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

K Makoviy¹ and Yu Khitskova²

¹ Senior teacher, Voronezh State Technical University, Russia
² Docent, Voronezh State University, Russia
E-mail: makkatya@mail.ru
prosvetovau@list.ru

Abstract. Strategic alternatives choosing of Virtual Desktop Infrastructure implement-in through combination of analytical hierarchy process and SWOT - analysis methods is considered. Virtual Desktop Infrastructure implementing al-lows simplifying administration for organization IT-department, enhancing productivity and saving financial resources. Different positive and negative aspects of the technology have been grouped and presented as a SWOT factors. Virtual Desktops deployment strategies have been offered and considered as alternatives for AHP technique.

1. Introduction
Strategic management is considered 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 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 threats resistance.

Strengths and weaknesses identify the internal environment evaluation, while opportunities and threats assess the external environment [2]. SWOT-analysis allows allocating the most important internal and external factors that are strategic as they may affect the future of an organization. External and internal environment consists of variables that are outside and inside the organization, respectively.

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 research [4, 5, 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].

Analytic Hierarchy Process eliminates some drawbacks of SWOT-analysis and allows identifying the prospects for each strategic alternative depending on the influence of various factors. AHP makes it possible to compare factors between each other and assess the importance of each compared factor to others [7].
Decision-making problem analysis in AHP starts from 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 and their view from computing resources. Virtualization decouples operating system and hardware, allowing creation of several isolated logical partitions. Each partition implements program model of a simple computer, on which you can start the 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 servers, and to make a reserved copies.

2.1. Virtual Desktop Infrastructure implementation subsection
Virtualization of application and system software in the organization leads to changes in methods of providing information security, to the use of new methods of administration, the principles of software licensing. Virtualization allows organization to reduce hardware costs, while simultaneously providing a higher level of protection and redundancy of critical functions 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 virtualization functioning mechanism is shown in figure 1. 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. The variety of supported client devices let us realize a conception BYOD (Bring Your Own Device) [8].

![Figure 1. Virtualization functioning mechanism.](image-url)
Virtualization is of great importance for increasing the efficiency of the use of information technology in the education system, it has some academic advantages in the system of teaching and setting up the desktops, which are used to train students. From a user’s perspective, desktop virtualization changes not so much the software itself or hardware, but the methodology and culture of using this software.

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 (is shown in figure 2). This technology allows several operation systems to run on one physical server and isolate applications from each other’s influence, minimize investment and operational costs, avoid overprovisioning. Desktop virtualization uses advantages of server virtualization and cloud technologies bringing together (combining) the benefits gained from hypervisor-enabled virtualization and modern display network protocols. Desktop operating systems run on a physical server under control of host operating system i.e. ‘hypervisor’ whilst screen image is delivered by a network protocol to a client device which may be a PC (Personal Computer), Thin Client, laptop, tablet, etc.

![Figure 2. Server virtualization.](image)

One of the key perspectives of VDI implementation is a possibility to execute any application on any device for which there is a VDI client since applications are executed on the operating system running on the server, not on the device itself.

The number of client computers in a typical organization far exceeds the number of servers therefore this is so important to be able to assess server resources required to run client virtual machines. No less important is to be able to choose the optimal set of hardware servers, for example, from the rage of particular vendor. The key moment to minimize expenses of hardware procurement is a clear view of the server hardware set that needed to provide execution of required number of virtual desktops. We consider VDI implementation in a high school institute, namely the Voronezh State Technical University, which has already a centralized server infrastructure and well-designed network. Desktop infrastructure in an educational institution contains as a rule several sets of identical computers that placed in computer labs. Definitely apart from desktops in computer labs there are a large number of computers with diverse soft-ware a university that is used by staff. These computers are not the best choice to being virtualized at the first stage of the project.
The problem of virtualized server optimization was considered previously in two aspects - static and dynamic. Static Server Allocation Problem is an approach based on a service concept, the model was introduced in [9] and designed to optimally allocate source servers to physically target servers and was proven that this model is NP-hard problem, heuristic solution based on bin packet problem is offered. Another option of using linear programming methods for virtualized system placement representing the dynamic aspect of the problem is used for creating application placement controller. There are several attempts to solve the problem of dynamic replacement of virtual machines on existed physical server infrastructure in datacenter to optimize energy consumption, minimize administrative efforts, increasing server utilization. An approach of dynamic resource allocation for large Internet-oriented data centers bases on queuing theory. On the other hand, it is proposed to use a genetic algorithm based approach. All the models proposed focuses on the server virtualization not the desktop virtualization. As for desktop virtualization an allocation algorithm based on a bin-packet problem is developed [10]. It is mainly focused on achieving a balance between resource usage optimization and user satisfaction.

