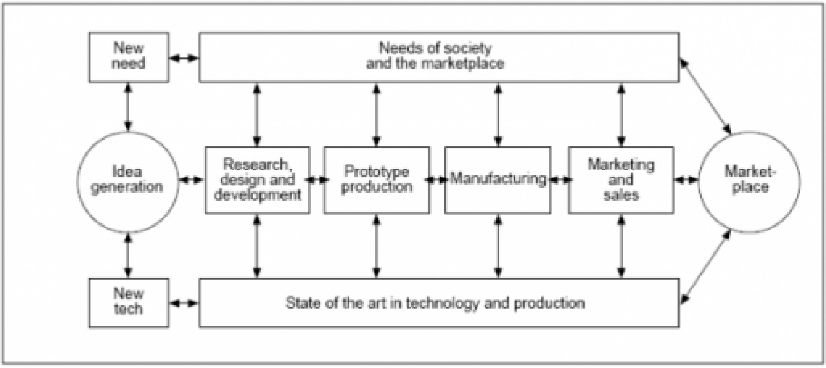

Fig. 2 - The interactive phase model

The classification of R. Rossvel's models allows us to trace the evolution from a mechanistic approach to understanding the innovation process to a more complex configuration, in which the relationships are much more complex. If we turn to a comparison of classifications of models of innovative processes proposed by different authors, we can note their certain similarity (see table below).

Generation	Rothwell (1994)	Marinova and Phillimore (2003)	Tidd (2006)	Berkhout ; Duin; Ortt (2006)	Bochm; Frederick (2010)
1st	Technology push	The black box model	The linear models – need pull and technology push	Technology push	Technology push
2nd	Market pull or need pull	Linear Models (including technology push and need pull)		Market pull	Demand pull
3rd	Coupling model	Interactive model (including coupling and integrated models)	The coupling model	Combination of technology push and market pull	Portfolio management
4th	Integrated model	Systems model (including networking and national systems of innovation)	The parallel lines model	Cyclic innovation model	Integrated management
5th	Parallel and integrated model	Evolutionary model	Systems integrations an extensive networking		Systems integrations
6th		Innovative milieu			Integration in network

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Fig. 3 - Innovation generation models *(Barbieri et al.,, 2016)*

In Figure 3, one can see a stable pattern in all the concepts considered by various researchers to the transition from linear models to more complex ones. Starting with the classification of models by D. Marinova and J. Fillimore, we see an unambiguous transition to the construction of a multitude of connections between participants in the external environment.

In turn, Johan Wissema in the book "University of the Third Generation" connects changes in research management approaches with changes in the external market environment.

	The main focus is on	Core characteristics
First generation 1990–1999	Performance management Compelling others to change Dealing with 'difficult' or remedial employees	Command and control Coaching to specific rankings/ratings Highly transactional
Second generation 2000–2010	Changing others/driving change Maintaining authority and hierarchy Holding standardised 1-2-1 conversations Attaining specific predetermined goals	Prescriptive 'how to coach' models Sees change as linear and to be controlled Highly jargonised training material Propriety coaching language IP owned by coach training company
Third generation 2010–?	Attraction not coercion Leaders modelling change behaviours Shifting individual and organisational mindsets Putting principles into practice Attaining organisational goals/ actualising values Change in both individual and system Ensuring synergetic goal alignment	Highly flexible and agile Coaching as a quality conversation not a goal-focused manipulation Appreciates the complexity of change Seamlessly integrates with organisation's language, brand, culture and values (more than white-labelled)

Fig. 4 - Features of approaches to research management
(Wissema,2012)

As you can see, we can compare the evolution of models of the innovation process (see Figure 3) with the evolution of approaches to research management (see Figure 4). The presented study by J. Wissema adds one more factor to the models of the innovation process - dependence on the external business environment. The evolution of the innovation process is interconnected with the evolution of the business environment itself. However, there is an influence of internal factors. "Innovations are often introduced into the organization's business processes in accordance with the company's development strategy and corporate culture, which means that the innovation process should be a metaprocess included in all organization's business processes. Since man is the carrier and creator of knowledge, the value of human potential increases and stands out in a separate direction of the theory of intellectual potential. More and more attention is paid to the role of such "soft" characteristics as knowledge, culture and network connections " *(Stavenko, 2012).*

At the same time, consideration of models of innovation processes would be incomplete without reflecting the contribution of G. Chesbrough - the model of "open innovation" (Figure 5).

