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WEBSITE DEPENDABILITY EVALUATION MODEL BASED ON A MULTI-CRITERIA APPROACH

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***Summary**. The paper examines the existing approaches to defining the concept of website reliability and specifies the concept of a "broad" interpretation of its reliability as dependability. Five key criteria for evaluating website dependability were formed (availability, fault tolerance, recoverability, integrity, and confidentiality), which were used to build an evaluation model. This multi-criteria model is based on the modification of the "best-worst method" (BWM), by simplifying its algorithm as a result of refusing to choose the worst option. This makes it possible to reduce the number of pairwise comparisons in the evaluation of alternatives. A detailed algorithm of the proposed model was developed and its approval was carried out.*

***Key words**: website dependability, information technology, criteria, model, multicriteria methods, weights, rating.*

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Problem statement. Reliability is one of the key characteristics of software systems quality to which websites belong. So, the requirements and recommendations of international standards should be analyzed as the basis of quality requirements development (including the reliability) of software systems, as well as the specified quality evaluation resulting in reducing the risks at the stages of development, introduction, and support of software systems. This problem is also urgent due to the fact that these standards are accepted in Ukraine as national ones.

The reliability of a website has to be assessed at all stages of its lifecycle starting from the requirements formation and ending with its testing and the amendments introduction. The phase of the website use is also not less important, particularly those websites which have to be dynamically modified and changed concerning their information basis. Such sphere as reliability involves a number of techniques and tools of their practical implementation, as well as the order of their use to provide a high level of reliability and stability of the website to achieve the required level of product readiness, to minimize the investments and to maximize the period of a software system operation.

Besides, the novelty of the study under discussion is caused by the fact that recently a large number of websites are being created and, therefore, their reliability should be estimated already at the stage of their design to avoid possible risks dealing with the actual increase of the users' number exceeding the expected one.

Analysis of well-known results of the research. The website's reliability has at least two aspects: provision and evaluation (measuring) of reliability. The existing literature is usually devoted to the first aspect, and the matter of the website reliability evaluation hasn't been enough processed yet.

Nowadays, a series of international standards ISO 25000 SQuaRE (Systems and software Quality Requirements and Evaluation) involves two main processes: specification of the requirements and quality evaluation of software programs. In particular, in the

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standard ISO/IEC 25010:2016 [1] the model of software program quality is given which is used to determine the requirements, develop the indices, and measure the website quality.

Some general models of website quality evaluation are mostly taken into consideration in scientific sources [2], where reliability is only one of the attributes of quality. One of the most popular approaches in this field is the use of multi-criteria methods of decision-making [3, 4] where the authors substantiate and apply their own set of quality criteria [5]. In particular, in the paper [6] a model of e-commerce website quality evaluation is used on the basis of a fuzzy VIKOR method, and in [15] a hybrid model of bank websites quality evaluation combines the AHP and COPRAS-G methods. The paper [7] contains a model structure supporting the website quality evaluation using the AHP method. In [8] the authors have studied the quality and reliability of websites using functional testing and the testing of comfortable use.

Nevertheless, the models and methods of website reliability evaluation haven't been paid great attention to, except for an old paper [9].

Paper purpose. To develop a mathematical model of website dependability evaluation on the basis of a multi-criteria approach.

Problem setting. To implement the above-mentioned model, one should specify the concept of website reliability concerning its «narrow» and «broad» interpretation, find the criteria of dependability evaluation, develop a model of website dependability evaluation using one of the multi-criteria methods of decision-making, as well as carry out the approval of the model.

Results of the study. First of all, we should specify the concept of website dependability. As for reliability in English literature, the «reliability» and «dependability» terms are mostly used. While there are no problems with the translation of the first term (reliability in the narrow sense), the discussion on the second term is still taking place in national science. The most widely spread translations of the term «dependability» are as follows: functional reliability, reliability (of the equipment), warranty capacity, and general reliability.

