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ANTI-CRISIS ADAPTIVE DIGITAL MODEL OF HIGHER EDUCATION INSTITUTION MANAGEMENT IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT OF THE SMART ECONOMY

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Abstract
The article presents the concept of an anti-crisis adaptive digital model of higher education institution management in the context of sustainable development of the smart economy. The proposed model combines tools of digital transformation, logical-linguistic analysis and cybernetic modeling to create a functionally reliable, flexible and institutionally stable management system. Particular attention is paid to the analysis of modern challenges, such as digitalization, demographic crisis, financial instability, as well as political and environmental factors. The study proves that the use of the fuzzy set method allows you to effectively take into account the uncertainty and dynamics of the external environment, which contributes to making strategic decisions in conditions of complexity and multifactoriality. The model is focused on strengthening the role of higher education as a driver of sustainable development, as well as on increasing its competitiveness in the global space.

Keywords: *Smart Economy, Higher Education Institution Management, Sustainable Development, Adaptation, Educational Policy, Innovation, Artificial Intelligence, Fuzzy Logic.*

JEL Codes*: I28, O33, H75, L86, C63.*

Introduction

The modern higher education system is under unprecedented pressure from multiple global challenges, dominated by digital transformation, political turbulence, economic instability, climate threats and rapid social changes. In this context, higher education institutions appear not only as centers of knowledge, but also as active adaptive systems that must respond to changes in a timely manner, maintaining the quality of educational and scientific processes.

The construction of innovative management models that can ensure systemic stability and at the same time strategic flexibility is of particular relevance. Reality proves that traditional administrative approaches are unable to guarantee the effective functioning of higher education institutions in a multidimensional crisis. That is why there is a need to create a digitally adaptive management model that would be not only functionally effective, but also ecosystemically sustainable - that is, one that is able not only to

react, but also to proactively model the future. The integration of digital technologies, in particular artificial intelligence, big data analytics and cybernetic modelling, allows changing the very nature of management decisions, turning them into anti-crisis tools with a high degree of adaptability.

A smart economy, within which education plays the role of an intellectual core, requires higher education institutions not only to train personnel for the new economy, but also to transform internal management systems into digital-cybernetic models. Such models should provide for dynamic interaction with the social, technological, regulatory and environmental environment. Digital management in the context of a smart economy is not only about tools, but also about a conceptual change in the paradigm of strategic thinking. Higher education institutions can no longer be considered as passive objects of educational policy - they must act as integrated digital-innovative systems that are embedded in the structure of national and global development.

In view of the above, the proposed anti-crisis adaptive digital model of higher education institution management appears as an institutional response to the growing challenges of the modern global environment. It encompasses logical-linguistic, cybernetic, ecosystemic and analytical components, which allows not only to stabilize processes in the short term, but also to form the basis for the long-term development of a higher education institution. The central idea of this model is the combination of managerial flexibility and institutional structuring based on the use of digital tools, which are responsible for the principles of predictive forecasting, ethical sustainability, decentralized decision-making and resource efficiency.

Therefore, the object of the study is the management system of higher education institutions in conditions of constant instability, and the subject is the development of a functionally reliable, anti-crisis and digitalized management model capable of ensuring sustainable development within the framework of a smart economy. Theoretical understanding and practical testing of such a model allows us to substantiate its feasibility and effectiveness in the context of modern educational policy.

Literature review and methodological basis

The following research methods were used in the scientific article: general scientific methods (analysis and synthesis; abstraction and generalization; induction and deduction); theoretical modeling methods (structural-functional modeling - determination of elements of the management system of higher education institutions and their relationships, system analysis - consideration of higher education institutions as a complex system that functions in conditions of change); cybernetic modeling (analysis of feedback mechanisms and management of the educational process); predictive modeling (assessment of the prospects for the development of management models in education); comparative analysis methods; conceptual modeling methods (development of a conceptual model of management of higher education institutions, expert evaluation method).

To form an anti-crisis adaptive digital model of management of a higher education institution in the context of sustainable development of the smart economy, it is important to take into account research that covers managerial, technological, social and economic aspects.

Bakhmat et al. (2022) consider the management of higher education quality in the context of sustainable development, which is key to ensuring the effectiveness and adaptability of management models in higher education institutions. Kalinina et al. (2018) propose models of management of general education institutions as active systems, which can be adapted for higher education taking into account digitalization and sustainable development. Bosniuk et al. (2021) analyze the social content of the professional activity of psychologists, emphasizing the importance of emotional and ethical competence, which is relevant for the training of managers in the field of education. Gryshchenko et al. (2023) investigate the management of the design of the environment for the development of innovative entrepreneurship in the conditions of post-war

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recovery, which can be applied to create an innovative educational environment. Sokolova (2022) considers the public-administrative aspects of the post-war recovery and reform of the higher education system of Ukraine, which is important for the development of adaptive management strategies. Kubitskyi et al. (2023) analyze the development of higher education institutions in modern conditions, emphasizing the need to adapt to changes and implement innovative approaches. Hryshyna & Pyzhova (2022) look for an effective model of management of higher education institutions, which is directly related to the topic of anti-crisis management. Hnatenko et al. (2024) conduct an analysis of the renewable energy market in Ukraine, which can be taken into account when developing environmentally sustainable models of management of higher education institutions.

Shumilova et al. (2023) investigate the formation of emotional and ethical competence of future education managers in conditions of transformational change, which is important for training change leaders. Kramskyi et al. (2021) propose a model for substantiating the organizational structure of the HEI management system, which can be used to build effective management structures. Hnatenko et al. (2020) consider the infrastructure of innovative entrepreneurship, which can be adapted to create innovative infrastructure in higher education institutions. Purdenko et al. (2023) analyze the financial management of innovative eco-entrepreneurship, which can be used to develop financial strategies for sustainable development in higher education institutions. Domaryev (2017) proposes a theory of situational management, which is relevant for anti-crisis management in conditions of instability. Mazur et al. (2021) investigate the improvement of controlling in the financial management of enterprises, which can be adapted for the financial management of HEIs. Korotka et al. (2020) consider computational intelligence and fuzzy set theory, which can be used to model complex management processes.

