Zamrii, I. V. (2024). Methodology of building a functionally sustainable in information system of an institution of higher education. *Actual Issues of Modern Science. European Scientific e-Journal, 29*, 60-69. Ostrava: Tuculart Edition, European Institute for Innovation Development.

DOI: 10.47451/inn2024-04-04

The paper is published in Crossref, ICI Copernicus, BASE, Zenodo, OpenAIRE, LORY, Academic Resource Index ResearchBib, J-Gate, ISI International Scientific Indexing, ADL, JournalsPedia, Scilit, EBSCO, Mendeley, and WebArchive databases.

Iryna V. Zamrii, Doctor of Sciences (Engineering), Associate Professor, Head of Department, Department of Software Engineering, State University of Information and Communication Technologies. Kyiv, Ukraine.
ORCID: 0000-0001-5681-1871, Scopus: 57441767000.

Methodology of building a functionally sustainable in information system of an institution of higher education

Abstract. The study object is the methodology of building a functionally stable information system of a higher education institution. The study subject is the process of organizing the unified information space, in which all information resources are uniquely identified, for the further implementation of an information system that meets a high level of security, productivity, scalability, management, and access to the system is provided regardless of the user's location. The purpose is to improve the quality of management and education in institutions of higher education through the introduction of modern information technologies. To achieve the goal and solve the tasks, such methods as recognition methods of information system elements and their features, methods of reconstruction of missing features of elements in the information space, methods of graph theory and game theory are used. This paper presents the developed methodology for building a functionally stable information system for a higher education institution. It consists of performing two main procedures: (1) the procedure of organizing an information system based on a single information space of a higher education institution; and (2) procedures for ensuring the functional stability of the information system of the higher education institution. The methodology of the procedure for the organization of the information system based on the unified information space of the institution of higher education is based on the model of the unified information space of the institution of higher education, methods of recognition of information system elements, reconstruction of features of information system elements and synchronous recognition of elements, algorithms of relationships between elements and their sets of feature values allows to increase the effectiveness of the information system of the institution of higher education and management decision-making. The implementation of the information system aims to optimize processes and save resources (human, financial, informational, etc.), allowing tasks to be performed remotely while ensuring a high level of system security and productivity thanks to ensuring the functional stability of the entire information system of a higher education institution.

Keywords: information system of a higher education institution (IS), functional stability (FS), information protection, SD-WAN, unified information space.

Abbreviations:

FS – functionally stable;

IS – information system.

Introduction

The rapid development of information technologies and digitization of all processes requires higher education institutions to use new methods of obtaining and processing information for effective management decision-making and ensuring the reporting system of the entire higher education institution. The solution to this issue lies in the creation of the system, based on the concept of a single information space and provides access and processing of all accumulated information, optimization of information interaction, improvement of the solution of complex management tasks in connection with the improvement of the organization of information support (*Bobrov et al., 2013*; *Shkitsa et al., 2019*; *Bannon & Bødker, 1997*).

Complex implementation and integration of all information systems of a higher education institution into the unified information space, based on which a functionally stable information system is built (*Mashkov et al., 2023*; *Sobchuk et al., 2022*), will provide, although not directly, a significant economic effect.

Informatization and digitalization are not a source of direct income but are an additional means of organizing the activities of the entire institution of higher education and an opportunity to effectively ensure management decisions, regulate financial flows, and organize the educational process (*Kopiyka & Korotchenko, 2018*; *Storchak et al., 2017*), cost minimization, preservation of personnel potential. The remote access provision for performing official duties is especially relevant in the conditions of the pandemic and martial law of Ukraine when higher education employees and students are scattered over large territories.

The main benefit of the implementation of higher education institution FS IS is to improve access to information resources of a higher education institution, both by employees and students of higher education, improve the reporting system and operational management, reduce the labour intensity of the implementation of the management process, i.e., reduce management costs, regulation of financial and economic indicators, reduction of labour costs for ensuring document circulation (*Smelyakov et al., 2018*).

Using the educational institution's information system based on the unified information space will make it possible to unambiguously recognize arbitrary information from various channels and systems and ensure its authenticity. At the same time, IS not only reduces information processing time, but also:

- implements automatic data processing in the "request-response" mode;
- integrates the information systems of various units into a single entity;
- reduces manipulation of information by IS users;
- avoids duplication of data when collecting primary information and when processing it;
- improves the general exchange of information;
- provides information users access to information resources of the institution;
- increases the efficiency of information management;
- allows to reduce the number of technical personnel in various structural units.