English sources give the following interpretation of the concept of «dependability»:

1. Trustworthiness of a computer system enables us to be absolutely sure of the service it provides [10].

2. Measuring the degree of an element's efficiency and its ability to perform the required functions at any (random) time during the specified profile of the mission, taking into account the element's availability since the mission started [11].

3. Ability to operate at any time and in the way it is necessary [12].

V. Kharchenko believes that the reliability of computer information systems «should be referred to as a complex characteristic feature in a more complex context, including not only traditional components, first of all, infallibility and readiness, but safety as well… According to international practice, this characteristic feature is called «dependability» (opposite to «reliability»), which, to the greatest extent, corresponds the Ukrainian version «reliability in a broad sense» [13].

According to the program system application, different focus can be made on different aspects of reliability, i.e. reliability can be taken into consideration in accordance with different but complementary characteristics which make it possible to define the attributes of reliability (dependability). Thus, in our opinion, there is a broad (dependability) and a narrow (reliability) interpretation of program system reliability. Narrow dependability is considered as one of the several measurements of broad dependability, along with availability, safety, integrity, etc.

So, in the paper under discussion, we have used a «broad» concept of reliability (dependability), involving different aspects of dependability. A similar approach is also

mentioned in «Electropedia»: «Dependability is used as a general term for the system quality characteristics dealing with time» [12].

Thus, we may give the following concretized concept of website dependability: «Dependability is a general term of temporal characteristics of website quality covering the concept of narrow reliability (dependability), accessibility, recoverability, resistance to failures, as well as safety and privacy».

The practice of web products developments aims at the assignment of priority of reliability provision over the assignment of its evaluation. Nevertheless, prior to providing reliability, one should know how to measure (evaluate) it. And in this case, one should have a practically acceptable unit of reliability measuring and a model of its calculation.

There are enough methods of reliability analysis that have some specific features for certain branches of industry and applications. The number of reliability models has exceeded a hundred and continues to increase at present. According to the point of view concerning the reliability and the concept of the research depth, different criteria and details are determined. Thus, the construction of a complete scheme is a very difficult process, and determining all relationships between the models and criteria even complicates the process of classification and selection. The system of dependability indices usually has a mixed network-hierarchical structure.

These indices (metrics) are mostly subjective and depend on the knowledge of experts who carry out a quantitative evaluation of the website attributes, the models used and the marks scales, the purpose and the context of the evaluation, etc. In our opinion, the criteria for evaluation of the «broad» dependability of websites should involve the criteria of the «narrow» dependability as well as the safety criteria.

A reliable website is characterized by minimal downtime, good data integrity, and the absence of errors that directly influence the users. To evaluate a website's dependability, first of all, one should develop the criteria for such evaluation. Having analyzed some models of quality, a set of metrics, and indices for software products' safety and reliability evaluation, we have selected 5 key criteria that will further be used for the construction of a model of website dependability evaluation.

Table 1

Criteria for evaluating the dependability of a website

№	Criterion	Description
1	Availability	Degree of efficiency and availability of the website
2	Fault tolerance	Website ability to operate properly despite any defects of software-hardware
3	Recoverability	Website ability to restore data and the necessary state in case of a failure or unauthorized influence
4	Integrity	Degree of prevention from unauthorized access or computer programs or data modification
5	Confidentiality	Providing the restriction of access to the data to unauthorized persons

According to the methodology of multi-criteria research, some hierarchical structure of the website has been developed (fig.1), on the top of which there is the purpose, namely website dependability evaluation. A set of criteria creating a further level of hierarchy has been determined for the evaluation procedure. A set of alternatives (websites), that are to be evaluated, i.e. to form their rating for further selection in terms of dependability, has completed the structure.