The study by Mykhailichenko et al. (2021) provides valuable approaches to digital personnel management, which can be adapted within the framework of an anti-crisis digital management model of higher education institutions to increase the flexibility and efficiency of personnel processes.

Ivakhiv & Nakonechnyi (2017) offer the foundations of building fuzzy logic management systems, which is useful for developing adaptive management models. Prokopenko et al. (2021) investigate models of state cluster management, which can be applied to the formation of clusters of higher education institutions in the context of globalization. Sychko (2021) analyzes the main approaches to modeling the information system of management of higher education institutions, which is important for the digitalization of management processes. Prylipko et al. (2021) model regional management of innovation activities, which can be taken into account when developing regional strategies for the development of higher education institutions. Semenov et al. (2021) investigate the management of energy and resource-saving innovation projects, which is relevant for the implementation of sustainable practices in higher education institutions. Voznyuk et al. (2022) propose synergistic modeling of management processes in the educational sector, which can be used to optimize management processes in higher education institutions. Zhyvko et al. (2024) analyze the impact of the US stock market on the institutional security of innovation development management, which can be taken into account when developing strategies for the financial stability of higher education institutions.

Such studies provide a comprehensive understanding of various aspects of higher education institution management in the context of sustainable development and digitalization, which is the basis for developing an effective anti-crisis adaptive digital management model. The general shortcomings of the reviewed works are the fragmentation of approaches that do not always provide systemic integration of higher education institution management. Some studies focus on individual aspects (educational, financial or administrative), without taking into account their interaction. There is also a lack of models that combine digitalization with fuzzy logic in the context of crisis instability.

Results

It is worth noting that modern higher education institutions have to operate in an environment of constant change, which necessitates the formation of an anti-crisis adaptive digital model of higher education institution management in the context of sustainable development of the smart economy. This approach allows us to develop not only adaptive strategies, increase the flexibility of decision-making, optimize the allocation of resources, but also improve the quality of the educational process and ensure the long-term sustainability of the higher education institution. Given the growing economic, socio-cultural, technological, geopolitical and environmental challenges, modeling of management in the field of higher education in modern conditions is becoming a key tool for the effective development of higher education institutions. In order to clarify both the feasibility and directions of modeling the management of a higher education institution, we will present the main modern challenges that affect their functioning (Table 1.).

Table 1. Challenges affecting the functioning of higher education institutions in the context of sustainable development of the smart economy

Challenge	Challenge specification
Economic and financial difficulties	Insufficient state funding for higher education institutions; forced increase in tuition fees, which causes a decrease in the number of students and increases the outflow of personnel; competition with private and international universities, which requires improving the quality of educational services
Digitalization and technological transformation	The development of distance learning, which requires changes not only in teaching methodology, but also in the infrastructure of the higher education institution itself; the need to adapt to artificial intelligence, which can both improve the learning process and create challenges for academic integrity; the introduction of the latest educational technologies, in particular VR, AR and adaptive learning based on big digital data
Demographic changes and shrinking student population	Declining enrollment due to demographic crisis; mass migration of youth due to military operations; growing demand for short-term training programs, requiring flexibility in the educational process
Political and geopolitical challenges	Military operations in the country, internally displaced persons, which complicates the organization of the educational process and psychological support for higher education students and scientific and pedagogical workers; constant changes in education legislation, which affect the autonomy of higher education institutions and their funding; restrictions on international cooperation due to geopolitical conflicts.
The need for sustainable development and social responsibility	Environmental responsibility of higher education institutions, in particular the implementation of sustainable development programs in the educational process; inclusivity and equality in education, ensuring access to education for disadvantaged groups of the population; adaptation of educational programs to the needs of the modern labor market, training personnel for new areas of the economy and technologies
Ensuring the quality of education and international competitiveness	Increasing requirements for accreditation and licensing of educational programs in accordance with international standards; the need to develop dual education and academic mobility for training specialists

Thus, given the above challenges, the anti-crisis adaptive digital model of higher education institution management in the context of sustainable development of the smart economy is an urgent task and a vital component of their activity process in accordance with the following needs:

1. Forecasting and adaptation to changes, because modeling allows: to assess risks and prospects for the development of higher education institutions, create flexible management strategies

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to overcome crisis situations, and ensure optimal allocation of resources.

2. Optimization of decision-making. The use of artificial intelligence and analysis of large data sets helps to make informed management decisions, and modeling allows to assess the effectiveness of educational programs and administrative processes.

3. Improving the financial stability of higher education institutions. Allows to optimize costs and develop financing strategies, contributes to the development of entrepreneurial activity of higher education institutions and attracting international investments.

4. Increasing the competitiveness of higher education institutions. Introduction of flexible learning models such as online learning, dual education; development of personalized educational trajectories for higher education students.

5. Sustainable management and environmental responsibility. Development of environmentally friendly university strategies, use of energy-saving technologies in buildings and dormitories.

Given the above, we can say that modeling the management of the functioning of higher education institutions is becoming a necessary tool for their adaptation to modern challenges.

The logical-linguistic matrix model of the anti-crisis adaptive digital model of higher education institution management in the context of sustainable development of the smart economy has a number of advantages that make it especially relevant for the management of higher education institutions in the context of modern challenges. Among them, the following are worth highlighting:

1. Adaptation to uncertainty and fuzziness: the model allows you to work with fuzzy data and expert assessments, which is important in dynamic conditions where traditional strictly quantitative approaches may be insufficient. The use of linguistic variables contributes to a more flexible analysis of complex situations.