2.3. VDI and Server Virtualization

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 as 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. (It is necessary to compare the proposed SWOT-factors in pairs). The following conditions must be satisfied for the matrix of pairwise comparisons:

1. \( a_{ij} = \frac{w_i}{w_j} > 0 \) for each \( i \) and \( j \), since all scores are positive.
2. \( a_{ij} = \frac{w_i}{w_j} = 1 \) for each \( i = 1, 2, \ldots, n \).

One can find the maximum real eigenvalue \( \Lambda_{\text{max}}^* \) and eigenvector \( w^* \) the matrix of pairwise comparisons. \( \Lambda_{\text{max}}^* \) and \( w^* \) do not coincide with the corresponding eigenvalue of the matrix \( \Lambda_{\text{max}} = n \) and eigenvector \( w \) of a matrix of relative weights in the scheme of ideal comparison. The idea of T. Saaty [7] is that if the coefficients \( a_{ij} \) of the matrix of pairwise comparisons \( \Lambda^* \) 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 \( \Lambda_{\text{max}}^* \) 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 \( \Lambda_{\text{max}}^* \) one can find vector \( w^* \) satisfying the normalization condition:

\[
\sum_{i=1}^{n} w_i^* = 1
\]

\[
\sum_{i=1}^{n} w_i^* = 1
\]

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:

\[
A^* = (a_{ij}) = \begin{pmatrix}
    a_{11} & a_{12} & \cdots & a_{1n} \\
    a_{21} & a_{22} & \cdots & a_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \cdots & a_{nn}
\end{pmatrix}
\]

In order to obtain the component \( w_i \) of an eigenvector
\[ \mathbf{w} = \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \]  

(5),

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:

\[ W_i = \sqrt[n]{\prod_{j=1}^{n} C_{ij}} \]  

(6).

The components of the eigenvector \( \mathbf{w} \) gives the weights of the compared factors.

Within the framework of the project of Virtual Desktop Infrastructure (VDI) deployment 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 different ones 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.

Further, steps 4-6 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 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.

Strategic alternatives concerning the prospects for using VDI have been proposed. The set of strategies contains the different ones from the refuse to continue the project to the extension the project to the whole educational client desktops infrastructure.

The choice of the final strategy by combining AHP and SWOT analysis.

Further, steps 4-6 will be discussed in more details, whilst the previous steps are described by us according to the links.

Stage 6. In the framework of the SWOT-analysis of VDI pilot project implementation consequences the following strengths and weaknesses, threats and opportunities have been identified (table 1). 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. In the following, we present a set of a strategic alternatives concerning further VDI implementation in IT-infrastructure of the University (table 2).

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

Stage 8. Choosing the final strategy by combining the AHP and SWOT analysis. In the framework of A’WOT (the name of the combined method, some authors) the expert evaluations that handle according to AHP are used. As an experts the top-managers and IT-professionals, as well as users of virtual desktops: teachers and students. Expert assessments were obtained with the help of questionnaires experts in the following areas (questions are presented in a brief outline).
Table 1. SWOT -analysis of the project of VDI deployment

| number | S - strengths                              | W - weaknesses                                      |
|--------|-------------------------------------------|-----------------------------------------------------|
| 1      | Reduction of pay-back period on investment ($s_1$). | Significant initial costs ($w_1$).                   |
| 2      | Reducing the cost of wages for personnel serving the information infrastructure of the University ($s_2$). | The need for staff training ($w$).                   |
| 3      | Reducing the time to deploy a workplace, reducing equipment downtime, simplifying deployment and maintenance processes ($s_3$). | The relatively high cost of additional equipment, due to the increased load on the network ($w_3$). |
| 4      | Improvement of the educational environment, including the possibility of using BYOD (Bring Your Own Device) concept ($s_4$). | Complicating the diagnosis of network problems, especially when using graphics applications ($w_4$). |
| 5      | Increase the information security of the organization, coordinated from a single center, incl. security of personal data ($s_5$). | The need to increase wages to employees of the IT department, due to the growth of their general qualifications ($w_5$). |
| 6      | Simplify the management of the information infrastructure of the University ($s_6$). | Appearance of current costs for licenses ($w_6$). |
| 7      | Savings in capital investments related to equipment upgrades ($s_7$). | Poor performance of graphics applications ($w_7$). |

