INFORMATION TECHNOLOGY SESSION
INVITED PAPER

MEASURING INFORMATION APPLICATION FOR ACTIVITY IN SYSTEMS SUCCESS

Alexander S. Geyda*,
Svyatoslav A. Derzhavin

Russian Presidential Academy of
National Economy and
Public Administration,
St. Petersburg, Russia

Abstract:

This article discusses the problem of measuring information quality through the lenses of Solow's "information paradox" in economic theory, drawing insights from fields such as system science, cybernetics, complexity science, and action theory. The author's research focuses on the pragmatic facet of information quality, which examines the success of information application in human activity. The article argues that mathematical models of multi-level changes in varying conditions must be created to study the pragmatic aspects of information quality. The aim is to develop a formal representation and predictive explanation of information applications, which could lead to accurate predictions of the impact of information applications based on mathematical models. The complex nature of multi-level changes and cause-and-effect relationships in information-driven systems makes building these models challenging. The article highlights several interrelated research directions in this area.

Keywords:

Information, Cybernetics, Models, Solow paradox, Quality.

INTRODUCTION

In 1987 Nobel Prize laureate Robert Solow [1] described his information technology paradox: “We can see the computer age everywhere but in the productivity statistics”. Despite various facets of the paradox being explained – at least partially, many times over, for example in [2] – [6] soon half a century passed, but this paradox tends to reincarnate oneself in one form or another. For example, in 2023 new report was published [3] about the very same paradox formulated for artificial intelligence applications by businesses. Still, modern research does not show clear growth in productivity due to information technology use. For example, recent Goldman Sachs research shows paradox still can be found as Paradox 2.0. I am trying to discuss this paradox from a wider view.

First, from a multidisciplinary view, it is not just a productivity or even economy theory problem, but a wider problem of information application peculiarities in the human activity of various kinds and quality obtained, due to information application, and practical results. Second, as a more general viewpoint of activity theory and information application by humans in activity. Third, as a problem of Cybernetics, System sciences and Complexity science.

Correspondence:
Alexander S. Geyda

e-mail:
geyda-as@ranepa.ru

DOI: 10.15308/Sinteza-2023-68-75

It may come as a surprise that these issues were not yet studied enough. Information application is at the cornerstone of activity theory [7], cybernetics, systemics, and complexity science [8], [9]. Still, we can plan space missions predictively, we can design and build rockets to fly to other planets at certain times, to certain points in the universe, predictively, with very high accuracy, based on the laws of ballistic and thermodynamics. We may know almost for certain where spacecraft will be in years, at which point, and why – based on cybernetics and system science, among other sciences. But compare this with what we can do when predicting information application. Generally, we can measure entropy and some other characteristics of information but cannot predict which results will be obtained with the information used. Such a situation looks extremely strange, considering the role of information application in human society. Our appearance as a species is to a large extent the result of our ability to process information, to communicate in our actions with other humans and later, to socialize activity. But we cannot yet predict the results of information application. As Russian poet Fedor Tutchev wrote, "We cannot know further ways of our word – how it'll be drifted." And there are scores of examples in history when "our word" changed almost everything, and it is always the word that precedes all changes made by humans. This system-theoretic, cybernetic, and action-theoretic statement is directly reflected in the first part of the first statement of the Old Testament: "In the beginning was the Word, and the Word was with God, and the Word was God" (John, 1:1). Still, we are unable to measure and predict what, how and when our own words will change us and the world around us. Looks very different from the spacecraft case. Further, the creation of the first societies and multiple civilizations has a direct cause in progress using information. Some stunning facts about this were the first known cases of information used by the first person in history whose name is known nowadays: Kushim from Mesopotamia, more than 5 000 years ago. He used information for bookkeeping and human activity. And signed it. Another known case from the same time. Beer recipe. From similar old times. Still actually used by us nowadays. Finally, if you will look at what is left after us, you will find out that the most valued artifacts from history are information artifacts. It is religious texts, myths, writings, and books. Photos and letters. Records. It is not material things civilizations used to produce or consume, but informational artifacts. Still, we have made a little effort to understand how that information is used, and what results we may predict.

