Complex interaction of AHP technique and SWOT – analysis for virtual desktop infrastructure (VDI)

K.A. Makoviy[1], Yu.V. Khitskova[1]

[1]Voronezh State Technical University, 20 let Oktyabrya st. 84, Voronezh, Russia, 394006

Abstract. VDI **(**Virtual Desktop Infrastructure) offers great opportunities for transforming the educational environment to academic institutions. This respectively new technology provides hardware resources consolidation and makes desktop administration more centralized and transparent for IT stuff. It represents a major transformation of the organization's IT-infrastructure. The scale of implementation in each organization may vary depending on different factors specific for an educational institution. The strategy of IT-infrastructure transformation can be considered as a component of the overall development strategy so formal analysis by means SWOT (Strengths, Weaknesses, Opportunities, and Threats) method can be applied. Different positive and negative aspects of the technology have been grouped and presented as a SWOT factors. VDI implementation options is considered strategy alternalives. AHP (Analytic Hierarchy Process) technique allows to evaluate each strategy alternative with respect to each SWOT factor and select the best one of them.

1. Introduction

Strategic management is considered to be an aggregation of decisions and activities, taken by organization's governance concerning operation activity, harmonization of interests of all structural levels and departments, in order to determine the long-term development prospects of the organization. A wide diversity of methods is used in strategic planning process [1]. One of the most common of them is a method of identification and evaluation of strengths, weaknesses, opportunities, and threats, i.e. SWOT-analysis.

SWOT analysis is an important tool for decision-making process support and is normally used as an instrument for system analysis of external and internal environment of the organization. By means of determining strengths and weaknesses, opportunities and threats organization may build a strategy forcing strengths, eliminating weaknesses, and using capabilities for the resistance to threats [2].

M. Kurttila, M. Pesonen, J. Kangas, and M. Kajanus developed a combined approach eliminating weaknesses of quantitative measurement and evaluation of SWOT-factors [3]. This combination of Analytic Hierarchy Process and SWOT-analysis mentions as A'WOT in following researches [4, 5 and 6]. The method was applied to the case study for a textile firm [4], for the rural waste management strategic plan development [5], for the airline industry strategic planning [6, 7].

AHP process starts with creating hierarchy including factors, alternatives and others considered criteria that influence the choice. This hierarchy reflects the understanding of the problem by the decision maker. Each element of the hierarchy can represent various aspects of the problem being solved at that both tangible and intangible factors, quantitative parameters and qualitative characteristics, objective data and subjective expert assessments can be taken into account.

We will consider the possibility of using the Analytic Hierarchy Process and SWOT-analysis for evaluation assessment of Virtual Desktop Infrastructure (VDI) deployment in IT infrastructure of the organization.

2. Materials and methods

Virtualization provides an abstraction of processes from computing resources. Virtualization decouples operating system and hardware, allowing creation of several isolated logical partitions on a single hardware server. Each partition implements program model of a simple computer, which can be used to start an operating system. It makes possible to work with operating systems as with a set of files: to start, to stop, to move on the other hardware servers, and to make a reserved copies.

2.1. Virtual Desktop Infrastructure implementation

Virtualization implementation in the organization leads to changing methods of providing information security, to using new methods of administration, the principles of software licensing. Virtualization allows the organization to reduce hardware costs, while simultaneously providing a higher level of protection and redundancy of critical functions. It also enables to scale and transfer customized and proven solutions. When desktop virtualization is used, the environment (operating system, data, application) and the client device are separated. The user ceases to be tied to his physical working place in the office, which allows him to work with his usual applications and data from any device and from anywhere. Instead of using his desktop, he can use a tablet, phone, thin client, whatever with a special software called VDI client [8].

2.2. VDI and Server Virtualization

Server virtualization is essentially a server consolidation, i.e. an approach to the efficient usage of physical servers, widely spread all over the world [9]. This technology allows several operation systems to run on one physical server and isolate applications from each other's influence, minimizes investment and operational costs, avoids overprovisioning. Desktop virtualization uses advantages of server virtualization and cloud technologies bringing together the benefits gained from hypervisor-enabled virtualization and modern video transmission network protocols.

2.3. Choosing the optimal strategy

The purpose of the study is to choose the optimal strategy for implementing (or completely refusing to implement) the virtualization of workstations in the higher educational institution. The VDI implementation project is considered a systematic approach to improve the information infrastructure of the educational institution, and, accordingly, increasing the effectiveness of educational technologies.