2. Integration of various factors: thanks to the matrix structure, the model allows you to integrate numerous parameters - from administrative to cultural and social - which provides a comprehensive approach to decision-making. This contributes to a more accurate consideration of the specifics of the activities of higher education institutions.

3. Improving the quality of management decisions: the logical-linguistic approach contributes to the structured processing of both quantitative and qualitative information, which helps managers build more substantiated strategies, reduce risks and take into account alternative development scenarios.

4. Flexibility and adaptability: in the era of modern challenges, when the environment is changing rapidly, the model allows you to quickly adjust management approaches in accordance with new conditions. It is able to adapt to external changes and internal needs of the organization.

5. Innovative approach to management: the use of logical-linguistic technologies opens up opportunities for the integration of modern information technologies into the management process, which allows you to create intelligent decision-making support systems.

Thus, the logical-linguistic matrix model is an effective tool for organizing the management of higher education institutions, because it allows you to take into account both formal and informal aspects of the management process in conditions of uncertainty and rapid changes in the modern environment.

Under these conditions, the use of the logical-linguistic matrix model of ensuring the management of the functioning of higher education institutions provides a flexible centralized distribution of resources in the interests of its components, which are created and can participate in solving situational tasks that arise in the complex dynamic circumstances of the functioning of the higher education system-institution. At the same time, for the purpose of operational analysis of situations and adoption of appropriate decisions, it may become possible through modeling to create such virtual environments that would allow the use of multi-form and multi-source information under the influence of standard and non-standard external factors in order to form new knowledge about the situation and make logical decisions and

conclusions on their basis. In this case, the use of artificial intelligence tools is also possible.

The final goal of such a modeling principle is the ability to integrate into a single basic matrix all processes for ensuring effective management of the process of functioning of higher education institutions.

Given the specified features of modeling an anti-crisis adaptive digital model of management of a higher education institution in the context of sustainable development of the smart economy, it is considered appropriate to define a logical-linguistic matrix model for ensuring such management Fig. 1.

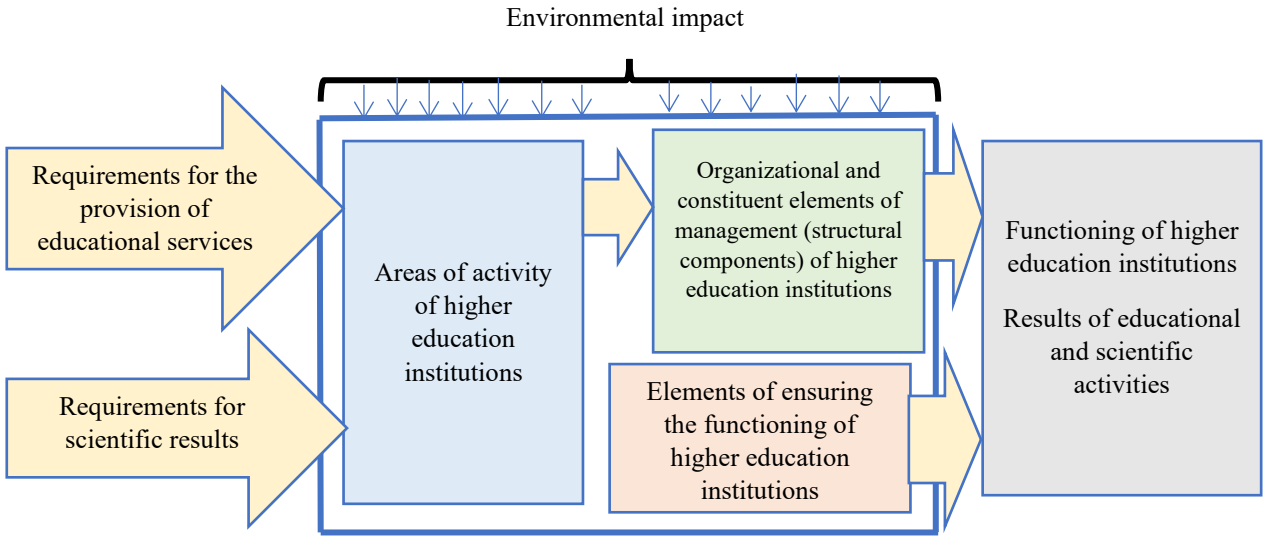

Figure 1. General structure of the functional model of a higher education institution in the context of sustainable development of the smart economy

Regarding the logical-linguistic matrix model of the anti-crisis adaptive digital model of higher education institution management in the context of sustainable development of the smart economy, structurally presented in Fig. 1, it can be embodied as a set of elements that are part of the structure of the institution, united by a common functional environment and the purpose of its functioning to ensure the proper implementation of:

educational functions, which consist in training qualified specialists adapted to the labor market;

scientific and research functions, which involve conducting scientific research and implementing innovations;

educational functions aimed at forming a socially responsible, culturally developed personality;

social functions aimed at supporting access to education for all segments of the population.

A typical table of the matrix model of functioning management can look like the one shown in Fig. 2.