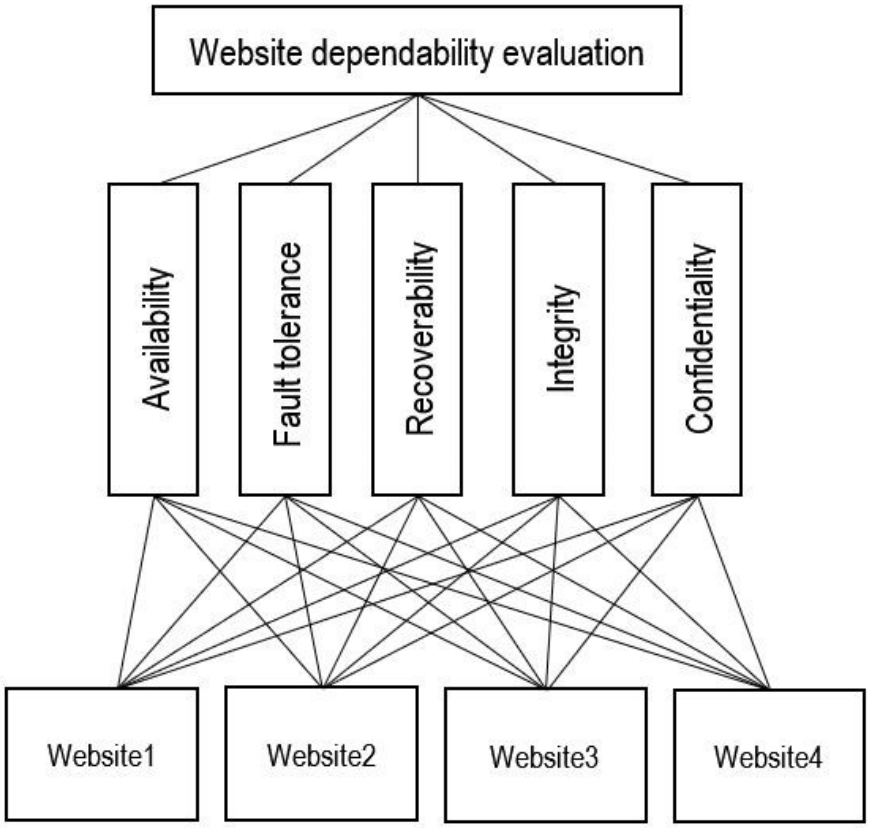

Figure 1. The hierarchical structure of website dependability evaluation

The study of website dependability and its evaluation is based on the use of expert evaluations. Such a method is used for the parameters of the processes or the things that cannot be measured immediately, so the evaluation should be carried out on the basis of the professional experience of an expert or a group of experts. The above-mentioned approach was used due to the fact, that for some criteria of «broad» dependability evaluation it was impossible to measure the parameters of websites or they were of private character.

To evaluate websites' dependability the authors have used the «best-only method» (BOM) as a modification of a well-known «best-worst method» (BWM) [14]. In the last one, an expert (or a group of experts) is proposed to select the best one and the worst one from the specified set of criteria. In decision-making, the best criterion plays the most important role, while the worst one – the least important role. After that, the advantages of the best criterion over the other criteria and the rest criteria – over the worst criterion are determined by the expert method. The comparison is made according to the specified scale. The found values of pairwise comparisons are the input data of the problem of optimization whose solution is the optimal weights of selected criteria. Unlike BWM, in the BOM method, it is necessary for an expert only to determine the best criterion according to which its pairwise comparison with other criteria is conducted. Thanks to the simplified procedure, the evaluations obtained at pairwise comparisons are ideally agreed upon.

Let's describe the stages of the proposed model of website dependability evaluation, whose general scheme is presented in fig. 2.