But – we are experiencing a clear "digital revolution" – still being unable, to a large extent, to predict its results. Like, for example, many modern creators of artificial intelligence (AI) openly discuss that they are being unable to predict the results of the latest AI incarnations use due to possible harm to human activity. Again, looks very different from rocket science results.

2. STATE OF THE RESEARCH

Concerning the state of the research in the fields, related to information use, it is urgent to notice relations of activity, causation, and information use in a broader sense. "Causation can be understood as the transfer of information, if information is understood in the proper way as a physical mode" [10]. Further, "Causation can be represented as a computational process dynamically embodied in matter or whatever other "stuff" is involved, in which at least some initial information is retained in each stage of the process" and "The most dominant current view of cognition is the syntactic computational view".

Thus, to describe information use, it can be considered a kind of use causation in nature – by humans. This use occurs due to humans' ability to act in nature based on cognition and consciousness and the use of causation. Action can be naturally represented by computation. These considerations provide hope for creating formal means of activity computational modeling regarding information use for causation in action. Such formal means can be based on the quantification and computation of forms. These formalisms should have a predictive nature and be able to explain possible future causal relations and their characteristics. I believe that they could be created using metamodels (representing meta-forms) and programming languages to support computational predictive formal modeling. As of now, for reasoning about information use various frameworks of best practices applied. Such frameworks are rarely based on formal, predictive models [11]. Formalizing this knowledge and building computational models based on "best practices" as well as on the data, collected during human actions may allow a significant rise capability of the system due to IT use. As stated in [12] "When an event $e_k \in E$ occurs, we may say that it is associated with some kind of information. In a system (multi-robot system considered), events may be classified along three classes, depending on the type of conveyed information: (1) internal events, concerning the robot's activities and information gathered internally by the robot (e.g. end of an internal processing task, reaching some position, etc.); (2) external events, concerning changes on the mission execution environment and information obtained through the robot's sensors (e.g. detection of an obstacle, finding an object relevant to the mission execution, observing the movements of another robot in the team, etc.); and (3) received messages, concerning the information provided by other team members (e.g. detection of an environmental condition, individual state information, a negotiation bid, synchronization-related information, etc.)." Then, relative performance variation $\frac{\Delta p_k}{p_k}$ and relative mission cost $\frac{\Delta ic_k}{c_k}$ estimated considering event o_k occurrence, Then, information utility associated with the event occurrence o_k is measured by the dimensionless ratio u_k of the values mentioned.

Next, state transition graphs are used to account for information values. It is worth noticing, that the author uses similar ideas, but based on measure-theoretic and probability theory, to suggest measures of system potential.

Automatic abstraction [13], [14] in scientific research can be used to build models of possible states, transitions, and cause-and-effect relationships depending on the information obtained. In [14] a new computational model of multiple abstractions of knowledge is proposed. This model is called Multi-AH (Abstract Hierarchical)-graph and is an extension of work on mobile robot navigation. It allowed for representing different types of relations between concepts, and virtually any kind of information, both in the form of concepts and relations and in the form of annotations attached to those concepts and relations.

Building models of activity regarding information use can be considered as a subdomain of Higher Order Mining [37], which encompasses methods for the discovery of knowledge by processing models (instead of data), such as meta-learning, model adaptation, model comparison, temporal mining, mining models (i.e., clustering of association rules) and Change Mining – the discovery of changes in evolving models. In [15] stated that "the need to store, maintain, query and update models derived from the data has been recognized and advocated. However, these are only two aspects of the dynamic world that must be analyzed with data mining: The world is changing and so do the accumulating data and, ultimately, the models derived from them. The challenge does not only lay in adapting the models to the changing world but also to analyze how the models change and when they do so". The authors of [15] proposed a new paradigm for data mining in the evolving world.

