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METHOD AND SOFTWARE SYSTEM FOR ASSESSING THE RELIABILITY OF INFORMATION SYSTEMS

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ABSTRACT

The article proposes a method that allows you to assess the level of fault tolerance of information systems. Fault tolerance is assessed according to several criteria and various areas of optimization. The method allows you to evaluate and rank alternative solutions. The level of the alternative solution is determined by comparing the analyzed version of the alternative with the ideally best one. A corresponding software system has been developed that implements the proposed method. The method and software system make it possible to determine the fault tolerance of information and automated systems. The developed software system and the proposed method were used and tested in practice to assess the fault tolerance of the information system according to several criteria. During the practical application of the method, the levels of fault tolerance of each of the components of a real information system were identified. Thus, in practice, it was shown that the method can be used to assess the level of fault tolerance of information systems.

Keywords: *Information System, Fault Tolerance, Reliability, Method, Expert Assessment.*

1. INTRODUCTION

Currently, in connection with the rapid development of digital technology, the problems of ensuring the reliability and fault tolerance of information and automated systems are gaining great relevance and importance. Failures in the operation of information and automated systems can lead to financial losses, deterioration of the image and reputation losses for the company, harm to health or a threat to human life, as well as other losses and threats. Of particular danger are the risks of information and automated systems associated with reliability, resiliency and security for critical information and communication infrastructures.

Ensuring the reliability and resiliency of information and automated systems is a difficult task. It is necessary to know the areas that lead to failures of Information Systems (IS) and create potentially dangerous situations. The problem must be solved in a complex, according to many criteria.

Much research is devoted to identifying risks and ensuring reliability and safety in various areas of activity, in particular, work [1-60]. Thus, multicriteria methods allow solving the problems of determining risks in different practical areas in which there are different interests [1-15]. In [16-60], the issues of ensuring reliability and safety were investigated, methods for identifying and neutralizing risks, ensuring reliability at the early stages of IS development were proposed, an appropriate software system based on the proposed methods was developed. The application of these methods was shown in the development of IS in various practical areas. These methods identify individual IP components and quantify their risks. To neutralize the risks, the most effective strategies are proposed that are stored in the database of the software system.

This article proposes a new approach to ensure the fault tolerance and reliability of information and automated systems. The proposed approach underlies the developed software system, and allows you to assess the fault tolerance of the IS. The resiliency of an IS is assessed against many criteria using the Multiple-Criteria Decision-Making (MCDM) methodology to achieve many different goals related to IS reliability. The software system allows you to select alternatives, rank them, assess their compliance with all criteria. The proposed multicriteria approach, based on the adaptation of the

ARAS (additive ratio assessment) and SWARA (step-wise weight assessment ratio analysis) methods, and the software system developed on their basis, make it possible to determine the studied IS components (alternatives), criteria for comparing alternatives, the significance (weight) criteria. The alternative can be described by both quantitative and qualitative criteria. The evaluation criteria can have different units of measurement, therefore, to obtain comparable scales of the criteria values, they are normalized. The multicriteria approach proposed in this article and the software system developed on its basis can be used to analyze the risks of information and automated systems. The main advantage of multicriteria methods is their ability to solve problems associated with various conflicting interests.

2. DETERMINATION OF THE LEVEL OF RELIABILITY AND FAULT TOLERANCE OF INFORMATION SYSTEMS

Determination of the level of reliability and fault tolerance of IS components consists of the following stages:

• Statement of the problem - the level of fault tolerance of which product should be determined (information system, automated system, a separate component of the system, information communication infrastructure, etc.);

• Appointment of experts - with qualifications, education, experience in this area;

• Description of alternatives to the task;

• Description of the criteria that affect the resiliency of alternatives;

• Description of criterion optimization;

• Calculation of criteria values for alternatives;

• Calculation of the weight (influence) of the criteria on the fault tolerance of the alternative;

• Calculation of the level of fault tolerance of alternatives by the adapted ARAS method (Additive ratio assessment);

• Calculation of the level of fault tolerance of alternatives by the adapted SWARA method;

• Analysis of results - done by experts. If the results are satisfactory, then the problem is solved. Otherwise, the problem is solved again.