According to AHP it is necessary to provide a paired comparison of a proposed SWOT- factors. The following conditions must be satisfied for the matrix of pairwise comparisons:

$$\mathbf{a_{ij}} = \frac{\mathbf{w_i}}{\mathbf{w_j}} > \mathbf{0}\ , \tag{1}$$

for each *i* and *j*, since all scores are positive.

$$\mathbf{a_{ij}} = \frac{\mathbf{w_i}}{\mathbf{w_j}} = \mathbf{1}, \tag{2}$$

for each *i*= 1, 2,…, n.

One can find the maximum real eigenvalue Λ^*_{max} and eigenvector w^* the matrix of pairwise comparisons. Λ^*_{max} and w^* do not coincide with the corresponding eigenvalue of the matrix $\Lambda^*_{max} = n$ and eigenvector w of a matrix of relative weights in the scheme of ideal comparison. The idea of T. Saaty [7,10] is that if the coefficients a_{ij} of the matrix of pairwise comparisons A^* are given relatively accurately, i.e. deviations a_{ij} from the true weights ratio $\frac{w_i}{w_j}$ are insignificant that is one can hope that Λ^*_{max} will be close to n. Here the statement of linear algebra is used, according to which small deviations from the initial values of the matrix elements correspond to a small deviation of its eigenvalues.

Having defined Λ^*_{max} one can find vector w^*satisfying the normalization condition:

$$\boldsymbol{w_1^*+w_2^*+\cdots+w_n^*=1} \quad (3)$$

Vector w^* always exists and is uniquely determined.

The application of the proposed approach will be justified if the actual situation proves to be close to ideal. The method involves the construction of a matrix of paired comparisons, usually it is made up based on the decision maker's judgment but in this case, to fill the values of this matrix we use a questionnaire survey of experts on the proposed questions. The resulting matrix looks like this:

$$\mathrm{A}^* = \left(\mathrm{a_{ij}}\right) = \begin{pmatrix} \mathrm{a_{11}} & \mathrm{a_{12}} \cdots & \mathrm{a_{1n}} \\ \mathrm{a_{21}} & \mathrm{a_{22}} \cdots & \mathrm{a_{2n}} \\ \cdots & \cdots \cdots & \cdots \\ \mathrm{a_{n1}} & \mathrm{a_{n2}} \cdots & \mathrm{a_{nn}} \end{pmatrix} \quad (4)$$

it is necessary to find the sum of each column of the matrix A^*, then divide each element of the column into the sums being found, then find the geometric mean of each line of a new matrix:

$$\boldsymbol{W_i = \sqrt[n]{\prod_{j=1}^{n} C_{ij}}} \quad (5)$$

The components of the eigenvector $\boldsymbol{w}$ gives the weights of the compared factors.

Within the framework of the project of Virtual Desktop Infrastructure (VDI) implementation in the educational institution, the following stages have been implemented.

1. The testing of VMware Virtual Desktop Infrastructure deployment methodology [8].
2. The initial costs for the project are determined [11].
3. The computer class as an object for deploying Virtual Desktop Infrastructure using twenty desktops has been chosen [12].
4. The server configuration, optimal for the implementation of this project, is determined [8].
5. Virtual Desktop Infrastructure has been deployed for one classroom with twenty desktops.
6. The SWOT-analysis of VDI pilot project implementation consequences was conducted on the basis of a survey of experts. The survey was based on the results of using the classroom with twenty virtual desktop in the educational process for one semester.
7. Strategic alternatives concerning the prospects for using VDI have been proposed. The set of strategies contains the variety from the refuse to continue the project to the extension the project to the whole educational client desktops infrastructure.
8. The choice of the final strategy by combining AHP and SWOT analysis is made.

Further, steps 6-8 will be discussed in more details, whilst the previous steps are described by us according to the links.

The SWOT-analysis of VDI pilot project implementation was conducted on the basis of a survey of experts. The survey was based on the results of using the classroom with twenty virtual desktop in the educational process during one semester.

Stage 6. In the framework of the SWOT-analysis of VDI pilot project implementation the strengths and weaknesses, threats and opportunities have been identified.

We have selected factors that influence to some extent on the decision-making process in the area of Desktop Virtualization. After the implementation of the VDI pilot project, some deployment consequences were firstly manifested, some became more obvious.

Stage 7. Further, we present a set of a strategic alternatives concerning VDI implementation to IT-infrastructure of the university.