Change models, as well as data models, can require higher-order models. The same applies to information and knowledge models. However, the role of higher order models in data, information, and knowledge use, in building and application of data, information, and knowledge is not yet described enough. The reason for this is, in my opinion, lower-level models of data, information, and knowledge use are not yet developed to the needed extent. This, in turn, is based on the absence of a solid concept of information applications in general and the role of high-order models in this – in particular. I am suggesting an explanation of data, information, and knowledge use as a hierarchical process of various aspects of activity model creation and further use of models created for action problem-solving purposes. This includes complex, higher order, predictive, dynamical models of activity construction and use, including such aspects of activity, which are related to answering complex questions about activity. According to such an explanation, activity models are complex in various ways or directions. First, activity always consists of some interrelated parts, at least – subject and object, as well as means of action and possibly other parts and relations between them. This direction is traditionally described by various combinations of parts possible (by varieties and holarchies) – in activity theory. Second, the direction related to predictions of the possible future outcomes depends on decisions made and actions fulfilled. Third, reflections of objects and relations are mentioned of various kinds and various levels in some reflection hierarchies. Such reflections are used to solve problems, raised before humans when we perform our activity. If to represent various directions as orthogonal coordinates, moving along coordinates can be explained as solving a system problem with the use of information of various kinds and various hierarchies in reflection order. An example can be seen in Figure 1.

In terms of the axis, by holarchy axis V, moving to a higher variety (less holarchy) will mean considering more parts of activity (including subject, object, and means parts) and more relations between them, which is common in various models of activity theory. By possible future outcomes (possible effects, P) of actions axis, moving by axis will mean better results of actions fitness to demands, according to goal, i.e. better results. By reflection axis R, moving to higher order reflection hierarchy would mean a kind of abstraction and back – kind of concretization.

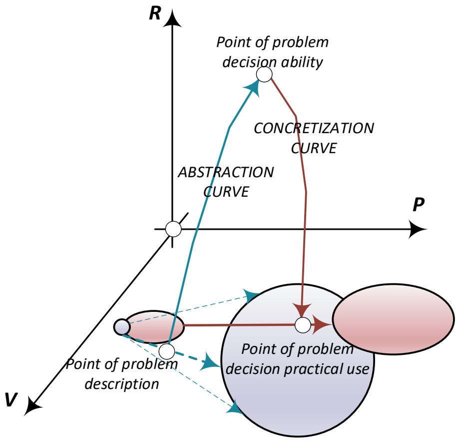

Figure 1 – Illustration of human activity problems solving with the use of various kinds of reflections in the space defined by V, P, R axis.

Thus, to represent the decision of human action problem, we may represent the initial problem formulation as a vector (or possible vectors) on the plane defined by variety V and possible effects P axis. Vector represents desirable types of outcomes by starting state and finish state. The decision of the problem could be represented as moving up by reflection axis R – by abstraction or other types of reflection – or example, till an abstract decision can be generated, and then – moving back to concretize and implement abstract decision obtained in practice. Such a way of the decision is the reminiscence of many systems theoretic and cybernetics methods to decide complex practical problems, with emphasis on information processing. Generally, such a trajectory in space of given coordinates would represent obtaining results of information used for solving practical (related to action, to human practice) problems. The next step in the research is to model and measure such trajectory and so – information use, based on formal mathematical models, predictively and quantitatively, because, as said by many researchers, "You can't manage what you don't measure". The quality of using information, information value, and business value of information has attracted researchers for decades. H. Tohonen, M. Kauppinen, and T. Manisto [16] conclude that the evaluation of IT business value is challenging and has been on both research and practitioner agendas for more than two decades but remains a challenge. One reason for this is that such measures must, among other facets, represent the quality of purposeful changes in activity caused by obtained information, particularly in changing conditions. This facet is closely related to the concept of information pragmatics. As stated by J. Talburt [17]: "That concept is the intent of the message—that is, to what use will the receiver put the information, and more importantly, will the information have value (utility) for the receiver in the context of its intended use? These three concepts of information format, meaning, and purpose form the foundation of information quality and allow it to be anchored in measurable terms. The same three concepts also underpin the study of signs and symbols known as semiotics, where they are called syntactic, semantics, and pragmatics." J. Talburt [17] formulated the main principles of information quality. The need for IQ measures includes measurements of the quality of deliberate potential changes in actions due to information obtained, as well as the fitness of the results to changing demands. Predictive mathematical models for such measures, based on mathematical formalism, have not been developed yet. This is particularly the case for predictive mathematical modeling of the use of information for actions and the success of systems in changing conditions. This approach requires a description of the characteristics of the use of information for actions and measures of the success of such actions in changing conditions.