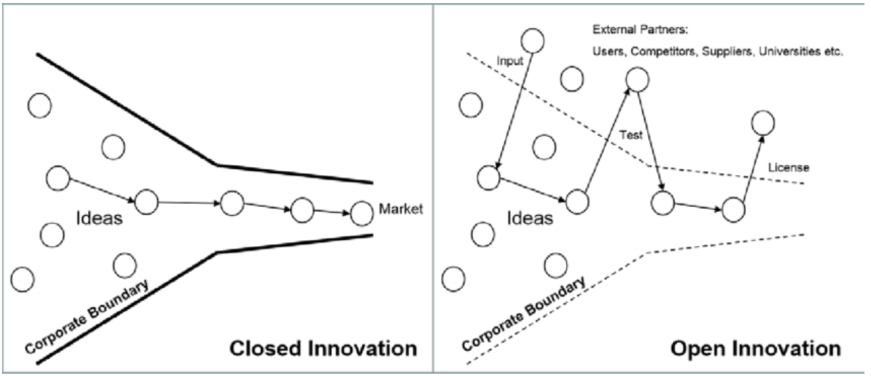

Fig. 5 - Closed vs. Open Innovation model *(Chesbrough, 2003)*

G. Chesbro pays particular attention to the issue of "how without the help of the central laboratories of industrial enterprises, which are key to innovation in the past, there is a diffusion of technologies at the present time based on the combined efforts of universities, national laboratories, start-up companies, suppliers, consumers, industry consortium *(Trifilova, 2008).*

The paradigm proposed by G. Chesbrough makes significant additions to the models of the innovation process. On the one hand, it coincides with the trends presented in the analysis of evolutions regarding the transition to "expanding networking" and "innovation process as a model of environmental management". On the other hand, it adds not only internal factors to the company, organization, but also represents the innovation process as a transition to decentralized - "ecosystem" management. This becomes especially significant in the early stages of the innovation process, where collaboration for the formation of "strong" ideas, with a large number of stakeholders, is becoming increasingly important in order to discard unnecessary ideas in the early stages and focus resources on the main directions. In other words, the university, engaged in basic and applied research, has always played an important role in the process of creating innovation, especially in the early stages of the innovation process. But, in connection with the change in the innovation process itself from linear to increasingly "parallel" or "cyclical", it becomes insufficient to know only the algorithm for performing research and development work -

there is a need for close collaboration with the business to understand key business processes (including understanding key market needs).

In 1993, James Moore coined the term “business ecosystem”, and since then the term “entrepreneurial / innovative ecosystem” *(Moore, 1999)* has become widespread.

According to the ideas of practitioners from RVC JSC, the innovation ecosystem is: “the totality of the relationships of all its elements, including investors, including venture capital funds, and infrastructure elements, which mean service and packaging companies, technology parks and technology transfer centers, as well as innovative campaigns themselves (startups)” *(Development of innovative ecosystems of universities and research centers, 2013).*

Thus, we can conclude that the innovation ecosystem of the university is a complex of relationships between the subjects of the innovation process with the aim of commercializing innovation. That is, the university’s innovation ecosystem is precisely the collaborative environment where innovative projects should arise in the early stages of the innovation process, which would simultaneously combine the achievements of scientific research, understanding of market needs, knowledge of the achievements of other players in this or an adjacent market.

To build such an “innovation ecosystem” requires the implementation of a number of conditions:

– development of horizontal connections;
– development of partnership both within the organization and with external participants;
– development of interdisciplinary research.

Almost all of these conditions rest on the issue of building a confidence field between all participants in the ecosystem. The reasons for their occurrence, affecting the development of an innovative project management system at an early stage, are:

1) weak cooperation between science – business – state;
2) “the lack of tools for the formation of a corporate culture conducive to the development of innovation”;
3) inflexible hierarchical structures in most universities;
4) the lack of adapted methods for the development of innovative project management in Russian universities.

The evolution of the innovation process, as well as the problems identified during the development of the innovation project management system at an early stage of the innovation process, make it possible to talk about the need to create models for understanding the interconnections of individual components directly at the university, as well as developing methods for managing innovative projects in the university-business cooperation environment.

Model of an innovation project management system at an early stage of an innovation process

Project management today is a proven methodology for implementing new ideas. During its existence, many tools and methods have been developed that allow you to manage projects more efficiently. There are international and national associations that develop standards and guidelines for project management IPMA, P2M, PRINCE2, PMI and others. However, when we talk about innovative projects (it is more correct to use the term "innovation management projects", but the term "innovation project management" has become widely used), the tools are not always obvious. We highlight a number of significant differences.