The main requirements for the IS are the low cost of restoring the functioning of the IS and ensuring the FS IS.

The study object is the methodology of building a functionally stable information system of a higher education institution.

The study subject is the process of organizing the unified information space, in which all information resources are uniquely identified, for the further implementation of an information system that meets a high level of security, productivity, scalability, management, and access to the system is provided regardless of the user's location.

The purpose is to improve the quality of management and education in institutions of higher education through introducing modern information technologies.

Based on the set goal, the following tasks are solved in the work:

- an analysis of modern approaches to the construction of information systems in higher education is performed;
- a procedure for organizing an information system based on the unified information space of a higher education institution is being developed;
- a procedure for ensuring the functional stability of the information system of a higher education institution is being developed using a combination of methods of functional reconfiguration of the top of the graph of the top level of the IS network hierarchy and functional reconfiguration of the hierarchical IS network in real time;
- a methodology is being developed that will allow to effectively build a safe, productive, scalable information system that corresponds to the specifics of the higher education institution and the educational process.

To achieve the purpose and solve the tasks, such methods as recognition methods of information system elements and their features, methods of reconstruction of missing features of elements in the information space, methods of graph theory and game theory are used.

In today's conditions, more and more diverse software, applications, technologies, and information services for the high-quality functioning of the information system of a higher education institution are appearing. However, on the other hand, restrictions on access to information are often imposed depending on the structural unit to which it belongs. That is, in the vast majority of information systems, even in one institution of higher education, they function in isolation, primarily in the interests of a separate structural unit (*Bobrov et al., 2013*). This causes the following:

- difficulties in accessing and exchanging information;
- the need for optimization during the collection and processing of information from the primary source;
- non-rational use of funds for operational costs.

The solution to these problems consists in the creation of the unified information space that provides access and processing of all accumulated information, optimization of information interaction, improvement of the solution of complex management tasks in connection with the improvement of the organization of information support (*Shkitsa et al., 2019*; *Storchak et al., 2017*). That is, the unified information space is a union of databases, information systems and information networks, technologies for their operation, which function and are organized according to unified rules, methods, approaches and provide information interaction between territorially distant centers and systems.

The unified information space consists of (*Bannon & Bødker, 1997*):

- information resources belonging to different databases and stored on different media;
- organizational structures that perform the collection, processing, storage, distribution, search and transfer of information for the expansion and stable functioning of the space;
- information technologies and means of their interaction, which provide access to information resources.

The unified information space concept provides (*Zavgorodnii et al., 2021*; *Zavgorodnii et al., 2019*) that information resources include information system data and applications implemented as part of information processing methods. At some levels, other information systems may be available to them. At the same time, applications can act as clients and servers for each other and jointly solve some tasks. As a result, information resources are used much more efficiently since there is an optimal balance between software and hardware load, and the costs of management, maintenance and modification of the system as part of the unified information space are reduced since information and methods of their processing are localized within a specific IS.

Cloud networks are a convenient and reliable tool for organizing work in the unified information space (*Basu et al., 2020*; *Lemeshko et al., 2020*).

In addition, in the concept of the unified information space, one of the main criteria is a high level of security, fault tolerance and reliability that meets international standards (*Sobchuk et al., 2021*). Ensuring the functional stability of the information system against destabilizing factors and conflicts in the system that lead to failures in the functional processes of the information system consists in ensuring the ability of the system to preserve or restore certain functions over a long period of time (*Mashkov et al., 2023*; *Sobchuk et al., 2022*).

Methods for ensuring a high security and fault tolerance level were developed in (*Zamrii et al., 2024*), the essence of which consists of choosing the optimal strategy for continuing to perform tasks under the influence of destabilizing factors, a complete search of configurations in the hierarchical network of the information system of a higher education institution, and the redistribution of network resources based on game theory.

The research presented in this work is a logical continuation of scientific research conducted in (*Zamrii et al, 2022*; *Zamrii & Vyshnivskyi, 2022*; *Zamrii et al., 2024*) and consists of the development of a methodology for building a functionally stable information system of a higher education institution based on the processes of organizing the unified information space and ensuring the functional stability of the information system by means of reconfiguration of virtual networks in virtual cloud environments.