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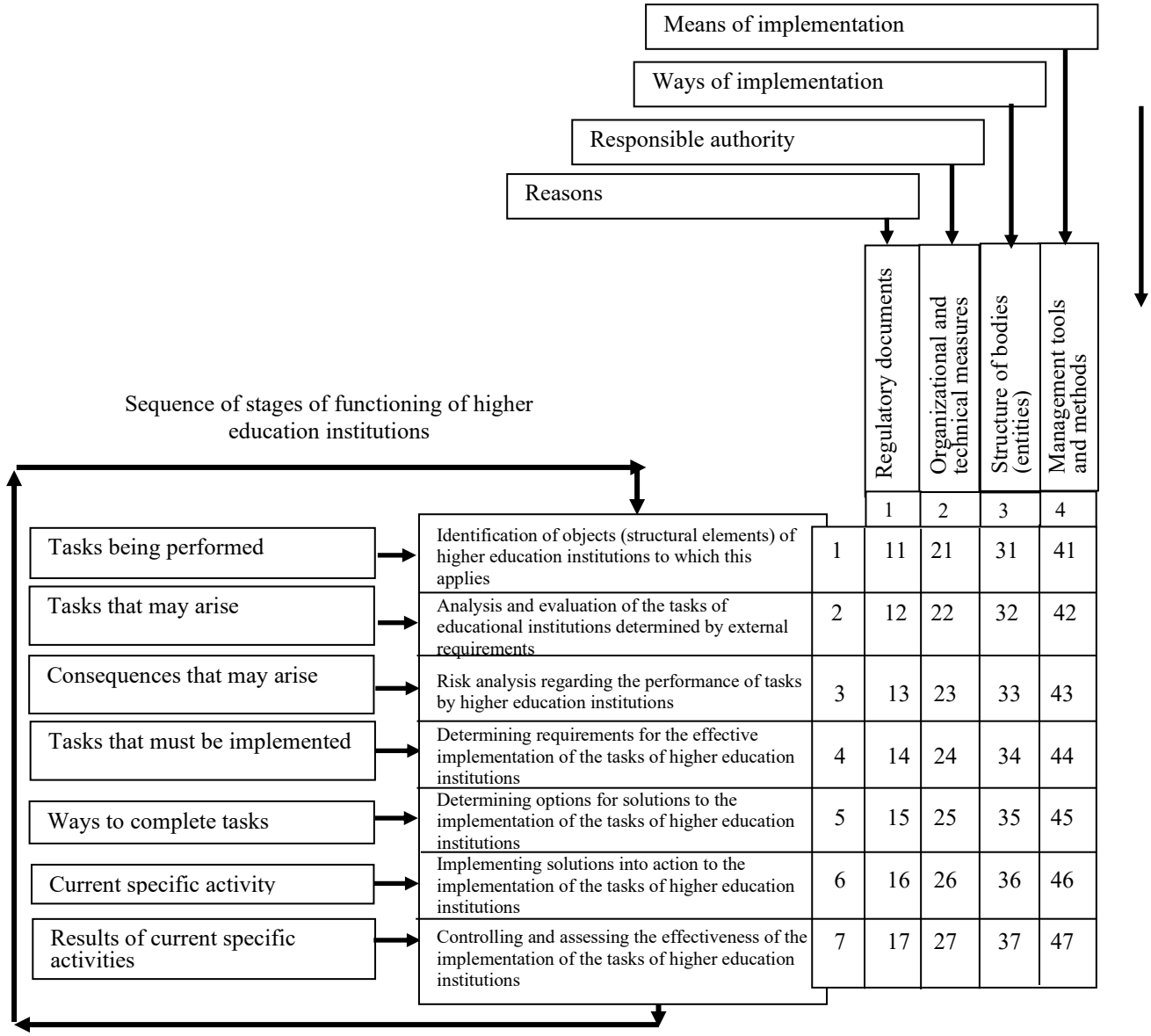

Figure 2. General view of a typical table of a matrix model for managing the functioning of a higher education institution in the context of sustainable development of a smart economy

Thus, the component "Organizational and constituent elements (structural components) of higher education institution management" of the logical-linguistic matrix of the model for ensuring the management of a higher education institution according to the general structure of the functional model of a higher education institution (Fig. 1) will describe the processes of:

analysis of the legislative and creation of a regulatory, normative-methodical, normative-scientific and scientific basis (documentation) on the issues of activity and ensuring the activity of a higher education institution;

formation of the structure of bodies (elements of the organizational structure) that carry out educational and scientific activities in a higher education institution at the appropriate level;

formation of the structure of bodies that ensure the activities of structural elements that carry out educational and scientific activities in a higher education institution;

formation of a complex of legal and organizational and technical measures to ensure educational and scientific activities in a higher education institution;

formation of methods, methods, means of implementing processes to guarantee a high level of educational and scientific activities in a higher education institution.

The component "Elements of ensuring the functioning of higher education institutions" of the logical-linguistic matrix of the model for ensuring the management of higher education institutions will describe the processes:

determining critical objects of a higher education institution at a certain moment in terms of tasks;

determining threatening situations in the relevant areas and areas of activity of higher education institutions;

analyzing risks and possible consequences from the point of view of implementing operational challenges and threatening situations;

forming and specifying requirements and tasks for the functioning of a higher education institution;

determining means and measures to counter threatening situations;

determining optimal solutions for the effective implementation of situational tasks and the functioning of higher education institutions;

implementing (ways of implementation) management measures and means of ensuring the implementation of situational tasks aimed at the effective functioning of higher education institutions;

assessing the effectiveness and control of the ability of higher education institutions to act according to the decisions made.

The component "Spheres of activity of higher education institutions" of the logical-linguistic matrix of the model for ensuring the management of higher education institutions will describe the processes:

educational activities of higher education institutions;

scientific and research activities;

educational and educational activities;

social activities;

international and grant activities;

economic activities;

activities for the material and technical development of higher education institutions (Ivakhiv & Nakonechnyi, 2017).

The structural elements of the model will be considered conditionally indivisible structural groups of higher education institutions (departments, departments, research laboratories, and other structural units of higher education institutions), which, under the influence of systemic logical-functional relationships, partially lose their individual properties.