As described above, a failure of the IS can lead not only to the disruption or termination of its functioning, but also to more global consequences. Thus, the presence of such risks leads to the need to find effective methods for their assessment.

The proposed method makes it possible to determine the complex fault tolerance and reliability of the IS components.

Therefore, when using this method, it is convenient to evaluate and rank alternative solutions. The degree of alternativeness is determined by comparing the analyzed variant with the ideally best one.

2.1 Adaptation of the ARAS method to determine the level of reliability and fault tolerance of information systems.

Consider the ARAS method [30-34]. First, the decision-making matrix (DMM) is formed. The task is represented by the following DMM:

$$X = \begin{matrix} x_{01} & x_{0j} & x_{0b} \\ x_{i1} & x_{ij} & x_{ib} \\ x_{a1} & x_{aj} & x_{ab} \end{matrix}; \ i = \overline{0,a}; \ j = \overline{1,b}, \qquad (1)$$

where a – number of alternatives, b - number of criteria describing each alternative, x_{ij} - a value representing the performance value of the alternative i in terms of the criterion j, x_{0j} - optimal criterion value j [9].

If the optimal value of the criterion j is unknown, then

$$\begin{aligned} x_{0j} &= \max_i x_{ij}, if \max_i x_{ij} \ is \ preferable; \\ x_{0j} &= \min_i x^*_{ij}, if \min_i x^*_{ij} \ is \ preferable. \end{aligned} \qquad (2)$$

The system of criteria, values and initial weights of the criteria are determined by experts [9]. Usually the criteria are different. Therefore, it is necessary to obtain dimensionless weighted values of the criteria. For this, the ratio of the criterion to the optimal value is used. There are various methods that describe the ratio of the criterion to the optimal value. Typically, values are displayed in the interval [0; 1] or the interval [0; ∞]. At the next stage, the initial values of all criteria are normalized - the values x_{ij} of the normalized decision-making matrix X are determined.

$$X = \begin{matrix} \bar{x}_{01} & \bar{x}_{0j} & \bar{x}_{0b} \\ \bar{x}_{i1} & \bar{x}_{ij} & \bar{x}_{ib} \\ \bar{x}_{a1} & \bar{x}_{aj} & \bar{x}_{ab} \end{matrix}; \ i = \overline{0,a}; \ j = \overline{1,b}, \qquad (3)$$

If the values of the criteria are to be maximized, then their normalization is done as follows:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{a} x_{ij}}. \qquad (4)$$

If the values of the criteria are to be minimized, then their normalization is done as follows (two-stage procedure):

$$x_{ij} = \frac{1}{x_{ij}^*}; \quad \bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{a} x_{ij}}. \qquad (5)$$

All criteria, initially having different measurements, are reduced to dimensionless values and can be compared.

At the next stage, the normalized weighted matrix X is determined. The criteria are evaluated with the weights w_j , $0 < w_j < 1$. The values of the weights w_j are determined using expert judgment. For the weights w_j the following condition must be met:

$$\sum_{j=1}^{b} w_j = 1. \qquad (6)$$

$$\hat{X} = \begin{matrix} \hat{x}_{01} & \hat{x}_{0j} & \hat{x}_{0b} \\ \hat{x}_{i1} & \hat{x}_{ij} & \hat{x}_{ib} \\ \hat{x}_{a1} & \hat{x}_{aj} & \hat{x}_{ab} \end{matrix}; \quad i = \overline{0,a}; \quad j = \overline{1,b}, \qquad (7)$$

The normalized weighted values of the criteria are calculated:

$$\hat{x}_{ij} = \bar{x}_{ij} w_j; \quad i = \overline{0,a}, \qquad (8)$$

where w_j - weight (importance) of criterion j,

$$S_i = \sum_{j=1}^{b} \hat{x}_{ij}; \quad i = \overline{0,a}, \qquad (9)$$

where S_i - is the value of the alternative optimality function. The larger the S_i value, the more efficient the alternative. Alternatives can be prioritized according to the S_i value. Thus, alternatives can be evaluated and ranked using this method.