A set of strategic alternatives is formed on the base of SWOT-factors, virtualization possibilities and development priorities of the university.

Stage 8. Choosing the final strategy was made by combining the AHP and SWOT analysis. In the framework of A'WOT the expert evaluations that handle according to AHP are used. As experts the following categories of participants were used: the top-managers and IT-professionals, as well as users of virtual desktops, i.e. teachers and students. To obtain expert assessments we used the questionnaires on the base of software application.

Example of the questions in the questioner:

Please rate the importance of a group of factors when implementing a desktop virtualization project in the training activities of an organization based on the practical use of the existing pilot virtualization

project of one classroom. Here, the importance of the strengths, weaknesses of the project, threats and opportunities in general, as a single set, is assessed.

Evaluate the importance of a group of strengths of the project (S).

Evaluate the importance of a group of weaknesses of the project (W).

Evaluate the importance of a group of opportunities of the project (O).

Evaluate the importance of a group of threats of the project (T).

Please compare the factors within each group and determine the value of each relative to the rest. Here, each factor from a group of strengths is compared with all the factors within its group. Then, in the same way, each factor from the groups of weaknesses, threats and opportunities is compared within the group. Comparison occurs only inside the group; factors from different groups are not compared with each other.

The evaluation performs in pairs according to the AHP technique, each factor is compared with each other. It has been experimentally established that it is not convenient for experts to use the Saati's scale. Therefore, we bring it to a scale that is clearer for the experts [12].

First, using the Analytic Hierarchy Process we calculate the significance of each group, the significance of each group using the comparison matrix by analogy with (4).

For further calculations, we introduce the following notation. For convenience, w is replaced by v.

V_s - the relative weight of the importance of the strengths of the project of VDI implementation in the educational activities of the organization.

V_w- the relative weight of the importance of the weaknesses of the project of VDI implementation in the educational activities of the organization.

V_o- the relative weight of the importance of the opportunities of the project of VDI implementation in the educational activities of the organization.

V_t- the relative weight of the importance of the threats of the project of VDI implementation in the educational activities of the organization.

3. Results and discussion

The result of using AHP technique for the calculation of expert assessment is given below:

$V_s = 0, 266$; $V_w = 0, 227$; $V_o = 0, 305$; $V_t = 0,202$.

Experts believe that the most important factors are the ones that characterize the opportunities offered by desktop virtualization ($V_o = 0, 305$). On the second place in importance for experts were the weaknesses of the project ($V_w = 0, 227$), the next place is for the strengths ($V_s = 0, 266$) and the least important for experts were threats to the project ($V_t = 0,202$).

Next, the experts assess SWOT-factors themselves within each group, for example, each element of the matrix $A - a_{ij}$, showing a comparison of the strengths of the project of VDI implementation among themselves. Further, a comparison of the factors of weaknesses, opportunities and threats of the project has been made. Then the matrixes were reduced to the form proposed by Saati for further use. To reduce the matrixes the scale was given to the original. On the next step the matrixes were normalized and the geometric mean calculated according to (5). Values of w_i, o_i, t_i were calculated similarly but using other matrix elements.

At the next stage, experts were asked to assess the significance of each factor for the implementation the proposed strategic alternatives. For the first alternative − SO strategy (use of Opportunities with the help of Strengths of the project, maxi-maxi strategy) − Implement VDI infrastructure within the entire educational process. Assess the significance of each factor of Strengths for the implementation the strategy SO, then, the significance of each factor of Weaknesses for the implementation of the strategy SO, after that the significance of factors of Opportunities and Threats to the implementation of the strategy SO.

For the second alternative – WO strategy (reducing the project's Weaknesses by maximizing the external environment potential, the mini-maxi strategy) – Implement virtual workstations only for old computers that are write-off. Re-engage them in the learning process of the organization. Assess the importance of the strength factors for the implementation of the strategy WO. Then, the significance