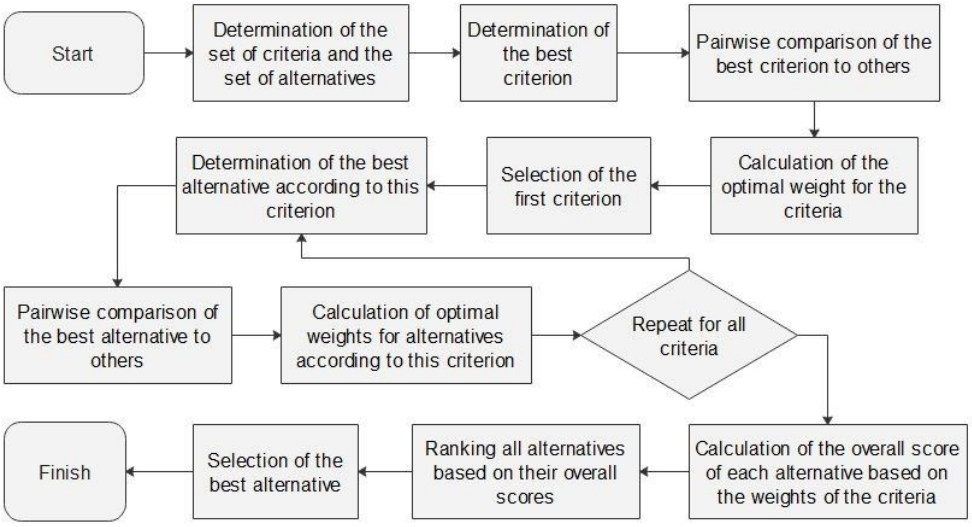

Figure 2. General scheme of the proposed model

Stage 1. Determining a set of criteria C = $\{C_1, C_2, \cdots, C_n\}$ and a set of alternatives (websites) S = $\{S_1, S_2, \ldots, S_m\}$.

Stage 2. Assumption of the best (the most important) criterion C_B concerning the selected purpose/assignment.

Stage 3. Defining the importance of the best criterion over all the rest criteria, using a whole-number scale from 1 to 5, where 1 corresponds to the highest importance and 5 – to the smallest one. The resulting vector of the best ones to the others (Best-to-Others) will be $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$, where a_{Bj} is the importance of the best criterion B over the criterion j, and $a_{BB} = 1$.

Stage 4. Finding optimal weights of the criteria as a vector CW = $(w_1, w_2, \ldots, w_n)$, where w_B is the value of optimal weight for the best criterion. To calculate the values of optimal weights one may use the following formulae

$$\frac{w_B}{w} = a_{Bi}, \ \forall i \neq B, a_{Bi} \in A_B \tag{1}$$

$$\sum_{i=1}^{n} w_i = 1 \tag{2}$$

Stage 5. Selection of the first criterion C_1 for further calculations.

Stage 6. Determining the best website S_B according to the first criterion.

Stage 7. Finding the values of pairwise comparisons of the best website S_B with other providers according to the criterion C_1. The results are written in the vector CS_B.

Stage 8. Calculation of optimal weights of websites according to the criterion C_1. The calculation is made by the formulae (1)–(2), where the values a_{Bj} belong to vector CS_B.

Stage 9. Finding the optimal weights of websites for all the rest criteria (stages 7–9 are repeated).

Stage 10. Construction of the matrix of weights of websites SW of size n x m, where each line of the matrix represents the optimal weights of the provider according to the criterion corresponding to the line.

Stage 11. Calculation of the general evaluation of the reliability of each website by the formula:

$$V_j = \sum_{i=1}^{n} CW_i \times SW_{ij} \quad j = 1,...,m\,. \tag{3}$$

Stage 12. Determining the rank of all websites on the basis of their general evaluation and selection of the best one among them.

In the first stage, apart from determining a set of criteria (see Table 1), a set of alternatives (websites) was formed. Four websites were selected for the approval of the developed model. After designing the hierarchy structure (fig. 2) we have passed to specifying the best criterion. Let it be C_2 – resistance to failures. After that, the experts determine the value of the pairwise comparison of the best criterion (C_2) with each other criterion from their set. The results of the comparison are presented in Table 2. Fig.3 demonstrates the optimal weights of selected criteria, calculated by formulae (1)–(2).