The degree of utility K_i of alternative i is calculated as follows:

$$K_i = \frac{S_i}{S_0}; \quad i = \overline{0,a}, \qquad (10)$$

The K_i values are in the range [0, 1] and can be sorted in ascending order and thus prioritized.

2.2 Adaptation of the SWARA method to determine the level of reliability and fault tolerance of information systems

When using the adapted SWARA method, criteria should be selected. For example, you can select as criteria: "Program type", "Data recovery", "Error type", "Access type".

Next, you should select the subcriteria.

Subcriteria can be:

1) Program type: website, desktop programs, mobile applications, devices.

2) Data recovery: provided, not provided.

3) Error type: notification, self-correction, support.

4) Access type: via EDS, login and password, two-step authentication.

Next, you should choose experts. Expert names are written as: id1, id2, id3, …… ..

The investigated information system is evaluated by experts according to the criteria, and their assessments are stored in the database.

Then the user selects the criteria options he needs. The weights of the criteria are calculated, while the assessments of the respective experts are taken from the database.

The process of determining the relative weights of criteria using the SWARA method consists of the following stages:

Stage 1. The criteria are sorted in descending order of their expected significance.

Stage 2. Starting from the second criterion, the expert expresses the relative importance of criterion j in relation to the previous (j-1) criterion for each specific criterion. This relationship is called the comparative importance of the mean s_j.

Stage 3. Determination of the coefficient k_j as follows:

$$k_j = \begin{cases} 1, & j = 1 \\ s_j + 1, & j > 1 \end{cases} \qquad (11)$$

Stage 4. Determine the weight q_j as follows:

$$q_j = \begin{cases} 1, & j = 1 \\ \frac{k_{j-1}}{k_j}, & j > 1 \end{cases} \qquad (12)$$

Stage 5. The relative weights of the evaluation criteria are determined as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \qquad (13)$$

where w_j denotes the relative weight of criterion j.

The weight of the criteria is determined by the expert's estimate. And the weights of the subcriteria are determined for each criterion.

Figure 1 shows an expert opinion as an example. The information in the columns marked in red was obtained by multiplying the weight of the criterion and subcriterion. Column S is equal to the sum of each row of the columns marked in red.

Stage 6. Determine the significance of the potentially acceptable options. The significance of each option can be determined as follows.

$$S_i^k = \sum_j^n w_j w_{lj} \quad (14)$$

where: S_i^k denotes the overall significance of option i based on the answers received from respondent k, w_j denotes the relative weight of criterion j, w_{lj} denotes the relative weight of option l from the area of criterion j.

Stage 7. Determine the overall value of each option based on a group approach. For a group of K decision-makers, the overall significance of each option Si can be calculated using the geometric mean as follows:

$$S_i = \left(\prod_{k=1}^K S_i^k\right)^{\frac{1}{K}} \quad (15)$$

The scores of each expert are calculated, and then the average of the expert ratings is calculated (Figure 2).

The reliability of information systems is determined by their ranks. In our case, options # 1 and # 3 have the highest rank equal to 1. Option # 1 - (Program type: website; Data recovery: provided; Error type: notification; Access type: via Electronic Digital Signature). Option # 3 - (Program type: website; Data recovery: provided; Error type: notification; Access type: two-step authentication).

3. PRACTICAL IMPLEMENTATION OF METHODS

The proposed methods were used to determine the level of fault tolerance of the IS "Student Portal" of the university. This IS consists of various interactive services and informational parts. The information part is intended for storing content and consists of a multi-level set of web pages. Interactive services are designed to implement various functionality and represent a database and a set of modules (Figure 3).

The information system is developed on the IBM WebSphere Portal platform. Interactive services are developed in the Java programming language. The system is built using a stack of technologies Java, EJB3.0, JPA, Javascript, HTML, Oracle 11g database. Operating system "Red Hat Enterprise Linux Server version 6.5 (Santiago)".