The results of the study

The methodology for building an FS IS consists of combining all organizational structures, information resources and external information influences for the IS organization based on a single information space of a higher education institution, systems, technologies and methods to ensure the functional stability of the IS. Using Prisma Access and Prisma SD-WAN software-defined WAN for this purpose (*Basu et al., 2020*; *Lemeshko et al., 2020*), the components of the Aruba SD-Branch solution are limited to a set of Aruba products that provide the ability to deploy and maintain the network, namely: Aruba Central; Aruba ClearPass; Aruba Headend

Gateways of the Aruba 7200 series; Aruba Virtual Gateways; Aruba branch gateways (Aruba Branch Gateways – BGW) of the Aruba 9000, 7200 and 7000 series; Aruba Access Switches 2930F, 2930M, 3810M and 5400R; Aruba access points (Aruba Access Points) models Aruba AP-5xx (dual APs 802.11ax Wi-Fi 6), and models AP-3xx (dual APs 802.11ac Wave 2 Wi-Fi 5).

After performing the procedure of organizing the information system based on the unified information space of the institution of higher education, it is necessary to provide FS IS. In this way, the FS IS construction procedure will be divided into two parallel procedures:

(1) IS organization procedure based on the unified information space of a higher education institution.
(2) FS IS provisioning procedure.

We will describe each of the procedures in more detail.

IS organization procedure based on the unified information space of a higher education institution

The stage of input elements recognition.

It is intended for updating and adding new input elements to the unified information space using the input element recognition method, that is, performing a step-by-step analysis of the set of features of each input element and their connections. At the stage of input elements recognition, the following steps are performed:

Step 1. Reading by the utility of a set of values to establish the characteristics of the input element for a unified presentation in the unified information space.

Step 2. The element recognition by using the synchronous recognition method, i.e., simultaneous search and comparison in all information spaces of the set of values corresponding to the input element. This method is described in detail in (*Zamrii & Vyshnivskyi, 2022*).

Step 3. The recognition results analysis: if, as a result of the study, a similar set of attribute values is found in the unified information space, then the input element is considered recognized and already added to the unified data store. If an identical set of feature values is not found in the unified information space, then the input element is considered new.

Step 4. Updating the unified information space by adding a new element to the unified data store and establishing relationships with other elements of the unified information space.

The procedure for organizing an information system based on the unified information space of a higher education institution directly depends on the flow of information, both inside the information space and from the outside. This is because the effectiveness of IS functioning in conditions of uncertainty depends on the promptness and quality of the information received. Therefore, information resources are of fundamental importance for the IS organization and its further development.

IS is organized based on the unified information space, creates an environment for prompt use of reliable information regardless of the user's location and without time restrictions, and the information itself is of fundamental importance for the functioning and support of IS.

FS IS provisioning procedure

The stage of security functions analysis and use.

At this stage, input data is determined and the vertices of the IS network hierarchy graph, which are unable to function fully under the influence of destabilizing factors (malfunctions, failures, lack of resources, attacks, etc.), are identified. To eliminate problems, the Prisma Access infrastructure is used to bypass faulty connections in the IS network.

If the problem is eliminated and all tasks assigned to the IS network are completed, the procedure for ensuring functional stability ends. Otherwise, it is necessary to proceed to the next stage.

The stage of determining the characteristics.

Step 1. With the help of reading by the IS controller, the values for the execution periods of the server and user algorithms $\mathcal{T}_c$, $\mathcal{T}_k$, the execution time t_c and the multiplicity of execution k are determined to fulfill the condition:

$$\mathcal{T}_c = t_c + k\mathcal{T}_k.$$

The periods and execution time of the specified algorithms are shown in the appendix (*Figure 1*).

Step 2. For each function f, the following are defined:

$\mathcal{S}_0(a_{fj})$ is the best decision scenario;

$\delta(a_{fj})$ is a weighting factor that allows the controller to determine the priority of the performed functions in the system;

$Q_0(a_{fj})$ is a limitation in the case of a partial loss of productivity.

For the objective function of the top-level vertex of the IS network hierarchy, the maximization of the wins in each of the strategies and the minimization of the constraints will be:

$$\mathcal{F}(a_{fj}) = \sum a_{fj}\left(\left(\mathcal{S}_0(a_{fj}) - \mathcal{S}_m(a_{fj})\right) \times \delta(a_{fj}) + Q_0(a_{fj})\right) \to min.$$

Methods $\mathcal{B}_1$ are functional reconfiguration of the top of the graph of the top level of the IS network hierarchy and $\mathcal{B}_2$ are functional reconfiguration of the hierarchical IS network in real time are being configured. A detailed study of methods $\mathcal{B}_1$ and $\mathcal{B}_2$ are presented in the collective work of I. Zamrii, V. Vyshnivskyi and V. Sobchuk (*Zamrii et al., 2024*).