Table 2

Comparative values of the best (C_2) criterion to others

C_2 -to- C_1	C_2 -to- C_2	C_2 -to- C_3	C_2 -to- C_4	C_2 -to- C_5
2	1	5	3	4

Similar to the calculations, dealing with the criteria, the calculations concerning websites are made. We have assumed, that an expert selects S_3 as the best website. After that, the pairwise comparisons of the best website (S_3) with other websites according to the criterion C_1 are made. Table 3 shows such comparative values concerning the criterion C_1, and fig. 4 – the calculated optimal weights of providers according to the criterion C_1.

Table 3

Comparative values of the best website (S_3) to other websites according to the C_1 criterion

S_3 -to- S_1	S_3 -to- S_2	S_3 -to- S_3	S_3 -to- S_4
2	3	1	2

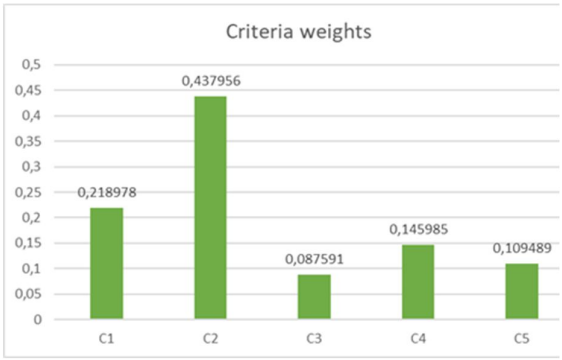

Figure 3. Optimal weights of selected criteria

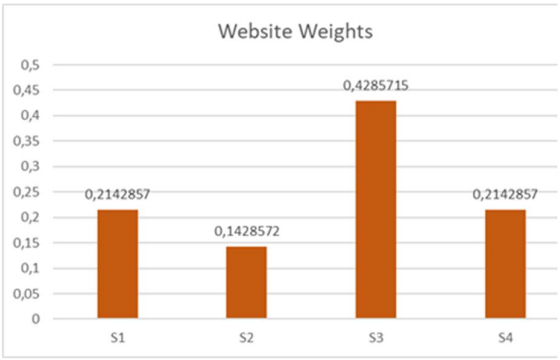

Figure 4. Optimal weights of websites according to criterion C_1

We will continue the procedure of calculation of websites' optimal weights for all other criteria. For each criterion C_i the experts select the best website (S_B) and evaluate its pairwise comparative values with other websites (according to the next criterion C_i). All pairwise comparisons of the value for the websites according to each criterion are given in Table 4. Each line of the Table represents the values of pairwise comparisons of the best website with others

for each criterion. The table (matrix) of evaluations involves five criteria (lines) and four websites (columns). The experts select the best website for each criterion and evaluate its pairwise comparative values with other websites. In the table, the shaded cells represent the best website according to each criterion.

Table 4

Value of pairwise comparisons of the best website with others for each criterion

	S_1	S_2	S_3	S_4
C_1	2	3	1	2
C_2	2	4	1	3
C_3	3	1	2	5
C_4	2	3	2	1
C_5	1	3	3	2

Next Table 5 represents the weight matrix of websites concerning their reliability. In the last stage, the general evaluation of each website is calculated by the formula (3). The final result is given at the end of Table 5.

Table 5

Weight matrix of websites for each criterion and overall rating of websites

	S_1	S_2	S_3	S_4
C_1	0,2142857	0,1428572	0,4285715	0,2142857
C_2	0,2400000	0,1200000	0,4800000	0,1600000
C_3	0,1639344	0,4918033	0,2459016	0,0983607
C_4	0,2142857	0,1428572	0,2142857	0,4285715
C_5	0,4615384	0,1538462	0,1538462	0,2307692
Rating	0,2482083 (2)	0,1646143 (4)	0,37373234 (1)	0,2134440 (3)

The main advantage of the BOM method used in the model of website reliability is that it requires fewer pairwise comparisons than other multi-criteria methods. For example, in the case of k criteria (alternatives) the above-mentioned BOM method requires $k-1$ comparisons, the BWM method – $2k-3$ comparisons, and the classical method of analytical hierarchy – $k(k-1)/2$ comparisons. Moreover, BOM is a completely agreed-upon method, as the consistency coefficient is equal to 0.