Web Server - A load balancer is used. The load is spread across three web application servers (nodes). The Dynamic cache service is used to cache data received from the database and LDAP. Oracle Database 11g is used for the database. For the development of the application are used: libraries - JQuery, ExtJS 4; platform - EJB 3.0; Java EE API Specification - JPA data storage and management - Oracle 11g. The architecture of the IS is shown in Figure 4. The web server processes requests, distributes loads between nodes. Three servers are used - Oracle, DB2 and LDAP. These three servers contain databases of: installed applications; data responsible for the performance of the portal; data about the users of the university.

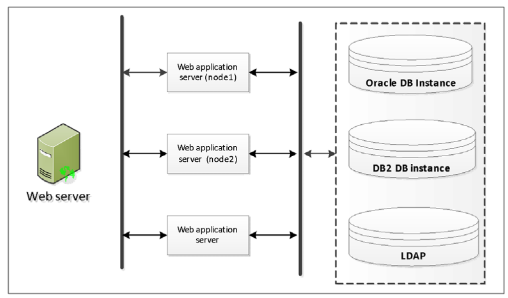

Figure 4. Information System Architecture

IS provides communication with the following subsystems:

1. Subsystem for authorization and obtaining personal information of the student. 2.Billing subsystem. 3. Subsystem office registrar. 4. Subsystem of accounting services. 5. Subsystem of hostel management.

IS "Student Portal" is integrated with 4 other systems of the University: invoicing; tracking the services provided; check in; identity management. The exchange of information between the IS "Student Portal" and other systems is carried out on the basis of the request-response principle.

We identified 4 components of the IS, which were used as alternatives in the multicriteria method. The criteria used were the characteristics that affect the level of fault tolerance of the IS components: The share of recoverability / maintainability; The presence of failures; The share of the impact of failures on the IS performance; Availability of redundancy of processed data; Compliance with legal requirements. Experts with relevant higher education and experience in the field of IT were involved in the assessment of the criteria. The criteria were compared with each other using the AHP method, and thus the significance of the impact of each criterion on the IS fault tolerance was calculated. Table 1 shows the results of comparing the weights of the criteria. The weights of the criteria affecting the fault tolerance of the IS components are

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shown in Figure 5.

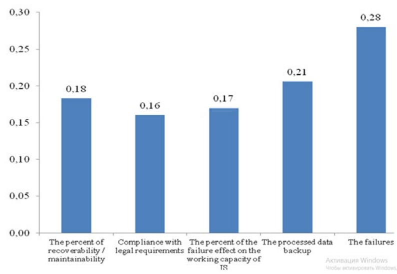

Figure 5. Weights of Criteria

For each refusal, the following attributes are indicated:

• Severity of failure;
• Priority (Priority) of rejection.

Severity indicates how serious the failure is and how it can affect the performance of the information system. 5 types of failure severity were selected (Table 2).

Priority specifies the order in which the failure is resolved for each task. 3 types of failure priority are selected (Table 3).

Based on Tables 2 and 3, Tables 4 and 5 were formed. It should be noted that “1” is used as the minimum value in the line “0 - optimal value”, since division by “0” is impossible. When calculating the priority of the failure and the severity of the failure, the average values of the results of the expert survey were used. The weighted normalized measurement values in the IS (weighted normalized decision-making matrix), calculated using formulas (9) - (10), are shown in Table 6 and Figure 6.

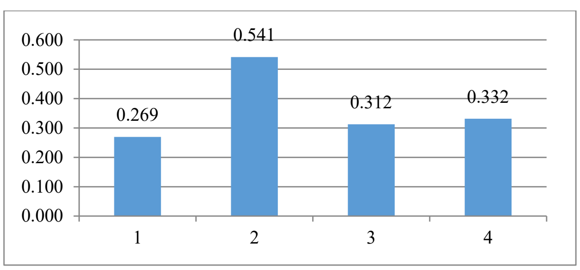

Figure 6. The Level of Fault Tolerance of is Components.

4. CONCLUSION

The proposed model is aimed at solving the problem of calculating the IS fault tolerance. Five main criteria were identified: “percentage of recoverability/maintainability”, “failures”, “percentage of the impact of failures on the operability of the IS”, “backup of processed data” and “compliance with legal requirements”.