of the Weaknesses for the implementation of the strategy WO, then the significance of factors of Opportunities and threats to the implementation of the strategy WO.
For the third alternative - ST strategy (maximizing the Strengths of the project, minimizing Threats through this, the maxi-mini strategy) – Implement virtual workstations on computers that do not run graphics applications that need a significant amount of RAM and processor resources and make it difficult to use VDI. Evaluation is also the same as in previous cases.
Similarly, experts are invited to evaluate a strategic alternative WT (Minimizing the Weaknesses of the project to avoid threats, the mini-mini strategy).
For automated calculation of the AHP technique and choosing a strategic alternative, you can use Matlab or specialized software products. We used our own software application, using which we received:
SO – Implement virtual workplaces within the entire educational process of the organization = 0,246. This strategy was put by experts in the second place, they positively assessed the positive factors of the pilot project (factors of Strengths in combination with Opportunities), their impact on the implementation of the strategy SO.
WO – Implement VDI only for old computers that are write-off. Re-engage them in the educational process of the organization. = 0,146. Despite the experts' high estimation of the importance of the opportunities offered by the project, a strategic alternative WO - «Implement VDI only for old computers that are write-off. Re-engage them in the educational process of the organization» is estimated quite low and takes the last place among all possible options for selection. Experts assessed the «low» impact of factors directly on the strategic alternative WO and each factor of strengths and opportunities.
ST – Implement virtual workstations on computers that do not require the use of graphics applications needed a significant amount of RAM and processor resources and make it difficult to use VDI = 0,398. This strategy is preferable, according to experts, despite a rather low assessment of the aggregates of factors of strengths and threats of the project, experts evaluated each of the factors highly, and their significance for the implementation of this strategy proved to be decisive.
WT – Do not implement virtual workplaces more than implemented within the pilot project, that is, leave in one chosen classroom for the purposes of training students =0,203. Experts did not consider important not only the significance of the project's threats, but also the threats themselves and their joint influence with the weak sides on the possibility of implementing the strategy WT.

4. Conclusion

The AHP technique allows us to choose a further strategy for implementing VDI in the classrooms of the University. The study shows the advantage of ST strategy, since it received the greatest approval of experts.

5. References

[1] Taha, H. Operation research: An introduction. – Moscow: Publishing House «Willams», 2005. – 912 p.
[2] Kotler, F. A framework for marketing management: textbook / F. Kotler, K. Keller // SPb.: Piter, 2017. – 800 p.
[3] Kurttila, M. Utilizing the analytic hierarchy process (AHP) in SWOT – analysis a hybrid method and its application to a forest-certification case // Forest policy and economics. – 2000. – Vol. 1(1). – P. 41-52.
[4] Yüksel, İ. Using the analytic network process (ANP) in a SWOT analysis-A case study for a textile firm / İ. Yüksel, M. Dagdeviren // Information Sciences. – 2007. – Vol. 177(16). – P. 3364-3382.
[5] Jozi, S.A. Rural waste management strategic plan by A'WOT c Hierarchy Process / S.A. Jozi, S.A. Dehghani, M. Zarei. – M.: Radio and communication, 1993. – 278 p.
[6] Sevkli, M. Development of a fuzzy ANP based SWOT analysis for the airline industry in Turkey // Expert systems with Applications. – 2012. – Vol. 39(1). – P. 14-24.

[7] Saati, T. Decision-making. Method of hierarchy analysis // Moscow: Radio and communication, 1993. – P. 278.
[8] Makoviy, K. Server hardware resources optimization for virtual desktop infrastructure implementation / K. Makoviy, D. Proskurin, Yu. Khitskova, Ya. Metelkin // CEUR Workshop Proceedings. Mathematical Modeling. – 2017. – Vol. 1904. – P. 178-183. DOI:10.18287/1613-0073-2017-1904-178-183.
[9] Armstrong, D. Contextualization: dynamic configuration of virtual machines / D. Armstrong, D. Espling, J. Tordsson, K. Djemame , E. Elmbroth // Journal of Cloud Computing: Advances, Systems and Applications, 2015. – P. 4-17.
[10] Speitkamp, B. A mathematical programming approach for server consolidation problems in virtualized data centers / B. Speitkamp, M. Bichler // IEEE Trans. Services Comput. – 2010. – Vol. 3(X). – P. 266-278.
[11] Makoviy, K.A. Economic basis of VDI deployment in institution of higher education IT-infrastructure / K.A. Makoviy, Yu.V. Khitskova // Modern economy: problem and solutions. – 2015. – Vol. 2(62). – P. 75-81.
[12] Makoviy, K.A. Using the method of hybrid estimates in the task of selecting the object of the pilot project/ K.A. Makoviy, Yu.V. Khitskova, S.V. Gerus // Materials of the International Scientific and Technical Conference "Actual Problems of Applied Mathematics, Informatics and Mechanics", Voronezh: VSU, 2016. – P. 96-99.