This approach can be seen as an extension of the Batini [18] and Scannapieco approach to evaluating the quality of information: we aim to investigate the relationship between the quality of information and the quality of the processes output (or, simply, the process quality) that make use of information to be produced. Since processes are made of decisions and actions, we aim in turn to relate information quality with the quality of actions and decisions that make use of information.… We want to deepen our understanding of how the information processor, be it a human being or an automated process, can manage the fitness for use of the information consumed" [18], [19]. This approach is based on the concept, described by Y. Lee, R. Wang, and D. Strong as: "the concept of "fitness for use" is now widely adopted in the quality literature" [19].

A review of the approaches for estimating the value of information, with a focus on fundamental and mathematical methods, was provided in [16] and by most other researchers using an empirical approach. As it is noticed by Y. Lee, R. Wang, and D. Strong about this approach: "The disadvantage is that the correctness or completeness of the results cannot be proven via fundamental principles" The fitness for use is investigated by [19]. As noticed by L. Floridi and P. Illari: "Qualitative descriptions of the meanings of words or phrases such as 'information quality', or 'timeliness' are not the same as formal metrics required to measure them, and which are needed for implementation" [20]. The approach suggested in the article is based on a fundamental, predictive mathematical modeling approach to compute formal IQ measures based on the theory of system potential results already obtained. The approach further elaborates on concepts and models suggested in [21].

New measures, suggested by authors, are based on probabilistic and entropy measures, which are calculated with mathematical models of information use and its use success levels. Such measures and formal models may allow solving various problems of information use, and digital transformation as mathematical problems, such as operation research and mathematical programming problems. Such an approach is like the approach to information processes modeling, suggested by C. Batini and M. Scannapieco in [22]. However, the approach has some deficiencies, as mentioned by its authors: "It does not distinguish between or provide specific formalisms for operational processes, which make use of elementary data, and decision processes, which use aggregated data" [18]. The reason for such a situation is defined by the nature of information processing. Such processing inevitably leads to the purposeful change of human action and the exchange with the environment [23]. But the mathematical models of such changes in human action are not yet available in the needed details. The situation could be improved with the use of various approaches available to describe the changeable activity, like the theory of functional systems [24] – if it is operationalized with appropriate mathematical means.

3. PROPOSED DIRECTIONS OF THE RESEARCH

Below are suggested hypotheses and formalisms to explain and formalize various research results related to the wider explanation of the "Solow paradox".

1. Robert Solow: "We can see the computer age everywhere but in the productivity statistics". Possible system science, cybernetics, complexity science, and action theory explanation: The economy does not produce more output with the same number of inputs because of IT use. Information technology does not change physical laws but changes possibilities to act, to innovate, helps to explain possible future results of actions and to change decisions and intentions (knowledge work made, information states produced). It is needed to research possible changes caused by information due to further realized cause-and-effect relations, not just relations of inputs and outputs. Various authors tried to explain the Solow paradox. Let us try to classify their main explanations, simultaneously suggesting system theoretic, cybernetic, and action theory versions of such explanations. Selected are three classes of explanations: prominent researcher of IT value problem, Eric Brynjolfsson explanations, further authors explanations, and modern explanations.