The study shows that the most fault-tolerant IS component is component #2 (level 0.541), components #3 and #4 (levels from 0.312 to 0.332) are less fault-tolerant components of a component, and component #1 (level 0.269) is the least fault-tolerant component.

Failures in the information system can lead to disruption in its operation or complete termination of its functioning. This can have serious consequences. Therefore, effective methods of assessing such risks are needed. The proposed method makes it possible to determine the level of fault tolerance of the IS components, take into account a number of criteria with different directions of optimization, evaluate and rank alternative solutions. The level of the alternative is determined by comparing the analyzed variant with the ideally best one. The proposed method was applied in practice to assess the fault tolerance of IC components according to five criteria. As a result of the computational work, the levels of fault tolerance of each of the IS components were identified. Thus, the practical application of the method has shown that it can be used to calculate the level of fault tolerance of information and automated systems

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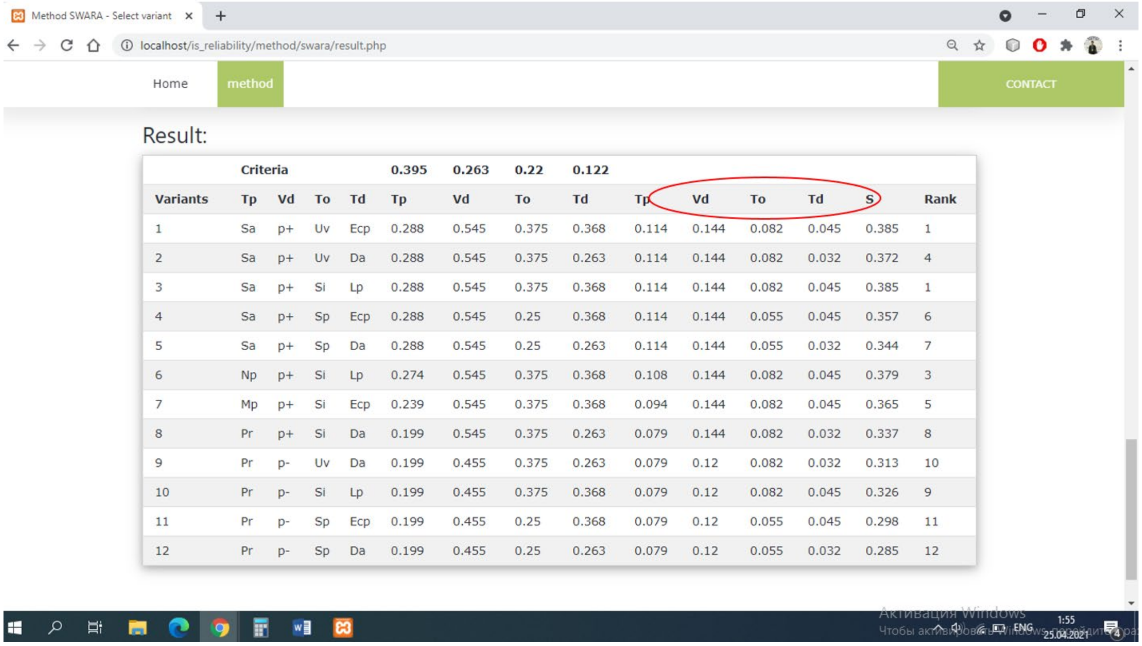
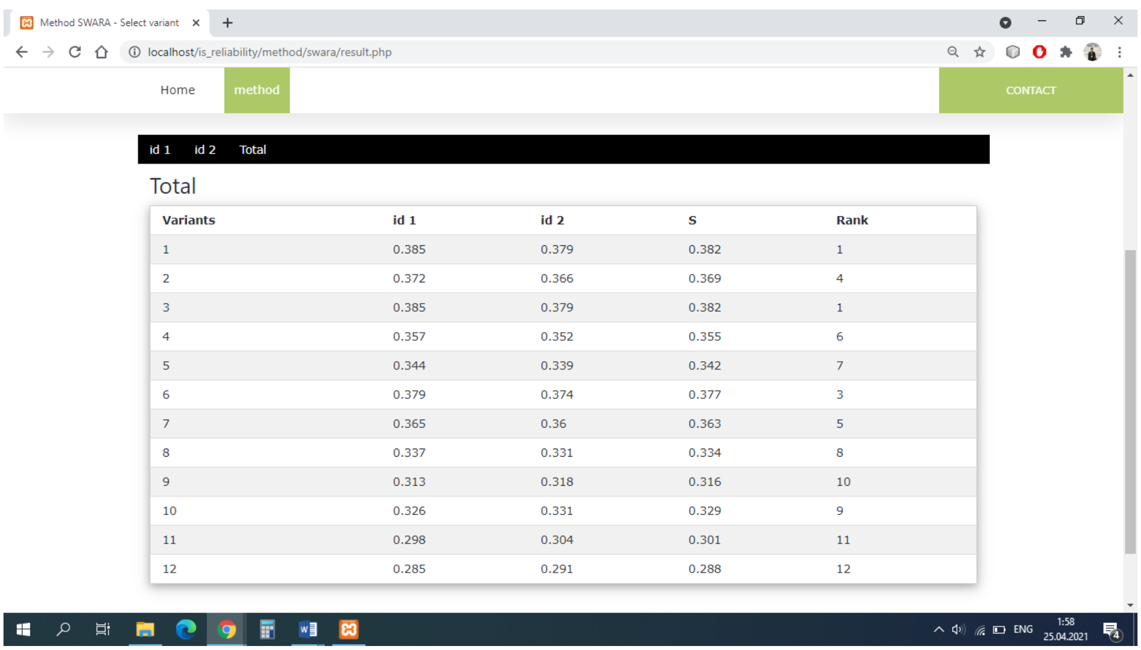