Step 3. $\mathcal{T}_c, \mathcal{T}_k, t_c, k$ are determined at the current time to adjust the order of application and execution time of the methods.

Step 4. Selection of the α value of partial IS productivity:

$$Q_0\left(a_{fj}\right) = Q_0^*\left(a_{fj}\right) + \alpha \times Q_1^*\left(a_{fj}\right).$$

Stage of implementation of methods.

To eliminate a malfunction in the system at the implementation stage, three options for the development of events are possible:

Option 1. Application of the $\mathcal{B}_1$ method of functional reconfiguration of the top of the graph of the top level of the IS network hierarchy.

Option 2. Application of the $\mathcal{B}_2$ method of functional reconfiguration of the IS hierarchical network in real time.

Option 3. Parallel application of both methods of functional reconfiguration of the hierarchical IS network in real time $\mathcal{B}_1$ and functional reconfiguration of the top of the graph of the top level of the IS network hierarchy $\mathcal{B}_2$.

After the deployment of events according to one of the scenarios, the level of functional stability of the IS is evaluated at the current moment in time using the SD-WAN cloud controller.

If, after assessing the level of functional stability of the information system with the help of the SD-WAN cloud controller, it was determined that the fault tolerance of the information system network of the higher education institution is ensured, then the procedure is completed. In the opposite case, there is a return to the stage of determining the characteristics to adjust the values of $\mathcal{T}_c$, $\mathcal{T}_k$, t_c, k and α.

The methodology of building a functionally stable information system of a higher education institution can be presented as shown in the appendix (*Figure 2*).

Therefore, the methodology of building a functionally stable information system of a higher education institution is based on the use of the unified information space and consists of the joint implementation of methods and techniques for ensuring the functional stability of the information system network to spread the property of functional stability to the entire system.

Thus, due to the implementation of two main procedures, the functional stability of the entire information system of the higher education institution is ensured.

Discussion

War constantly creates new dangers and generates new challenges that require quick adaptation and flexible approaches to solving problems. The implementation of the information system will make it possible to relieve people, optimize processes, and save resources, allowing tasks to be remotely performed while ensuring an increased level of security and productivity of the system thanks to ensuring the functional stability of the entire information system of the institution of higher education. Such an approach, subject to compliance with the developed methodology, can be applied to the functioning of other critical structures.

Conclusions

The effect of a functionally stable information system of a higher education institution is to increase labour productivity, i.e., to reduce work time. According to estimates, if the use of the system is extended to all tasks, it can be predicted that half of the employees' working time will be freed from unproductive time-consuming tasks.

A characteristic feature of increasing informatization in the institution due to the use of IS is that the more time and money is spent on the system, the higher the economic benefit from its use. If all processes are defined, identified and adjusted at the design and implementation stage of FS IS due to the selection of a software-defined network, increased information protection and management, then the time and costs of future operations can be significantly reduced, especially at the level of divisions, services and employees.

Thus, FS IS implementation reduces the costs of organizing effective interaction between all units, simplifies information exchange, and document flow, and reduces the time required to complete tasks. At the same time, a high level of system security and productivity is ensured due

to ensuring the functional stability of the entire information system and the possibility of remote work for deploying branches in different countries and even continents.

References:

Bannon, L., & Bødker, S. (1997). Constructing Common Information Spaces. *Fifth European Conference on Computer Supported Cooperative Work*, 81-96. Springer. Dordrecht. https://doi.org/10.1007/978-94-015-7372-6_6

Basu, K., Hamdullah, A., & Ball, F. (2020). Architecture of a Cloud-based Fault-Tolerant Control Platform for improving the QoS of Social Multimedia Applications on SD-WAN. *13th International Conference on Communications (COMM)*, 495-500. https://doi.org/10.1109/COMM48946.2020.9142038

Bobrov, S. V., Levshenko, O. S., & Porivai, O. V. (2013). Methods of forming a unified information environment in the institution. *Collection of scientific works of the Center for Military and Strategic Studies of the National Defense University of Ukraine named after Ivan Chernyakhovsky*, *3*(49), 26-32. (In Ukrainian). [Бобров, С. В., Левшенко, О. С., Поривай, О. В. (2013) Методи формування єдиного інформаційного середовища в установі. *Збірник наукових праць Центру воєнно-стратегічних досліджень Національного університету оборони України імені Івана Черняховського*, № 3(49), с. 26-32]. http://nbuv.gov.ua/UJRN/Znpcvsd_2013_3_6