2. First "wave" explanations (Eric Brynjolfsson, Paul Strassman, John Thorp from Fujitsu consulting group [4], [25], [26]): 2.1. Uneven and concentrated distribution of the labor productivity gains. Possible system science, cybernetics, complexity science, and action theory explanation: Physical ("material") results (effects) enhancements can be obtained sporadically and unevenly because (2.1.1) cause-and-effect relations changes do not necessarily happen once information obtained (input/output relation may be unchanged or minor changes happened immediately, some other requirements have to be satisfied, some additional actions and events required in some systems, by some people), and (2.1.2) Information may change action entirely, including its goal and requirements to inputs and outputs, thus efficiencies of old and new ones cannot be compared, because results of an action before changes applied and after changes applied not comparable. For example, (2.1.1) for the ratio of input and output to be enhanced, some other additional actions shall lead to some needed events to enhance efficiency, and (2.1.2) enhanced action may lead to action or its results (product or service) of better quality, or result, which satisfy other need, solve another task.

2.2. Implementation lags. Possible system science, cybernetics, complexity science explanation: (2.2.1) Time is required to realize cause-effect relations once information changes. (2.2.2) To modernize, innovate, to progress chains of requirements can be needed to be satisfied, this may take various resources, complex efforts, and some time.

2.3. Mismeasurement. Possible system science, cybernetics, complexity science explanation: (2.3.1) Not only input/output measures characterize actions change. Input and output quantity and quality (separately or together) as well as their changes of various kinds shall be considered too. (2.3.2) Other facets of actions and their results as well as changes may be required to measure, not just inputs and outputs.

3. OTHER PROMINENT AUTHORS' EXPLANATIONS.

3.1. Free products and services created due to modern information technologies, which cannot be measured in terms of economic efficiency. Possible system science, cybernetics, complexity science explanation: Modern IT may lead to various free products and services creation because of business models innovation, including the use of non-financial results, in some cases with hopes for future or indirect monetization [27]. They cannot be easily compared with traditional products and services due to differences in business models, among other differences in related activities.

3.2. New products and services or higher quality products and services created due to modern information technologies. Possible system science, cybernetics, complexity science explanation: Modern IT may lead to various products and services creation or radical changes in their quality. Many of them are incomparable with traditional products and services, the result of innovation and creative thinking, and cannot be easily measured concerning traditional products and services. For example, so-called "uberization" results are hard to compare to traditional businesses.

4. NEWEST EXPLANATIONS OF MODERN DIGITAL TECHNOLOGIES PARADOXES [3] – [28].

4.1. Competition mechanisms. Businesses, which do not use modern IT properly, tend to disappear. Possible system science, cybernetics, action theory, complexity science explanation: IT use allows new, innovative, creative reactions to market changes, environmental changes, and on appropriate changes in the competition. Such reactions must incur information processing before they are realized. Competition is exceptionally dynamic. This system's dynamics shall be measured predictively, with mathematical models. Competition helps to create new, innovative products and services, and it is one of the facets of using information.

4.2. Price increase due to higher quality. Products and services of different qualities cannot be compared by the relation of their input to output. Possible system science, cybernetics, complexity science explanation: A product or service with better quality shall be considered a new product. The new product may solve other tasks, have other functions, have other stakeholders, and other requirements. For example, traditional wire phones cannot be compared with modern smartphones. Traditional ones can be 1000 times cheaper and consume 1000 times less energy. But it cannot perform all the 1000 tasks which modern smartphones can. We shall compare products and services by all possible functions, goals, and requirements they can fulfill – in various, changed conditions. Such a measure is not a measure of economic efficiency, but a more complex measure. For example, dynamic capability measures or the measure of the system potential regarding information use can be used [29] – [31].