Result:

Variants	Tp	Vd	To	Td	Tp	Vd	To	Td	Tp	Vd	To	Td	S	Rank
Criteria					0.395	0.263	0.22	0.122						
1	Sa	p+	Uv	Ecp	0.288	0.545	0.375	0.368	0.114	0.144	0.082	0.045	0.385	1
2	Sa	p+	Uv	Da	0.288	0.545	0.375	0.263	0.114	0.144	0.082	0.032	0.372	4
3	Sa	p+	Si	Lp	0.288	0.545	0.375	0.368	0.114	0.144	0.082	0.045	0.385	1
4	Sa	p+	Sp	Ecp	0.288	0.545	0.25	0.368	0.114	0.144	0.055	0.045	0.357	6
5	Sa	p+	Sp	Da	0.288	0.545	0.25	0.263	0.114	0.144	0.055	0.032	0.344	7
6	Np	p+	Si	Lp	0.274	0.545	0.375	0.368	0.108	0.144	0.082	0.045	0.379	3
7	Mp	p+	Si	Ecp	0.239	0.545	0.375	0.368	0.094	0.144	0.082	0.045	0.365	5
8	Pr	p+	Si	Da	0.199	0.545	0.375	0.263	0.079	0.144	0.082	0.032	0.337	8
9	Pr	p-	Uv	Da	0.199	0.455	0.375	0.263	0.079	0.12	0.082	0.032	0.313	10
10	Pr	p-	Si	Lp	0.199	0.455	0.375	0.368	0.079	0.12	0.082	0.045	0.326	9
11	Pr	p-	Sp	Ecp	0.199	0.455	0.25	0.368	0.079	0.12	0.055	0.045	0.298	11
12	Pr	p-	Sp	Da	0.199	0.455	0.25	0.263	0.079	0.12	0.055	0.032	0.285	12

Figure 1. Expert Opinion



Total

Variants	id 1	id 2	S	Rank
1	0.385	0.379	0.382	1
2	0.372	0.366	0.369	4
3	0.385	0.379	0.382	1
4	0.357	0.352	0.355	6
5	0.344	0.339	0.342	7
6	0.379	0.374	0.377	3
7	0.365	0.36	0.363	5
8	0.337	0.331	0.334	8
9	0.313	0.318	0.316	10
10	0.326	0.331	0.329	9
11	0.298	0.304	0.301	11
12	0.285	0.291	0.288	12