Kopiyka, O. V., & Korotchenko, L. A. (2018). Approaches to building a modern IT infrastructure as a basis for creating a unified information space. *Collection of scientific papers VITI*, *1*, 34-42 (In Ukrainian). [Копійка, О. В., Коротченко, Л. А. (2018). Підходи до побудови сучасної IT-інфраструктури як основи для створення єдиного інформаційного простору. *Збірник наукових праць ВІТІ*, № 1, с. 34-42].

Lemeshko, O., Yeremenko, O., Hailan, A. M., Yevdokymenko, M., & Shapovalova, A. (2020). Policing Based Traffic Engineering Fast ReRoute in SD-WAN Architectures: Approach Development and Investigation. *New Trends in Information and Communications Technology Applications. NTICT 2020. Communications in Computer and Information Science*, 1183. https://doi.org/10.1007/978-3-030-55340-1_3

Mashkov, O., Bychkov, A., Kalahnik, G., Shevchenko, V., & Vyshemyrska, S. (2023). Application of the Theory of Functional Stability in the Problems of Covering Territories by Sensory Networks. *Lecture Notes on Data Engineering and Communications Technologies*, *149*, 266-285. https://doi.org/10.1007/978-3-031-16203-9_16

Shkitsa, L. E., Kornuta, V. A., & Kornuta, O. V. (2019). Unified information space of innovative project activities of a specialized institution of higher education. *Information programs and computer-integrated technologies. Scientific Bulletin IFNTUNG*, *2*(47), 57-64 (In Ukrainian). [Шкіца Л. Є., Корнута В. А., Корнута О. В. (2019) Єдиний інформаційний простір інноваційно-проєктної діяльності профільного закладу вищої освіти. *Інформаційні програми та комп'ютерно-інтегровані технології. Науковий вісник ІФНТУНГ*, № 2(47), с. 57-64]. https://doi.org/10.31471/1993-9965-2019-2(47)-57-64

Smelyakov, K., Pribylnov, D., Martovytskyi, V., & Chupryna, A. (2018). Investigation of network infrastructure control parameters for effective intellectual analysis. *14th International*

Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET). Proceedings, *IEEE 2018*, 983-986. https://doi.org/10.1109/TCSET.2018.8336359

Sobchuk, V., Barabash, O., Musienko, A., Kozlovskyi, V., Shcheblanin, Y. et al. (2022). Evaluation of Efficiency of Application of Functionally Sustainable Generalized Information System of the Enterprise. *HORA 2022 – 4th International Congress on Human-Computer Interaction, Optimization and Robotic Applications. Proceedings*, 1-7. https://doi.org/10.1109/HORA55278.2022.9799892

Sobchuk, V. V., Zamrii, I. V., Barabash, O. V., & Musienko, A. P. (2021). Methodology for building a functionally stable intelligent information system of a manufacturing enterprise. *Bulletin of the Taras Shevchenko National University of Kyiv. Physics and Mathematics*, 4, 116-127. https://doi.org/10.17721/1812-5409.2021/4.18

Storchak, K. P., Vyshnivskyi, V. V., Hnidenko, M. P., Ilyin, O. O., & Haydur G. I. (2017). A model of a unified information space for the management of the educational process. *Communication*, *1*, 30-34. (In Ukrainian). [Сторчак, К. П., Вишнівський, В. В., Гніденко, М. П., Ільїн, О. О., Гайдур, Г. І. (2017). Модель єдиного інформаційного простору управління навчальним процесом. *Зв'язок*, № 1, с. 30-34]. http://nbuv.gov.ua/UJRN/Zvjazok_2017_1_9

Zavgorodnii, V., Dodonov, A., Mukhin, V., Komaga, Ya., & Zavgorodnya, A. (2021). Method of searching for information objects in unified information space. *System research and information technologies*, *1*, 34-46. https://doi.org/10.20535/SRIT.2308-8893.2021.1.03

Zavgorodnii, V., Zavgorodnya, A., Plisenko, V., Provatorov, N., & Kudientsov, P. (2019). Methods Modeling Systems for the Improvement of Their Reliability. *International Academy Journal Web of Scholar*, *9*(39), 1, 3-11. https://doi.org/10.31435/rsglobal_wos/30092019/6683

