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ПРОГНОЗИРОВАНИЕ ПОТРЕБНОСТИ В СПЕЦИАЛИСТАХ ПО ЗАЩИТЕ ИНФОРМАЦИИ

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Forecasting the Demand for Information Security Personnel

Keywords: Information Security; Demand for Information Security Personnel; Information Security Specialists; Information Security Practitioners.
During the formation of information society the problem of determining the demand for IS personnel (DfISP), consisting of IS specialists and IS practitioners, is of particular relevance at present. The goal of the paper is to calculate the demand for IS specialists (DfISS). To achieve it we used the informal heuristic methods and introduced some important indicators for DfISP forecast. As a validation of the conceptual approach proposed we show how to apply it on the regional level of one country on one real-world example. All the reasoning and calculations can be narrowed down to the DfISS forecasting within one corporation or IS professionals of a specific profile.

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ПРОГНОЗИРОВАНИЕ ПОТРЕБНОСТИ В СПЕЦИАЛИСТАХ ПО ЗАЩИТЕ ИНФОРМАЦИИ

Ключевые слова: информационная безопасность, потребность в специалистах по защите информации; специалисты по защите информации; практики в области защиты информации
В условиях формирования информационного общества проблема определения потребности в кадрах в сфере информационной безопасности (ПКИБ), состоящих их специалистов по защите информации и практиков по защите информации, имеет в настоящее время особое значение. Цель данной статьи заключается в расчете потребности в специалистах по защите информации (ПСЗИ). Для достижения этой цели использовались неформальные эвристические методы и вводились некоторые важные показатели для прогноза ПКИБ. В качестве проверки предложенного концептуального подхода показано, как его применить на региональном уровне одной страны на одном реальном примере. Все рассуждения и расчеты могут быть сужены до прогнозирования ПСЗИ в рамках одной корпорации или в отношении профессионалов в области ИБ определенного профиля.

Introduction

The insurance of information security (IS) and the fight against computer crimes and terrorism are very important tasks during the formation of information society. The competent policy of specialist training in the field of IS can essentially influence a decrease in cybercrimes. An effective solution of the IS issues on a solid scientific basis requires an appropriate staffing. The staffing process includes regular training, retraining and short-term or long-term improvement courses for the required number of personnel with sufficient knowledge, abilities and skills. Thus, the problem of determining the demand for IS personnel (DfISP) and improvement of the staffing process management are of particular relevance at present [where IS personnel consist of IS specialists and IS practitioners.]

In forecast implementing it is very difficult to take into account various phenomena affecting the sufficiency of personnel for different sectors of the economy. For example, the scientific and technological revolution, the number of employees, their age and qualification structure, number and quality of training of young professionals, migration processes and others. The combined influence of these factors should be noticed.

The DfISP forecasting puts many requirements to the information basis of this research. The long-term time series of indicators are needed in order to establish the most important trends and key ratios (they characterize the DfISP structure and dynamics) and to determine the corresponding coefficients and parameters. Currently available statistical information is not enough to build the adequate models for science-based forecasting. In this regard, it is the most urgent to create some simplified models or methods that would give practical results nowadays, in conditions of insufficient information provision. Therefore, the heuristics are chosen. To determine the strategies they use approximate solutions based on accounting an experience in solving similar problems in the past, as well as the experts' intuition.

The remainder of the paper is organized as follows. The related works are analyzed in Section 2. Usage of the psycho-intellectual generation of ideas (PIGI) method to forecast DfISP is briefly shown in Section 3. The main indicators for the DfISP forecasting are introduced in Section 4. Section 5 contains initial data and assumptions taken for the real-world example, described in Section 6. Three possible directions of determining the effectiveness of spending on education in modern conditions are shown in conclusion.

Related works

The above issues are the subject of several papers of the authors of this paper [1-5] and foreign authors [6-9].

The paper's ideas heavily rely on the forgotten now experience of the Soviet Union, personal Malyuk's experience in the Ministry of Higher and Secondary Special Education of the USSR in 1974-1985, as well as the results of research on specialist training conducted during this period by the Scientific and Research Institute of Problems of the Higher Education and the leading universities of Russia, in particular, the Ukrainian school under the guidance of Professor A.V.Golovach [10]. The statistical data used by the authors of this paper are largely based on the studies conducted by the Association of Producers of Computer and Information Technologies [11].

The problem of cost-effectiveness of education is very important in dealing with the development of vocational education for the market economy. The most interesting results in this direction have been obtained by the Soviet economic school headed by S.G.Strumilinym and A.G.Aganbegyanom in 60-70-ies of the last century. Since that time, this problem has not been given attention by both domestic and foreign economists. Let us briefly analyze the results obtained at that time and the possibility of their usage in modern conditions.

First of all, the erroneous and even harmful (to justify the cost) assignment of education to the services sector should be noticed from our point of view. In this case, the great social importance of education and its role in the development of scientific and technical progress and the formation of an innovative economy are actually forgotten.