Figure 2. Expert Estimates

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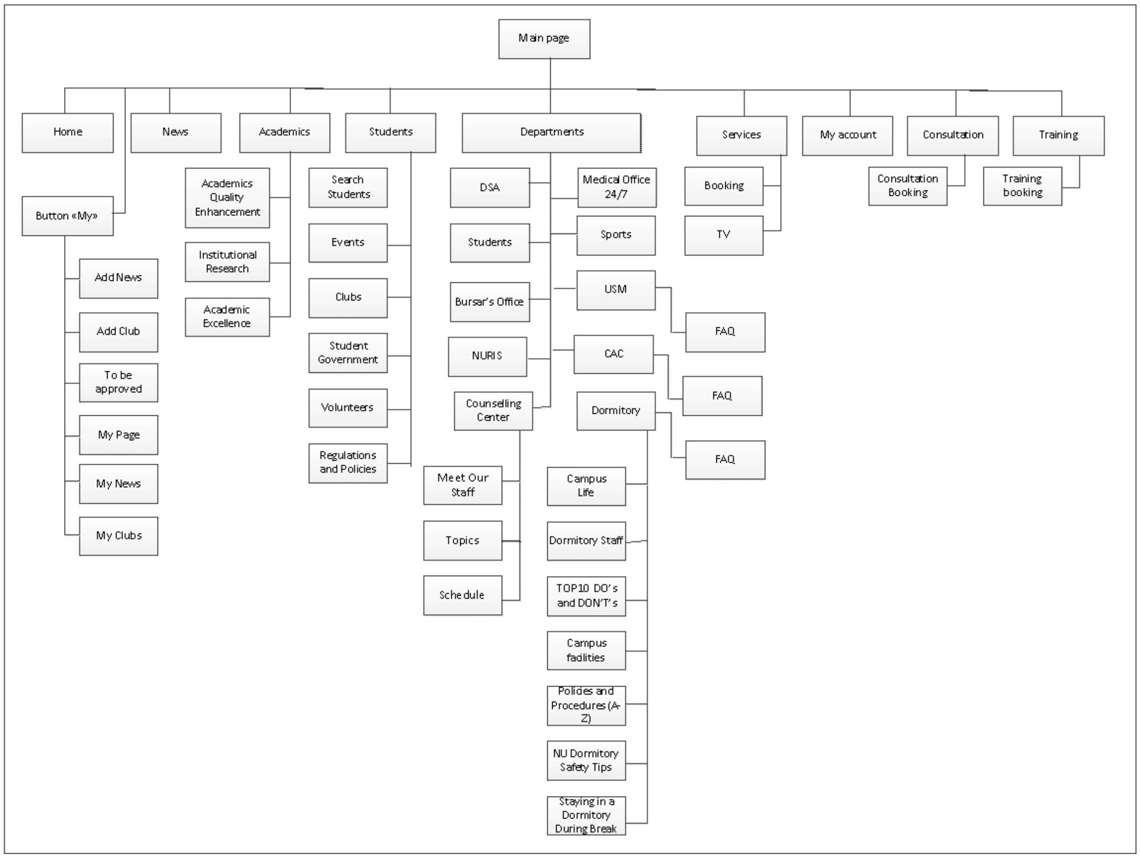

Figure 3. Information System Structure.

Table 1. Comparisons of the Weights of the Criteria

	E_1	E_2	E_3	E_4	E_5	w	Normalized weight
X_1	0,15	0,25	0,17	0,15	0,20	0,18	0,653
X_2	0,14	0,13	0,17	0,17	0,20	0,16	0,574
X_3	0,16	0,14	0,17	0,23	0,15	0,17	0,607
X_4	0,16	0,19	0,23	0,20	0,26	0,21	0,737
X_5	0,40	0,29	0,26	0,26	0,20	0,28	1
Total						1,00	3,57

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Table 2. Severity of Failures [18].