The structural elements of the model for ensuring the management of the functioning of higher education institutions certainly have functional-logical relationships among themselves. The set of such relationships of the logical-linguistic matrix of the model for ensuring the management of the functioning of higher education institutions in the form of a table forms the matrix of the system of higher education institutions, which in turn is a simple, universal and sufficiently effective means of modeling and implementing the processes of ensuring the management of the functioning of a higher education institution.

The functional environment of the model for ensuring the management of the functioning of higher education institutions is considered to be a set of legal, regulatory and normative frameworks that regulate the functioning of higher education institutions, a set of legal, organizational, technical and scientific and methodological measures, a list of methods, tools, algorithms and parameters for implementing scientific and educational processes, according to which interaction is carried out between the elements of the model (structural components of higher education institutions) and the environment of its functioning.

By the structure of the model for ensuring the management of the functioning of higher education institutions, we will understand the set of relationships that ensure interaction between the elements of the system in the conditions of its functioning and the ways of its interaction with the external environment.

The logical-linguistic matrix model for ensuring the management of the functioning of

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higher education institutions will include various forms of information components. These can be text documents, quantitative information and characteristics, structuring elements (for example, diagrams, tables, schemes, graphs, etc.).

Formalization in the mentioned model will embody the processes of describing the requirements of laws, guidelines, recommendations and other meaningful statements using formal means and symbols of mathematical logic, which can even be words and word combinations with clear meaning (terms) (Domaryev, 2017; Korotka et al., 2020).

It is obvious that the organization of interaction of all components of the structure of higher education institutions will determine the effectiveness of the functioning of the institution as a whole and the fulfillment of its target functions and tasks.

Since the system of higher education institutions, despite its peculiarities in terms of structural elements, composition and tasks, is a managed system, it necessarily requires and assumes the presence of appropriate structures and regulations for the adoption and implementation of management decisions.

If we assume that a typical logical-linguistic matrix model for ensuring the management of the functioning of higher education institutions has the structure shown in Fig. 3, then in the form of a table it can be presented as Table 2, and taking into account its main functions of higher education institutions - as Table 3.

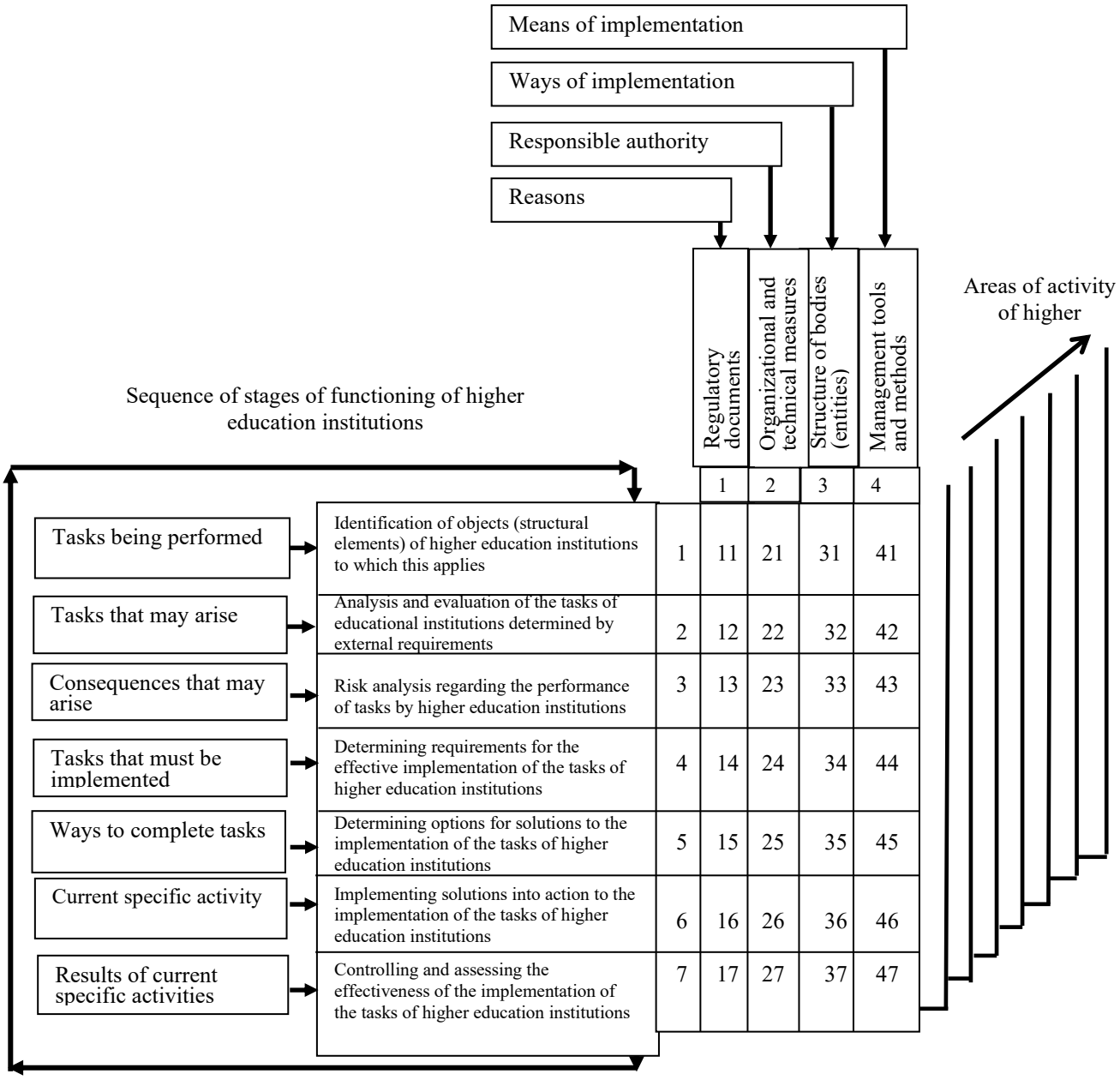

Figure 3. Logical-linguistic matrix model for ensuring the management of the functioning of a higher education institution

The matrix for ensuring the management of the functioning of higher education institutions is a tool for forming logical-functional relationships between the elements of the matrix, which describe the content of functional-logical relationships between the structural elements of higher education institutions.