Innovative projects, as a rule, begin with poorly defined, sometimes even ambiguous goals, which become clearer as the project progresses. The processes used are more experimental and research and rarely follow strict linear rules.

The teams of the innovation project require more diversity (interdisciplinarity), should have a higher level of trust, as they explore a new territory where failure is possible.

Due to the high proportion of unsuccessful projects, requirements for risk management are increasing, teams need to learn how to quickly abandon their current actions in order to move to more attractive options.

If we are talking about corporate management of innovative projects, then the decision-making control points, including budget allocation, are much more than is necessary for traditional projects. This situation requires a higher ability to collaborate and work effectively in a team.

In case of failure of the innovation project, the organization, in any case, receives knowledge of a new kind, which can be used in making both strategic and operational decisions for further development.

According to the definition of ICB 3.0 (Project Management Guide - International Project Management Association (IPMA)), a project is a unique set of interrelated activities (activities) aimed at creating a product or service in the context of specified requirements and restrictions.

It is proposed to understand an innovative project as a unique set of interrelated works that ensure the creation and bringing to a state suitable for operation of a new type of product or technology within a limited time and resources.

An innovative project refers us to industry specifics, which means that we are dealing with a project designed to transform science into a final realized product that brings profit to an organization. However, industry specifics do not change the very definition of a project.

Project management - the use of knowledge, skills, methods, tools and technologies for planning, organizing, monitoring and controlling all aspects of project implementation in order to achieve or exceed the expectations of project participants.

To ensure management, the project should be described in a structured form with clearly defined goals, results, final product and implementation life cycle. The more important aspect for us is precisely the early stage. We noted above that innovation in universities is increasingly going beyond the scope of research work familiar to scientists and begins to capture experimental design work, and also extends to the start of implementation, which is associated with the function of finding investments and moving from the university laboratory to the market. Therefore, we can draw a line from the beginning of fundamental research to the implementation stage with some overlap on the processes within this stage. Or, in other words, the early stages include those stages that are responsible for the development of a particular product until the organization of its production.

The expansion of the requirements for the work of university scientists leads to the need to have new competencies, namely prototyping, attracting extrabudgetary funds and risky investments in order to show that the development can really claim to enter the market.

With an increase in the stages carried out directly at the university, the team performing the project expands, and accordingly, roles that conflict with each other appear. Such a situation in early models was characteristic of the conflict between the culture of the university and an external company. Now, due to bias, this is becoming a factor “tearing apart” interests within a single team for creating and implementing innovations (Figure 6).

Researchers’ Interests		Companies’ Interests
Basic research or applied research takes priority	↔	The need for experimental development and launching on market
Meticulous, thorough research	↔	Quick market appearance
New research result	↔	New product or service
Publication of new research results	↔	Monopolizing new research results and keeping them secret
Meeting academic requirements	↔	Compliance with official regulations
Excellence, fame	↔	Market share and making profits
Researchers’ freedom	↔	Influencing the way of research

Fig. 6 - Interests and Conflicts of Interest in Research Projects *(Deak, Csaba, 2019)*

As mentioned above, this expansion and conflict of interests require new processes and approaches to managing an innovation project team at an early stage, on the one hand, a more predictable research part, and on the other hand, competencies: in assessing market needs, the ability to attract extrabudgetary funds, ability to create a prototype and often design documentation, the ability to protect the intellectual property of your project (without revealing commercial secrets for general use).

In their study, G. Stevens and J. Burley calculated the average transition efficiency of innovative projects by stage (Figure 7). We see that out of 3,000 initial ideas, 1 successful project arises on the market, which can be attributed to extremely low efficiency.