It seems that the cost of education is similar to the cost of production goods in narrow economic sense. They are also the costs of creating the necessary production conditions. The cost of education and the cost of production good are mutually reinforcing. They contribute to the creation of material and intellectual factors in raising productivity and production development. In other words, the costs of production goods and education are an integral part of the costs that society has to bear in order to produce more consumer values. This idea is confirmed by a number of publications [12-16].

In addition, in the 1970s the Scientific and Research Institute for the Higher Education of the USSR has been developed a forecasting methodology consisting of four stages at which different indicators were calculated [17].

I stage:

1.1) the specialists' saturation coefficient $SS=NS/NE$, where NS is a number of specialists and NE is a total number of employees;

1.2) the total demand for specialists (DfS) for s sector of the economy: $TNS_s^{t+m}=NE_s^{t+m}*NS_s^{t+m}$, $m=0,5,10,\ldots$, where $t+m$ is a last year of the forecasting period and t is a last year of the basic (previous) period;

1.3) the total DfS for all sectors of the economy (E): $TNS_E=\Sigma TNS_s^{t+m}$.

When forecasting the saturation the following restrictions should be provided: $TNSG_P>TNSG_{NP}$, $SW_P^{t+m}>SW_P^t$, $SW_{NP}^{t+m}<SW_{NP}^t$, where $TNSG$ is a growth rate of total DfS; SW is a specific weight of specialists working in this group of sectors of the economy; P is a branch of productive sector and NP is a non-productive sector of the economy.

II stage:

2.1) the coefficient of the qualification structure of specialists $QS=(NS_s*100)/NS_h$, where h is a higher vocational education and v is a vocational education;

2.2) the total DfS with h and v: $TNS_h=(TNS*100)/(QS+100)$, $TNS_v=TNS–TNS_h$.

III stage:

3.1) the indicator of professional structure of specialists: $\Sigma P_i=1$, $i=1,2,\ldots$, where P_i is a proportion of specialists of i professional group;

3.2) the total DfS with h and v: $TNS_h=\Sigma TNS_h*P_i$, $TNS_v=\Sigma TNS_v*P_i$.

IV stage:

4.1) the coefficient of actual outcoming of specialists from the field of their professional activity t: $AO=(G–(NS_t^A–NS_{t-1}^A))/NS_{t-1}^A$, where G is a number of specialists graduated from the educational institutions;

4.2) the expected number of specialists: $NS_t^E=NS_t+G–NS_t*AO$;

4.3) the total DfS: $TNS_{t+k}=TNS_t+AAI*k$, $k=1,2,\ldots$, where AAI is an average annual increase in the total DfS and k is a number of the year;

4.4) the additional DfS in each professional group t: $ANS_t=TNS_t–TNS_{t-1}–TNS_{t-1}*AAI$.

Using this technique, it should be borne in mind the significant changes in the ratio of productive and non-productive sectors of the economy of the modern post-industrial (information) society. This mainly concerns the restrictions of the first stage of forecasting.

Informal heuristic methods of forecasting

The basis of informal heuristic methods is the management of intellectual activities (productive thinking) of a man in the search for optimal solutions in the complicated unstructured or semi-structured situations. The productive thinking in addition to informality has the following characteristics: the ability to summarize and to orientate in uncertain situations, the tendency to dissipate and to lose some information (the ability to forget). From the point of view of effectiveness of solving complex problems first three properties are positive (they enhance the effectiveness of the decision), the last two are negative (they reduce the effectiveness of the decision). Neutralization of negative influence of the properties on the effective solutions of the complex problems is one of the main goals of the management of intellectual activities. This phenomenon is called the psycho-intellectual generation of ideas (PIGI) [18]. It is an analytical method of individual expert estimation using the programmed control over the process. The process of finding a solution by the PIGI method is carried out in a controlled conversation (discussion) of two indispensable participants: a leading and a decision maker. The leading set some questions (problems) to the decision maker, on which the latter expressed his opinion. The discussion, guided by leading towards a more complete and in-depth examination of the problem, is fastened on the basis of these judgments. An opponent and a few experts can assist the leading. The task of the opponent is to find some weaknesses in the decisive judgments of the decision maker and the formation of objections and criticisms, inducing him to debate. The experts help the leading to evaluate the judgments and to schedule sequence and content of further discussion of the problem. The experts on any profile of the discussed problem may be involved (in the case of the DfISP forecasting they are economic experts, expert in IS training, legal experts, etc.). The best solutions of discussed problem are found among all the decisive statements of the decision maker.