To implement such a model, the method of fuzzy sets (Fuzzy Sets) can be used. This method is a powerful tool for modeling processes in nonlinear systems characterized by uncertainty, inaccuracy, intuitiveness or subjectivity of data, which is the system of higher education institutions. It is generally accepted that the method of fuzzy sets is especially effective for systems where human logic and fuzzy conditions are important. It allows you to build models close to natural thinking in conditions of a high level of uncertainty, which makes it possible to use it when building a model for ensuring the management of the functioning of higher education institutions. From the point of view of managing the functioning of higher education institutions, it is precisely such a process that is

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characterized by vaguely determined quantities such as fuzzy logic, fuzzy linguistic variables, fuzzy relations, fuzzy connections, etc.

Table 2. Logical-linguistic matrix model for ensuring the management of a higher education institution in the context of sustainable development of the smart economy

Logical-linguistic matrix model of management of higher education institutions		In all areas of activity of higher education institutions			
		Regulatory documents on education, higher education and scientific activities, other documents	Structure of constituent elements (model components) of the HEI	Organizational and technical measures to guarantee the fulfillment of the tasks of the HEI	Means and methods of managing HEIs in terms of fulfilling their tasks
		1*	2*	3*	4*
Definition of structural units of the HEI	*1	Documents containing information about the functional objects of the HEI	Entities that perform the relevant function within the functional objects of the HEI	Organizational and technical measures to identify HEI objects capable of effectively performing their functions	Means, methods and criteria used for objects capable of performing the corresponding functions
Monitoring of tasks vital for the effective functioning (performance) of the HEI	*2	Documents containing information about tasks (events) that are vital for the HEI	Entities that carry out activities related to the definition of vital tasks and their assessment	Organizational and technical measures to identify vital tasks and their assessment	Means, methods and criteria used to determine vital tasks and their assessment
Analysis of the consequences that may arise as a result of certain tasks (events, challenges) vital for the HEI	*3	Documents containing information about the risks and consequences of performing tasks (events) that are vital for the HEI	Entities that carry out activities to determine risks and consequences of the performance (implementation) of vital tasks	Organizational and technical measures to determine risks and consequences of the performance (implementation) of vital tasks	Means, methods and criteria used to determine the risks and consequences of the performance (implementation) of vital tasks
Determination of requirements for ensuring the performance of vital tasks of the HEI	*4	Documents containing information about the requirements for ensuring the performance of vital tasks	Entities that carry out activities to determine requirements to ensure the performance of vital tasks	Organizational and technical measures to determine requirements to ensure the performance of vital tasks	Tools, methods and criteria used to determine requirements for ensuring the performance of vital tasks
Choice of solutions for the effective performance of vital tasks of the HEI	*5	Documents containing information about the options for solutions to ensure the performance of vital tasks	Entities that carry out activities to determine options for solutions to ensure the implementation of vital tasks	Organizational and technical measures to determine options for solutions to ensure the implementation of vital tasks	Tools, methods and criteria used to determine options for decisions to ensure the performance of vital tasks
Implementation and control of the implementation of decisions on the performance of vital tasks of the HEI	*6	Documents containing information about measures to implement decisions to ensure the	Entities that carry out activities regarding adopted decisions to ensure the implementation of vital tasks	Organizational and technical measures to ensure the implementation of adopted decisions to implement vital tasks	Tools, methods and criteria used to implement decisions made to perform vital tasks

		performance of vital tasks			
Evaluation of the effectiveness of the HEI functioning	*7	Documents containing information about the assessment of the effectiveness of measures taken to perform vital tasks	Entities that carry out activities to assess the effectiveness of measures taken to implement vital tasks	Organizational and technical measures to determine the assessment of the effectiveness of measures taken to perform vital tasks	Tools, methods and criteria used to assess the effectiveness of measures taken to perform vital tasks

Table 3. Logical-linguistic matrix model for ensuring the management of a higher education institution in the context of sustainable development of the smart economy, taking into account its main functions

	Areas of activity of higher education institutions	**1				**2				**3				**4				**5				**6				**7			
		Educational component				Research component				Organizational and management component				Infrastructure component				Educational component				International component				Socio-economic component			
	Components	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods	Regulatory Documents	Structure of the constituent elements	Organizational and technical measures	Management tools and methods
		1**	2**	3**	4**	1**	2**	3**	4**	1**	2**	3**	4**	1**	2**	3**	4**	1**	2**	3**	4**	1**	2**	3**	4**	1**	2**	3**	4**
1	Determination of the objects to which the function applies	111	211	311	411	112	212	312	412	113	213	313	413	114	214	314	414	115	215	315	415	116	216	316	416	117	217	317	417
2	Identification and assessment of challenges to the performance of the function	121	221	321	421	122	222	322	422	123	223	323	423	124	224	324	424	125	225	325	425	126	226	326	426	127	227	327	427
3	Analysis of risks to the performance of the function	131	231	331	431	132	232	332	432	133	233	333	433	134	234	334	434	135	235	335	435	136	236	336	436	137	237	337	437
4	Determination of requirements for the performance of the function	141	241	341	441	142	242	342	442	143	243	343	443	144	244	344	444	145	245	345	445	146	246	346	446	147	247	347	447
5	Selection of solutions (action plan) for the performance of the function	151	251	351	451	152	252	352	452	153	253	353	453	154	254	354	454	155	255	355	455	156	256	356	456	157	257	357	457
6	Implementation of measures to perform the function	161	261	361	461	162	262	362	462	163	263	363	463	164	264	364	464	165	265	365	465	166	266	366	466	167	267	367	467

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7	Qualitative assessment of the effectiveness of the performance of the function	171	271	371	471	172	272	372	472	173	273	373	473	174	274	374	474	175	275	375	475	176	276	376	476	177	277	377	477

The main provisions of the application of the fuzzy set method include (Korotka et al., 2020; Ivakhiv & Nakonechnyi, 2017):

1. Basic concepts such as: fuzzy set: an object (structural element) where elements have a degree of membership from 0 to 1 (as opposed to a classical set with binary membership of 0 or 1); membership function: a mathematical representation of the degree of membership of an element in a fuzzy set (e.g., triangular, trapezoidal, Gaussian); linguistic variables: variables whose values are described by natural language words (e.g., "few", "many").