Zamrii, I. V., & Vyshnivskyi, V. V. (2022). Method of identification of atomic elements of information space with the help of a unified information space. *Bulletin of the Taras Shevchenko National University of Kyiv. Physics and Mathematics*, *3*, 47-54. https://doi.org/10.17721/1812-5409.2022/3.6

Zamrii, I., Shkapa, V., & Vlasyk, H. (2022). Recovery and identification of information in the information space. *2022 IEEE 4th International Conference on Advanced Trends in Information Theory (ATIT'2022)*, p. 187-192. https://doi.org/10.1109/ATIT58178.2022.10024209

Zamrii, I., Vyshnivskyi, V., & Sobchuk, V. (2024). The method of ensuring the functional stability of the information system based on detection of intrusions and reconfiguration of virtual networks. *CEUR Workshop Proceedings. CPITS-2024: Cybersecurity Providing in Information and Telecommunication Systems*, 252-264. https://ceur-ws.org/Vol-3654/

Appendix

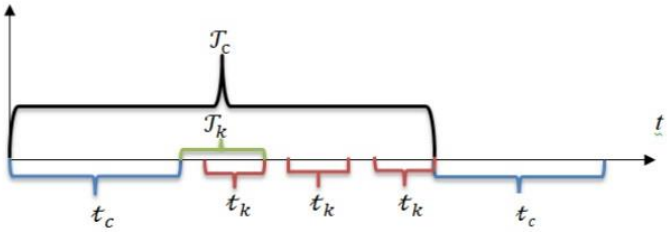

Figure 1. Periods and execution time of algorithms

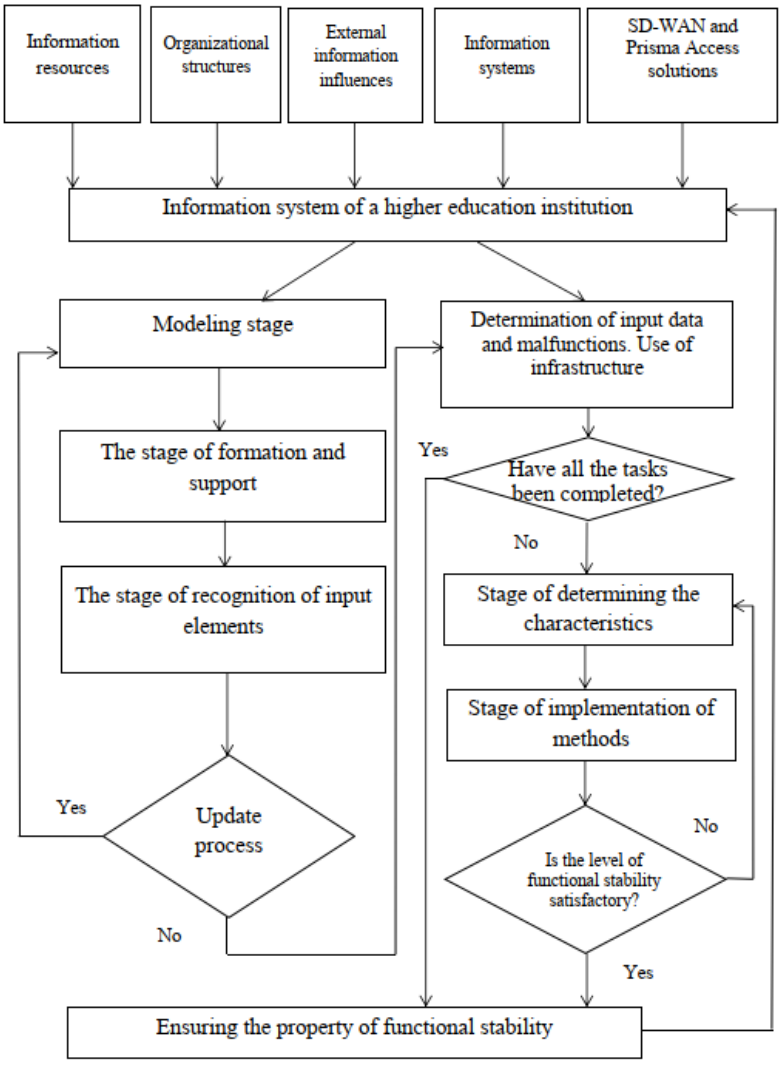

Figure 2. Methodology for building a functionally stable information system of a higher education institution