4.3. Monopolistic behavior. No comparison may exist for the products and services of monopolists. Possible system science, cybernetics, complexity science, and activity theory explanation:

Disregarding market position, business use of information brings results. The measure of that results correspondence to changing market and environmental conditions can be measured. This measure of correspondence can be enhanced concerning the measure before enhancement is made. Conceptional explanations provided should lead to further research which could lead to the creation of modern theory, with the potential to formally explain the formation of information use, thus able to predict the results of information use on mathematical models. Such formalisms, if created, could be used as part of system science, cybernetics, complexity science, and activity theory to build models of information use and methods to predict such use results.

5. CONCLUSION

The problem of information use and its quality research are discussed. The pragmatic facet of information quality is considered based on the system theoretic and cybernetic paradigm of information use. As a result, the facet of information quality is determined by information used for actions in the systems discussed. It is shown that information is used in practice to change, enhance, to ensure systems actions' success. The main features of the problem of information use and its quality research from a pragmatic viewpoint are discussed. To solve the problem, mathematical models of multi-level changes due to possible multi-level reflections obtained in possible changing conditions should be built. As well, appropriate measures of system success due to the specified multi-level reflections use shall be suggested. Such measures could be based, for example, on information use success assessment with mathematical predictive modeling of human activity results in fitness to the demands. They should allow deciding problems, devoted to possible purposeful alternating of systems and their functioning, due to information of various kinds use.

6. REFERENCES

[1] R. Solow, "We'd better watch out," *New York Times Book Review*, July 12, 36., 1987.

[2] J. E. Triplett, "The Solow Productivity Paradox: What do Computers do to Productivity?" *The Canadian Journal of Economics / Revue canadienne dEconomique*, vol. 32, p. 309, 1999.

[3] A. Bäck, A. Hajikhani, A. Jäger, A. Schubert, and A. Suominen, *Return of the Solow-paradox in AI? AI-adoption and firm productivity. Papers in Innovation Studies 2022/1*, Lund University: CIRCLE - Centre for Innovation Research, 2022.

[4] E. Brynjolfsson, and L. M. Hitt, "Beyond computation: Information technology, organizational transformation and business performance," *Journal of Economic Perspectives*, vol. 14, pp. 23–48, 2000.

[5] R.-J. B. Jean, R. R. Sinkovics, and D. Kim, "Information technology and organizational performance within international business to business relationships," *International Marketing Review*, vol. 25, pp. 563–583, 2008.

[6] D. Acemoglu, D. Autor, D. Dorn, G. H. Hanson, and B. Price, "Return of the Solow Paradox? IT, Productivity, and Employment in US Manufacturing," *American Economic Review*, vol. 104, pp. 394–399, 2014.

[7] D.K. Allen, A. Brown, S. Karanasios and A. Norman, "How should technology-mediated organizational change be explained? a comparison of the contributions of critical realism and activity theory?" *MIS Quarterly,* 835–854, 2013.

[8] A. B. Downey, *Think Complexity: Complexity Science and Computational Modeling*: O'Reilly Media, 2012.

[10] J. D. Collier, "Causation is the Transfer of Information," in *Causation and Laws of Nature,* H. Sankey, Ed., Dordrecht: Springer Netherlands, 1999, pp. 215–245.

[11] A. N. Neto and J. S. Neto, "Metamodels of information technology best practices frameworks," *JISTEM*, vol. 8, no. 3, pp. 619–640, 2011, doi: 10.4301/S1807-17752011000300006.

[12] R. Rocha, J. Dias, and A. Carvalho. "Accessing information utility in cooperation based robotic system": *Proceedings of ICAR 2003 The 11th International Conference on Advanced Robotics June 30 - July 3, 2003*. Coimbra, Portugal, pp. 840-845, 2003.