2. Key principles of application: fuzzy rule modeling: the use of conditional rules of the "if-then" type to describe dependencies between input and output parameters; fuzzy inference: combining rules using fuzzy logic operations (e.g., min-max for AND/OR operations); defuzzification: transformation of a fuzzy result into a clear numerical value (methods: center of gravity, average of maxima).

3. Stages of process modeling: definition of linguistic variables (for example, input: "load", output: "speed"); construction of membership functions for each variable; formulation of fuzzy rules based on expert knowledge or data; aggregation of rules and defuzzification to obtain control signals or forecasts.

An example of a matrix for ensuring the management of the functioning of higher education institutions in the field of educational activities is shown in Fig. 4.

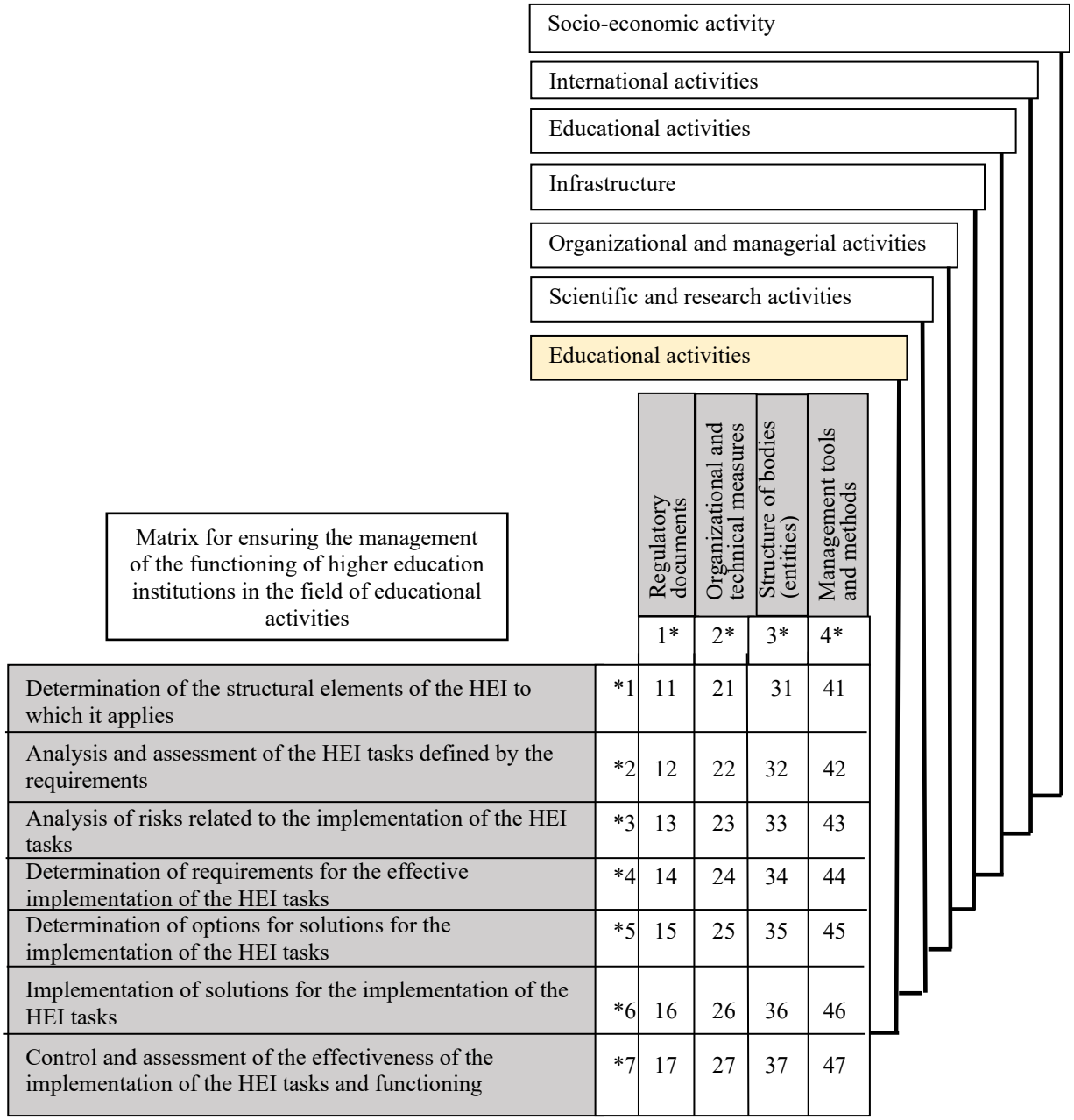

Figure 4. Matrix for ensuring the management of the functioning of higher education institutions in the field of educational activities

According to the classical theory of sets, each element included in a certain list is necessarily an element of a certain corresponding set (for example, a certain sphere of activity of a higher education institution) in which a large role is assigned to undefined (fuzzy) factors. These elements are thus, as it were, partially elements of other sets.