Conclusions. The conventional approaches to defining the concept of website reliability are taken into consideration in the paper under discussion. It was found, that there is a broad (dependability) and a narrow (reliability) interpretation of software systems reliability, including websites. The concept of a «broad» interpretation of website reliability has been specified, which means that its reliability is a common term of temporal characteristics of the website quality covering the concept of narrow reliability, availability, recoverability, resistance to failures as well its safety and privacy.

Five key criteria of website dependability evaluation have been developed on the basis of the analysis of models of quality, a set of metrics, and indices to assess the safety and reliability of software products: availability, fault tolerance, recoverability, integrity, and confidentiality. The above-mentioned criteria were used to build a model of website reliability evaluation.

As website dependability evaluation (being one of the most important characteristics of its quality) covers many criteria and is carried out using different methods and models, to achieve the goal set the multi-criteria methods of decision-making are the best options, namely the modification

of the well-known «best-worst method» (BWM). The modification of the BWM method involves its algorithm simplifying due to the refusal of the worst version choice. It makes it possible to reduce the number of pairwise comparisons in alternatives evaluation. The detailed scheme of the proposed model has been developed and its approval has been carried out. The hierarchy structure of decision-making involving five criteria and four alternatives has been applied in this case. The results of the approval have proved the efficiency of the developed method.

For further research, it is necessary to broaden the model due to the criteria addition and detailing on the basis of subjective expert evaluation with the criteria (sub-criteria) based on objective assessment, including those collected automatically.

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МОДЕЛЬ ОЦІНЮВАННЯ НАДІЙНОСТІ ВЕБ-САЙТУ НА ОСНОВІ БАГАТОКРИТЕРІАЛЬНОГО ПІДХОДУ

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Резюме. *Надійність є однією з ключових характеристик якості програмних систем, до яких належать веб-сайти. Для успішного функціонування веб-сайту необхідне чітке розуміння його можливостей, щоб звести до мінімуму ймовірність відмови в роботі та обслуговуванні сайту. Тому для веб-сайту як системи, розрахованої на постійну безперебійну роботу, надійність відіграє важливу роль. У роботі досліджено існуючі підходи до визначення поняття надійності веб-сайту, встановлено, що існує широке (надійність) і вузьке (надійність) трактування надійності програмних систем, у тому числі веб-сайтів. Уточнено поняття «широкого» тлумачення надійності веб-сайту, яке полягає в тому, що його надійність є збірним терміном для часових характеристик якості веб-сайту, який включає поняття вузької надійності, доступності, відновлюваності, стійкості до збоїв, а також його безпеку та конфіденційність. На основі аналізу моделей якості, набору метрик та індикаторів для оцінки безпеки та надійності програмних продуктів сформовано п'ять ключових критеріїв оцінювання надійності веб-сайту: готовність, стійкість до відмов, здатність до відновлення, цілісність та конфіденційність. Зазначені критерії були використані для побудови моделі оцінювання надійності сайту. Оскільки оцінювання надійності веб-сайту (як однієї з найважливіших характеристик його якості) охоплює багато критеріїв і здійснюється з допомогою різноманітних методів і моделей, багатокритеріальні методи прийняття рішень, зокрема модифікація відомого «кращий-гірший» метод (best-worst method, BWM) найкраще підходять для вирішення поставленої мети. Модифікація методу BWM полягає в спрощенні його алгоритму шляхом відмови від вибору найгіршого варіанту. Це дає змогу скоротити кількість попарних порівнянь при оцінюванні альтернатив. Розроблено детальну схему запропонованої моделі та здійснено її апробацію. Для цього була використана ієрархічна структура прийняття рішень, яка охоплює п'ять критеріїв і чотири альтернативи. Результати випробувань підтвердили ефективність розробленого методу, продемонстрували можливість застосування на різних етапах життєвого циклу веб-сайту.*

Ключові слова: *надійність веб-сайту, інформаційні технології, критерії, модель, багатокритеріальні методи, ваги, рейтинг.*

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