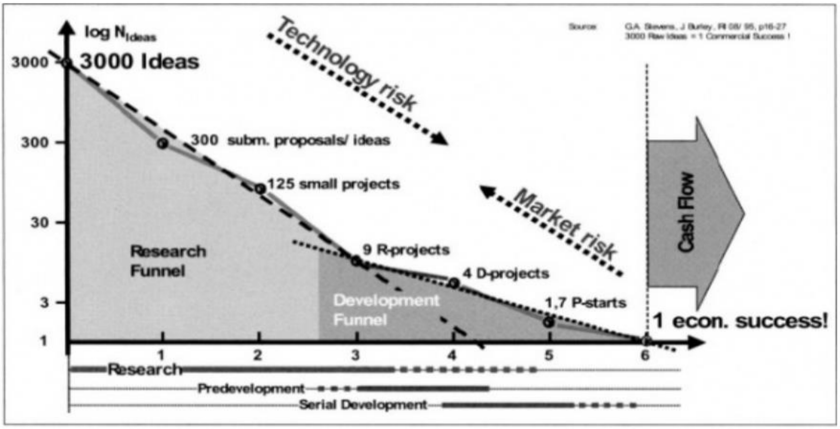

Fig. 7 - the Efficiency of converting ideas into development, successful in the market (Stevens, 1997)

The project at an early stage (or the term “pre-project stage” is sometimes used in the works of various authors) is actually “born” or, more correctly, “crystallized” from existing developments, technologies, ideas by mixing different participants. The project at an early stage is inextricably linked with the knowledge available to the participants. The combination of this knowledge creates a new object with added value. This object is still difficult to formalize into an understandable framework of the product, however, it is already possible to assess its potential, as well as develop in terms of research work to see the possible directions of product development.Thus, at an early stage, we are dealing with knowledge, their combination to obtain a new object with added value. Today, in this part, a number of difficulties arise.:

1. To obtain an object, interdisciplinary knowledge is needed.

2. To assess value, one needs a look from the market, which means that not only knowledge about technologies is needed, but also about needs, that is, knowledge of markets.

3. In the discussion, it is necessary to hear and combine the points of view of researchers, engineers, production and business, just then you can get an idea of a new quality for the project.

Based on the foregoing, the author proposes the following definition of “managing an innovative project at an early stage” - it is the use of knowledge, skills, methods, tools and technologies for synthesizing, developing, evaluating and structuring requirements for a new type of result / product that potentially has added value to satisfy the needs of certain groups in the market.

The author identifies the principles, the observance of which allows providing the conditions necessary at the early stage of innovative projects: comprehensiveness, sufficiency, interdisciplinarity and focus of innovations on the needs of consumers.

Returning to the practice of classical project management, we will consider the "Project Management System Model" (Figure 8), presented in the "National Requirements for the Competences of a Project Management Specialist". It is important for us to divide into 3 principle groups: objects, subjects and processes. We transfer part of the model to the management of innovative projects. Let's start with the management objects.

As we see in Figure 8, management objects include:

– projects and programs: Projects, Programs, Portfolios, Project-oriented activities in the organization, Project-oriented activities in the system of organizations;

– phases of the life cycle of the control object.

Drawing an analogy, we single out the following objects in the innovation sphere:

– innovative projects (we gave a definition above);

– portfolios of innovative projects (a set of projects combined to simplify management, characterized by a single pool of resources and the task of achieving the strategic goals of the organization);

– project-oriented activities of organizations (implementation and development of innovative activities in organizations).

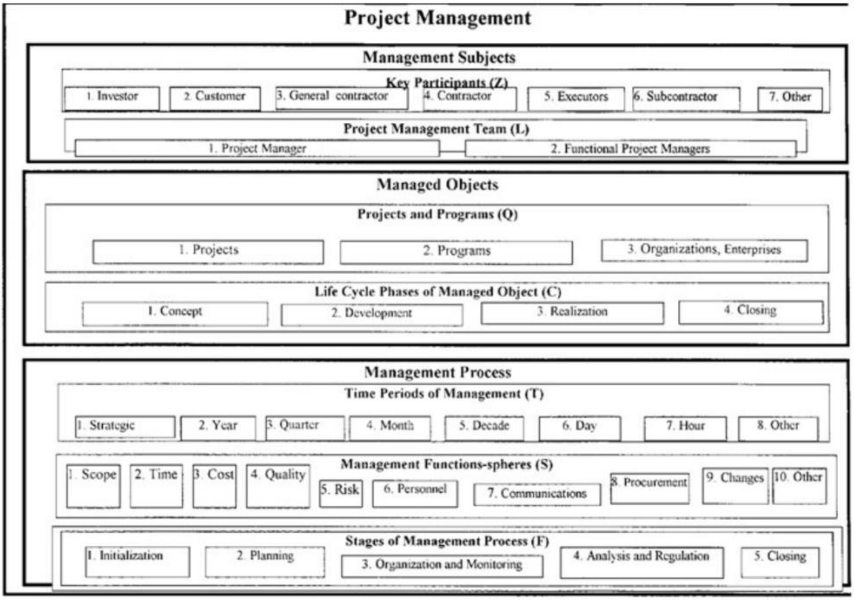

Fig. 8 - The project management system model (NCB, 2010)

We did not identify innovative programs, since this object is much less common and in practice represents to a greater extent either a project or a portfolio of projects.