Fuzzy set methods involve the use of linguistic variables instead of numerical ones, the description of simple relations between structural elements of the system - a higher education institution using fuzzy statements, and more complex ones - using fuzzy algorithms.

As is known, the basic concepts of the theory of fuzzy sets are membership functions. Therefore, determining the degrees of membership of elements of a set and constructing membership functions on their basis is the main issue of practical implementation of the logical-linguistic model of ensuring the management of the functioning of a higher education institution.

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They can be formulated by various methods, based on the subject knowledge of information and certain experience. Certain knowledge is also required for the formation of dependencies that connect vaguely expressed input and output data during modeling, processing non-numeric and fuzzy information, and establishing cause-and-effect relationships between linguistic parameters of the model.

However, it is worth noting a significant drawback of using the fuzzy set method in modeling, such as its certain inaccuracy, which must be taken into account when making informed management decisions regarding the response to the challenges of higher education institutions in today's complex conditions.

The logical-linguistic approach and the specified features of the logical-linguistic model for ensuring the management of the functioning of higher education institutions will allow for the accelerated processing of complex combinations, which can be considered a certain advantage of such models. In addition, given the advantages of the modeling method based on fuzzy sets, the model for ensuring the management of the functioning of higher education institutions in the specified conditions will be characterized by great flexibility and adequacy to a complex real process.

The logical-linguistic matrix model is one of the approaches to the management of higher education institutions, which is based on logical analysis and linguistic evaluation of activity parameters. However, despite its advantages, it should be taken into account that in real conditions, such a model has a number of disadvantages:

1. Subjectivity of assessments. The logical-linguistic model uses linguistic variables (for example, “high level”, “medium risk”, etc.), which can be interpreted differently. This can lead to subjectivity in decision-making, especially when there are no clear criteria for assessment.

2. High dependence on expert judgments. Since the model requires qualitative analysis by experts, its effectiveness depends on the level of competence and objectivity of specialists. In the case of erroneous or biased assessments, inaccuracies in forecasts and management decisions are possible.

3. Difficulty in formalization and standardization. Since the model uses vague concepts and logical rules, it is difficult to formalize it in the form of universal algorithms. This complicates its adaptation to different higher education institutions, since each institution has its own specific features.

4. Large amount of data for analysis. For the high-quality functioning of the model, it is necessary to collect and process significant amounts of qualitative and quantitative information. This can be a difficult task for higher education institutions with limited resources.

5. Vulnerability to the human factor. Since the model depends on rules formulated by people, a situation is possible when errors in logical dependencies or failure to take into account important factors can lead to incorrect decisions.

Given the above shortcomings, the logical-linguistic matrix model of managing the functioning of higher education institutions is most appropriate to use in combination with other management methods based on quantitative analysis and forecasting.

Conclusions

Summarizing the presented research results, it should be noted that the anti-crisis adaptive digital model of higher education institution management, developed in the context of sustainable development of the smart economy, appears as a holistic institutional and functional structure capable of ensuring multi-level transformation of management approaches, strengthening organizational resilience, digital flexibility and strategic efficiency. The validity of such a model is based on the synthesis of interdisciplinary knowledge in cybernetics, systems analysis, fuzzy set theory and innovative management in education, which allows ensuring a high level of adaptation of higher education institutions to unstable conditions of the socio-economic, technological and political environment.

In the process of implementing this model, it was proven that higher education institutions are able not only to formally respond to external

crises, but also to create dynamic internal mechanisms for predicting, preventing and overcoming negative scenarios. This is possible due to the combination of digital analytics tools, flexible management logic, institutional forecasting and simulation modeling of educational processes. At the same time, the proposed logical-linguistic matrix model is not limited to rigidly formalized solutions, but takes into account the heterogeneity of management environments that operate in a state of constant variability, including the influence of the human factor, the complexity of assessing social changes and the dynamics of political regulators.

The effectiveness of the model is manifested in the possibility of creating an adaptive institutional platform that enables flexible redistribution of functional powers, dynamic routing of management decisions, and mobilization of digital and human resources in accordance with changing goals. Its logical-linguistic nature allows interpreting and formalizing a set of meaningfully complex, multi-vector processes that are difficult to classical algorithmization. In particular, the model is able to reveal hidden relationships between the processes of education management, scientific activity, infrastructure modernization and foreign economic activity of higher education institutions, taking into account not only objective, but also subjective factors of influence.

The model justifies the feasibility of using fuzzy sets as a tool for overcoming the limitations of traditional formal logic, which provides the possibility of making decisions in situations of insufficient information or its high variability. Fuzzy parameters allow the institution not to lose efficiency in difficult crisis situations, but on the contrary - to accumulate stability due to adaptive algorithms of learning, diagnostics, communication and organizational reflection. Logical-functional relationships formed within the management matrix provide the possibility of an operational response to systemic risks and increase management coordination at all levels.

The model proves its effectiveness in the process of strategic forecasting of the functioning of higher education institutions in interaction with the conditions of sustainable development, since it allows not only to structure internal processes, but also to formalize interaction with the socio-economic environment. Such an approach becomes the key to the transformational ability of higher education institutions to act in a mode of advanced development, and not exclusively in the format of reaction to external events. The priority value here is not technological modernization as such, but its organic integration into the system of strategic decision-making, which is based on the smart principles of sustainability, ethics, transparency and innovative responsibility. As a result, the logical-linguistic matrix model not only conceptualizes anti-crisis management, but also sets a new paradigm of educational administration, within which digital tools do not replace human thinking, but strengthen it through accurate, although not always unambiguous, cognitive models of interpretation of complex educational and organizational phenomena. Such a model has potential not only in the education sector, but also in the broader system of public governance, which requires new architectures of adaptive response in an era of turbulence, globalization, and the digital revolution.

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