| number | O - opportunities                             | T - threats                                        |
|--------|----------------------------------------------|----------------------------------------------------|
| 1      | Favorable attitude of the administration towards the centralization of the information infrastructure ($o_1$). | The administration's unfavorable attitude towards the centralization of the information infrastructure ($t_1$). |
| 2      | Improving the interaction of the administration and IT-staff ($o_2$). | Dependence on technology, including from a VDI vendor ($t_2$). |
| 3      | Business process reengineering in the University ($o_3$). | Absence of funds for the initial purchase of necessary equipment ($t_3$). |
| 4      | Providing discounts for educational institutes by the VDI vendors ($o_4$). | The risk of layoffs of trained employees and increase IT-staff turnover, because of skill development ($t_4$). |

Table 2. Strategic alternatives of VDI pilot project implementation results

|   | SO | WO | ST | WT |
|---|----|----|----|----|
|   | Implement virtual workplaces within the entire educational process of the organization. | Implement virtual workstations only on old computers that are write-off. Re-engage them in the educational process of the organization. | 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. | Do not implement virtual workplaces more than implemented within the pilot project, that is, leave it in one classroom for the purposes of training students. |
1. 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.

1.1. Evaluate the importance of a group of strengths of the project (S).
1.2. Evaluate the importance of a group of weaknesses of the project (W).
1.3. Evaluate the importance of a group of opportunities of the project (O).
1.4. Evaluate the importance of a group of threats of the project (T).

2. 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 (see table 3).

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.

| User-friendly scale | Linguistic Interpretation | Comparative AHP scale (Saaty) |
|---------------------|--------------------------|------------------------------|
| 8                   | Extremely High importance| 9                            |
| 6                   | Very High importance     | 7                            |
| 4                   | High importance          | 5                            |
| 2                   | Medium High importance   | 3                            |
| 0                   | Equal importance         | 1                            |
| -2                  | Medium Low importance    | 1/3                          |
| -4                  | Low importance           | 1/5                          |
| -6                  | Very Low importance      | 1/7                          |
| -8                  | Extremely Low importance | 1/9                          |

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 matrices are reduced to the form proposed by Saati for further use of the hierarchy analysis method. To reduce the matrices, table 3 was used. On the next step the matrices were normalized and the geometric mean calculated according to (6). 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 of 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 of the organization. Assess the significance of each factor of strengths for the implementation of 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 on older 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 require implementation potential, the mini strategy). For the first alternative − ST strategy (maximizing the weaknesses of the project to avoid threats, the mini-mini strategy).

We introduce the notation of the values obtained because of expert estimates.

- $k_{1i}$ - the significance of SWOT-factors of strengths for the strategic alternative SO.
- $k_{2i}$ - the significance of SWOT-factors of weaknesses for the strategic alternative SO.
- $k_{3i}^*$ - the significance of SWOT-factors of opportunities for the strategic alternative SO.
- $k_{4i}^*$ - the significance of SWOT-factors of threats for the strategic alternative SO.
- $p_{1i}$ - the significance of SWOT-factors of strengths for the strategic alternative WO.
- $p_{2i}$ - the significance of SWOT-factors of weaknesses for the strategic alternative WO.
- $p_{3i}^*$ - the significance of SWOT-factors of weaknesses for the strategic alternative WO.
- $p_{4i}^*$ - the significance of SWOT-factors of threats for the strategic alternative WO.
- $b_{1i}$ - the significance of SWOT-factors of strengths for the strategic alternative ST.
- $b_{2i}$ - the significance of SWOT-factors of weaknesses for the strategic alternative ST.
- $b_{3i}^*$ - the significance of SWOT-factors of opportunities for the strategic alternative ST.
- $b_{4i}^*$ - the significance of SWOT-factors of threats for the strategic alternative WO.
- $c_{1i}$ - the significance of SWOT-factors of strengths for the strategic alternative WO.
- $c_{2i}$ - the significance of SWOT-factors of weaknesses for the strategic alternative WO.
- $c_{3i}^*$ - the significance of SWOT-factors of opportunities for the strategic alternative WT.
- $c_{4i}^*$ - the significance of SWOT-factors of threats for the strategic alternative WT.