Dividing the objects in this way, we can assume that the management tools used to work with each of these objects will differ, which is caused by the difference in the purpose of each control object. In further work, we will consider and analyze certain algorithms for managing these objects.

We will not focus on the phases of project management (since the life cycles were discussed in detail in the previous paragraph).

The next major section is the subjects of management. Management entities play an important role, as they are the driver of the project management process. In turn, the management entities, in addition to the resources and motivation provided in the project, also carry certain risks due to the heterogeneity of interests.

It is important that, depending on the management object, the number of stakeholders, project participants, portfolio or a specific innovative organization will differ.

Project participants include both organizations that are directly involved in the project and organizations whose activities and interests can affect the results of the implementation or completion of the project.

The external participants of the project include various government agencies, which are both a source of financing the early stages of innovative projects and determining the priority areas of projects for the development of the economy and state security. These are also various organizations that help in the development of an innovative project or are customers of its results. This can include both enterprises, small companies, universities, and various technology parks, business incubators, community centers, and others.

Internal participants of the university's innovation are: students, teachers, and other employees. All other participants are outside the university and have been classically involved in evaluating a solution that is already "ready" for the R&D stage, including for generating "ideas" - to which market this solution can be applied. But due to the large dropout of such ideas, today it is necessary to build a different configuration of interaction with the "external" participants of innovative activity, involving them more deeply in the "internal" activity of the university.

Above were highlighted fundamental points for the innovative activities of the university:

– universities are increasingly forced to enter new stages of the innovation process - not only research, but also design, engineering and sometimes the supply of finished goods;

– to reduce the number of "rejected" ideas at the start, and ever closer relationship with the future market and verification of tasks through organizations and specialists located today on the technological and scientific frontier are required. It can be safely said that this is a "pre-project" activity (in terms of classical project management), since it is revealed more by the task of searching for the idea itself, the problem, rather than setting the technical task to solve it;

– the objects of management in the early stages, in addition to individual projects, are also project portfolios, as well as innovative activities of the entire organization;

– as subjects, in addition to “intra-university” (students, teachers, other employees), “external” should also be involved: early-stage investors, representatives of enterprises/companies, individual specialists who understand the situation in specific markets, entrepreneurs and other participants providing both getting faster feedback on solutions under development, and joint generation of more powerful ideas. The role of the third management object is growing - the innovative activity of the organization, not as a process, but as an innovation ecosystem with sufficient qualifications of the participants and the relationships between them.

The model for managing innovative projects at an early stage can be represented in the form shown in Figure 9

The model retains the groups of processes of classical project management: initiation, planning, execution, completion, monitoring, and control, which are a complete cycle from the start of the idea to the end result. However, in the innovation project management model, the emphasis is on a group of initiation processes, it has been significantly expanded, an iterative process has been included to generate and select ideas at the same time. As indicated above, it is on this group of processes that a large screening of ideas takes place today. For this, it is planned to form closer ties between scientists, technology companies and industrial companies. Such a “cauldron” is meant to be important for generating or selecting the most interesting ideas from three perspectives; it provides not just expertise, but also discussion and feedback, which allows not only to find one idea, but also form a groundwork for the “platform” of ideas. It is important that the representatives of these three parties should be from the leading companies in the market in order to provide an understanding of the “fronts”: scientific, technological, market. It is also in the model that the exit from such a “boiler” can be not only ideas for research, but also directly ideas that, based on the existing backlog, can be quickly enough finalized before going into production.

It is also important that the result of each project should be access to a specific solution that has been implemented, which means that it can really be recognized as an innovation. It can be both knowledge and technological solutions, production technology or the final product. The principle of “entering the market" is important, which can be achieved by increasing the efficiency of processes (moving away from linear and moving to non-linear models).