[13] Z. H. Ismail and N. Sariff, "A Survey and Analysis of Cooperative Multi-Agent Robot Systems: Challenges and Directions," in *Applications of Mobile Robots*, E. Gorrostieta Hurtado, Ed.: IntechOpen, 2019.

[14] J. A. Fernández and J. González, "Multi-Hierarchical Representation of Large-Scale Space". Dordrecht: Springer Netherlands, 2001.

[15] M. Bottcher, F. Hoppner, and M. Spillopoulou, “On Exploiting the Power of Time in Data Mining,” *ACM SIGKDD Explorations*, vol. 10, no. 2, 2008.

[16] H. Tohonen, M. Kauppinen, and T. Mannisto, “Evaluating the business value of information technology: Case study on game management system,” in *2014 IEEE 22nd International Requirements Engineering Conference (RE)*, Karlskrona, Sweden, Aug. 2014 - Aug. 2014, pp. 283–292.

[17] J. R. Talburt, "Entity resolution and information quality". S.-Francisco, Ca.: Morgan Kaufmann/Elsevier, 2011.

[18] C. Batini and M. Scannapieco, "*Data and Information Quality*". Springer International Publishing, 2016.

[19] Y. W. Lee, D. M. Strong, B. K. Kahn, and R. Y. Wang, “AIMQ: a methodology for information quality assessment,” *Information & Management*, vol. 40, no. 2, pp. 133–146, 2002, doi: 10.1016/S0378-7206(02)00043-5.

[20] L. Floridi and P. Illari, "The Philosophy of Information Quality". Cham: Springer International Publishing, 2014.

[21] A. Geyda and L. Fedorchenko, “Digital Twins of Activities: Role of Information Actions,” in 32nd Conference of Open Innovations Association (FRUCT), Tampere, Finland, Nov. 2022 - Nov. 2022, pp. 102–111.

[22] C. Batini and M. Scannapieca, "*Data quality: Concepts, methodologies and techniques"*. Berlin, New York: Springer, 2006.

[23] R. P. Smiraglia, “The Nature of Information,” in *Cultural Synergy in Information Institutions,* R. P. Smiraglia, Ed., New York, NY: Springer New York, 2014, pp. 9–16.

[24] V. Rusalov, “Functional systems theory and the activity-specific approach in psychological taxonomies,” *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, vol. 373, no. 1744, 2018, doi: 10.1098/rstb.2017.0166.

[25] P. A. Strassman, "The Economics of Corporate Information Systems: Measuring Information Payoffs". Paul Strassmann, 2007.

[26] J. Thorp, "The information paradox: Realizing the business benefits of information technology". John Thorp and DMR's Center for Strategic Leadership. New York, London: McGraw-Hill, 2003.

[27] D. B. Laney, "Infonomics: How to Monetize, Manage, and Measure Information as an Asset for Competitive Advantage», Milton: Routledge, 2017.

[28] R. Capello, C. Lenzi, and G. Perucca, “The modern Solow paradox. In search for explanations,” *Structural Change and Economic Dynamics*, vol. 63, no. 4, pp. 166–180, 2022, doi: 10.1016/j.strueco.2022.09.013.

[29] A. S. Geyda, "Essentials of the theory of system's potential". Moscow: Russian academy of science, 2021.

[30] A. S. Geyda, “The method of information use schematization,” in *International Conference on Digital Transformation: Informatics, Economics, and Education (DTIEE2023)*, Fergana, Uzbekistan, Mar. 2023, p. 19.

[31] A.S. Geyda, “The Concept Model of Information Application for Actions in System,” in *Proceedings of International Workshop "Hybrid methods of modeling and optimization in complex systems" (in the framework of The Eleventh International Conference on Mathematical Models and their Applications), November 22-24, 2022,* Krasnoyarsk, the Russian Federation, 2023, pp. 283–295.