The evaluation of the final strategy is also the same as previously described in Table 3, in step 8 and formula (6). Based on all the above, according to the AHP technics, we can calculate the indicator characterizing each of the strategies considered, as a result, we obtain the following expression:

$$SO = V_S((\sum_{i=1}^3 S_i * k_{1i}) + V_O((\sum_{i=1}^7 W_i * k_{2i}) + V_O((\sum_{i=1}^4 O_i * k_{3i}) + V_T((\sum_{i=1}^4 T_i * k_{4i})$$  \hspace{1cm} (7)  

$$WO = V_S((\sum_{i=1}^7 S_i * p_{1i}) + V_O((\sum_{i=1}^7 W_i * p_{2i}) + V_O((\sum_{i=1}^4 O_i * p_{3i}) + V_T((\sum_{i=1}^4 T_i * p_{4i})$$  \hspace{1cm} (8)  

$$ST = V_S((\sum_{i=1}^7 S_i * b_{1i}) + V_O((\sum_{i=1}^7 W_i * b_{2i}) + V_O((\sum_{i=1}^4 O_i * b_{3i}) + V_T((\sum_{i=1}^4 T_i * b_{4i})$$  \hspace{1cm} (9)  

$$WT = V_S((\sum_{i=1}^7 S_i * c_{1i}) + V_O((\sum_{i=1}^7 W_i * c_{2i}) + V_O((\sum_{i=1}^4 O_i * c_{3i}) + V_T((\sum_{i=1}^4 T_i * c_{4i})$$  \hspace{1cm} (10)
In the course of the study 50 experts were surveyed, among which 3 middle managers (in the field of information technology); 1 top manager (in the field of information technology); 7 specialists - IT staff; 18 university lecturers who teach disciplines related to the use of computers and 21 students who were trained in both ordinary classrooms and in the classroom where virtual workstations were used.

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 product, 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 and to complete this project. The study shows the advantage of ST strategy, since it received the greatest approval of experts. Implementation of this strategy will reduce a number of costs for information support, increase the flexibility of the information infrastructure, and increase the level of fault tolerance. It is planned to monitor the implementation of the pilot project during half a year. Perhaps, after six months of implementing the desktop virtualization project, experts will review their point of view, or other SWOT factors will become more relevant and experts will be offered a new questionnaire.

References
[1] Taha H A 2005 Operation research: An introduction, 7th edition (Moscow: Publishing House «Williams») pp 514-520
[2] Kotler F and Keller K 2017 A framework for marketing management: textbook, 14th edition (SPb.: Piter) p 800.
[3] Kurttila M et al. 2000 Utilizing the analytic hierarchy process (AHP) in SWOT - analysis - a hybrid method and its application to a forest-certification case (Forest policy and economics) vol 1 pp 41-52
[4] Dagdeviren Yü I 2007 Using the analytic network process (ANP) in a SWOT analysis - a case study for a textile firm (Information Sciences) vol 177 16 pp 3364-3382
[5] Jozi S A et al 2012 Rural waste management strategic plan by A’WOT c Hierarchy Process (Radio and communication J Environ Studies) vol 38 64 pp 93-108
[6] Sevkli M et al. 2012 Development of a fuzzy ANP based SWOT analysis for the airline industry in Turkey (Expert systems with Applications) vol 39 1 pp 14-24
[7] Saati T 1993 Decision-making. Method of hierarchy analysis (Radio and communication) p 278
[8] Makoviy K et al 2017 Server hardware resources optimization for virtual desktop infrastructure implementation (Mathematical Modeling. Information Technology and Nanotechnology Proceedings of the International Conference Information Technology and Nanotechnology, Samara, Russia) vol 1904 pp 178-183

[9] Speitkamp B and Bichler M 2010 A mathematical programming approach for server consolidation problems in virtualized data centers (IEEE Trans. Services Comput) vol 3 X pp 266-278

[10] Armstrong D 2015 et al Contextualization: dynamic configuration of virtual machines (Journal of Cloud Computing: Advances, Systems and Applications) pp 4-17

[11] Makoviy K and Khitskova Yu 2015 Economic basis of VDI deployment in institution of higher education IT-infrastructure (Modern economy: problem and solutions) 2 (62) pp 75 - 81

[12] Makoviy K et al 2016 Using the method of hybrid estimates in the task of selecting the object of the pilot project (Materials of the International Scientific and Technical Conference "Actual Problems of Applied Mathematics, Informatics and Mechanics", Voronezh: VSU) pp 96-99