Name	Failure Severity Rate	Recoverability / maintainability ratio	Description
Blocker	5	0% - 40%	The most serious error in which work with IP is impossible. These kinds of mistakes must be corrected without fail. The IS is difficult to recover due to the severity of the error.
Critical	4	41% - 70%	Critical error in which a certain part of the IS does not work. This problem needs to be solved in order to continue working with the basic functions of the system. IS recoverability is below average.
Major	3	71%-80%	This kind of error, in which something does not work correctly, but not particularly dangerous, since it is possible to continue working using other input points. Recoverability of IS is average.
Minor	2	81% - 90%	Usually, minor errors do not disrupt the operation of the IS, the problem may occur in the user interface. IS recoverability is above average.
Trivial	1	91% - 100%	An error that does not pose a threat to the IS, usually a problem with a third-party library or service. The level of IS recoverability is high.

Table 3. Priorities of Failures [35].

Description	The proportion of the influence of failures on the IS operability (priority)	Definition
Extremely Hazardous	100%	Failure could result in human death or damage to infrastructure.
Very Dangerous	90%	Failure can result in serious injury or serious infrastructure disruption due to service interruptions.
	80%	
Dangerous	70%	Failure can result in minor or moderate injury with a high degree of personal dissatisfaction or significant infrastructure problems requiring repair.
	60%	
Medium hazard	50%	Failure can result in minor injuries with some frustration or significant infrastructure problems.
Low to moderate hazard	40%	Failure can result in very minor or no injury, but it annoys customers or results in minor infrastructure problems that can be overcome with minor infrastructure or business changes.
	30%	
Minor hazard	20%	Failure cannot result in injury and the client is unaware of the problem; However, there is a possibility of minor injury.
No danger	10%	Failure does not harm or affect infrastructure.

Table 4. The Results of Measurements in the is (Matrix X of the Initial Decision)

IS Components Criteria	Criteria				
	The share of recoverability / maintainability	The presence of failures	The share of the influence of failures on the IS operability	The presence of redundancy of the processed data	Compliance with the requirements of the legislation
	X_1	X_2	X_3	X_4	X_5
Units of measurement	%	pieces	%	pieces	Yes/No (1/0)
Optimization direction	Max.	Min.	Min.	Max.	Min.
Criterion weight	0,18	0,28	0,17	0,21	0,16
0 – optimal value	100	1	1	3	1
1	81	14	20	1	1
2	91	1	20	1	1
3	81	6	10	1	1
4	91	5	10	1	1

Table 5. Normalized Measurement Values in is (Normalized Decision Matrix X)

IS Components Criteria	Criteria				
	The share of recoverability / maintainability	The presence of failures	The share of the influence of failures on the IS operability	The presence of redundancy of the processed data	Compliance with the requirements of the legislation
	X_1	X_2	X_3	X_4	X_5
Criterion weight	0,18	0,28	0,17	0,21	0,16
0 – optimal value	0,225	0,410	0,769	0,43	0,20
1	0,182	0,029	0,038	0,14	0,20
2	0,205	0,410	0,038	0,14	0,20
3	0,182	0,068	0,077	0,14	0,20
4	0,205	0,082	0,077	0,14	0,20

Table 6: Weighted Normalized Measurement Values In is (Weighted Normalized Decision Matrix) and Decision Results.

IS Components Criteria	The share of recoverability / maintainability	The presence of failures	The share of the influence of failures on the IS operability	The presence of redundancy of the processed data	Compliance with the requirements of the legislation	*S*	K	IS Component Grade
	X_1	X_2	X_3	X_4	X_5			
0 – optimal value	0,041	0,115	0,131	0,088	0,032	0,407	1	
1	0,033	0,008	0,007	0,029	0,032	0,110	0,269	4
2	0,037	0,115	0,007	0,029	0,032	0,221	0,541	1
3	0,033	0,019	0,013	0,029	0,032	0,127	0,312	3
4	0,037	0,023	0,013	0,029	0,032	0,135	0,332	2