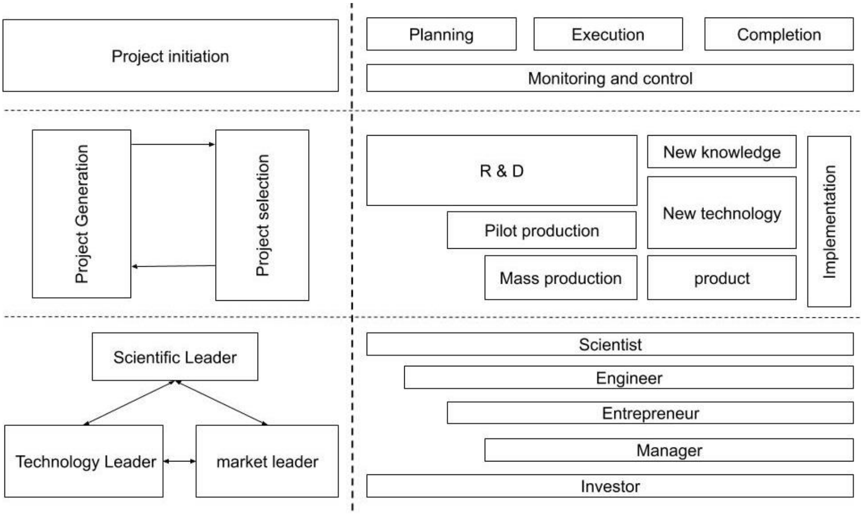

Fig. 9 - An author's model of the innovation project management system at an early stage of the innovation process

The next factor is the presence of a project team that combines several roles for various projects: engineering, entrepreneurship, investment, professional management. Today, bringing a project to market requires more and more interdisciplinary competencies. In addition to competencies, there should be a set of specific resources: for example, an entrepreneur should have a wide range of contacts, and an engineer should have a relationship with industrial enterprises to understand their standards.

Thus, in order to improve the management of innovative projects at the university, in addition to changing the process itself, it is also necessary to set the task of developing the innovation ecosystem as a whole, since in the early stages the scientist should have the opportunity to discuss his ideas with representatives of the leading industry, as well as representatives of leading technology companies. The tools and methods for assessing the effectiveness of this activity are extremely blurred today and do not constitute a holistic management mechanism.

In the given model, we did not take into account another participant in the project activity at the university - students. Obviously, having no scientific competencies, technological basis, or entrepreneurial experience, students require additional processes, which in turn is offset by the lack of "psychological inertia" in relation to new ideas and ambitious projects.

The purpose of developing the author's model for managing innovative projects at an early stage of the innovation process at the university is to visually represent the requirements for the “non-linearity” of processes at various stages, as well as the need to involve various participants in solving the following problems of developing an innovative project management system at an early stage:

1. Improving the efficiency of processes for managing innovative projects of the early stages (through the creation of a sufficient examination of project ideas at the time of their generation by various participants).

2. Improving the efficiency of managing portfolio of innovative projects in the early stages (through a change in approach to the selection of projects, consideration of the project from the market, and not just the novelty inherent in scientists).

3. Development of the innovation ecosystem of the university as a whole (involving a sufficient number and quality of participants, as well as building close relationships between all participants: scientists, advanced companies, leading technology holders, entrepreneurs, etc.).

4. The development of a culture of innovative entrepreneurship, including through the creation of an effective process for supporting the implementation of student innovative projects.

The sources of information for the study were the data of public accounting (financial reporting) of universities, as well as small innovative enterprises established at universities, international and Russian ratings, and also, specialized associations (Academic Ranking of World Universities, Association of European Science and ASTP- Proton, AUTM, Global Entrepreneurial University Metrics (GEUM), QS Employer Reputation Methodology, The Global Entrepreneurial University Metrics initiative, Expert RA, etc.), university development programs (published on university sites), research and materials from the institute of innovations development (RVC JSC, Rusnano JSC, Innovation Support Fund, Skolkovo Innovation Center), information on the average number of employees of the enterprise, data from the Federal State Statistics Service.

The conducted research contributes to the development, firstly, of the theory and methodology of project management and innovation management, and secondly, the practice of managing innovative projects.

The results enriching the theory were the emphasis on the development of the need for non-linear approaches in the management of innovative projects. Determining the possibility of forming more mature innovative projects through the use of open systems. This study should draw the attention of leaders of innovative projects, as well as those responsible for the development of innovations, that the investment of resources should go not only into monitoring the development of an individual project or portfolio, building a funnel of finished projects and selecting the most powerful, but also a fundamentally different approach consisting in the development of internal innovation ecosystems, where the main criterion is the presence of horizontal communication, trust and the ability to quickly exchange ideas and results.

Further research should be directed to creating tools for implementing the approaches indicated in the model, as well as testing them in practice.

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