In summary, the rules of the PIGI session for its greater effect can be formulated as follows:

- selection of the session participants and the distribution of roles between them, depending on the nature and complexity of tasks being solved;
- the discussion should be informal, really creative, emotionally intense and elevated;
- close psychological interaction between the session participants;
- step by step, formalized solution of complex problems with their detailed dissection (separation of the main problems and subproblems, goals and subgoals, criteria of comparison of different options, and so on);
- purposeful management of the problem solving by reminding the content of the problem/subproblems to be solved at this stage to the decision maker at every stage, and concentrating his attention on the issues discussed as long as it will not be considered in sufficient detail;
- information support for the problem solving, i.e. timely delivery to the participants of all necessary information in the required amount and form;
- a quick check of the possible consequences of taken or proposed problem solutions;
- organization of the sessions' technical support.

In order to ensure a focused discussion its detailed scenario should be worked out in advance. The main its part is a special psycho-heuristic program (PHP). PHP contains a list of issues discussed, the goals that should be achieved during their discussions and the recommendations on discussion management depending on the current situation. The PHP basis is a special page that contains all the details necessary for the consideration of the matter under discussion. An example of the possible form of such a page is shown in Fig. 1.

Let us formulate the main problems that should be solved by using the PIGI method to forecast DfISP:

- selection and training of the leadings (they should have not only a deep and comprehensive knowledge in the discussion area, but also have the ability to gain pers, mobilize their intelligence and manage it;
- professional and psychological training of the decision makers;
- overcoming the psychological barriers, general awareness of the fact that these methods are most effective for this class of problems and psychological readiness to mobilize and to subordinate one's intellect for the problems' solving in accordance with PHP;
- deep insight into the essence and content of tasks to be solved (in our case the tasks of ensuring IS of the specific protection objects);
- creation of the necessary external support (information support system, work space equipment, creation of an environment comfortable for the participants).

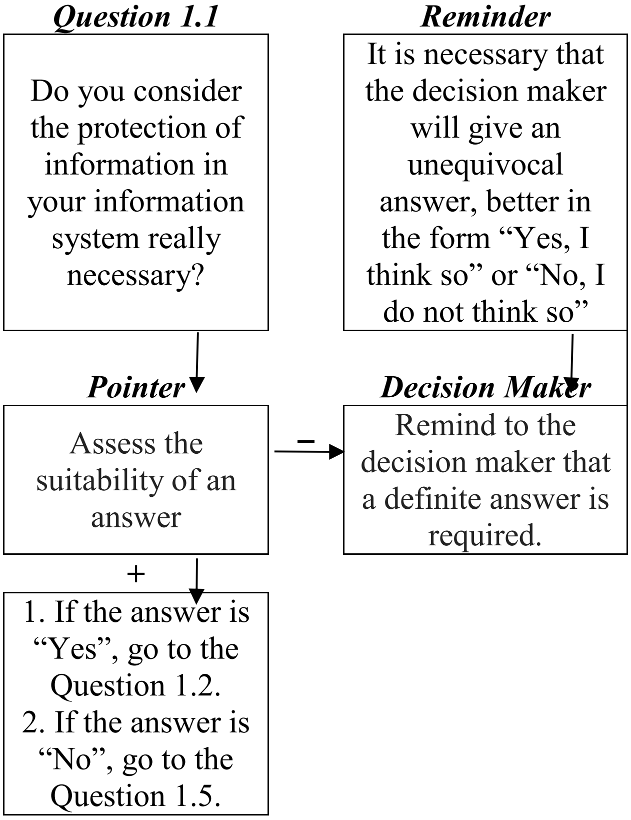

Figure 1. The psycho-heuristic program (fragment).

Main indicators used in dfisp forecasting

The indicators used in the analysis and forecast of DfISP should reflect the basic requirements of the economy and the problems of innovative development. On this basis, the calculation of the future (perspective) DfISP should include the definition of the following indicators:

1. The nominal DfISP at the end of the forecast period (the demand according to the staff lists).
2. The long-term expected number of IS practitioners.
3. The real DfISS.
4. The total additional DfISS for the forecast period (the required incoming of personnel for the entire forecast period, supporting a transition from the actual number of IS personnel to the real DfISS at the end of the forecast period). Within the overall additional DfISS two components can be identified:
   a) incoming supporting the direct additional DfISS;
   b) incoming compensating outcoming, including the preservation of simple reproduction of IS specialists and ensuring their expanded reproduction.
5. The expected incoming of IS specialists for the entire forecast period, while maintaining the existing levels of annual incoming for each training direction, including the incoming from the educational institutions and other sources.
6. The total DfISS for the entire forecast period, supplemented from the educational institutions.
7. The annual indicators for the main types of calculated DfISS.

All these indicators should be separately calculated for each training direction. The calculations are desirable to separate for the first and the second stages of the forecast period, if this period exceeds 5-7 years.

Initial data and assumptions

Let us suppose that the DfISP to ensure IS of the information systems of organizations located in one of the region of the given country has been equal to 1,200 pers (according to their staff lists) at the beginning of 2014. 980 IS specialists with the higher education and 220 IS practitioners have worked in these positions at that moment. The nominal DfISP has been increased by 50 pers by the end of 2014. In fact, 1,020 IS specialists with the higher education and 2,130 IS practitioners worked by the end of the year.

85 pers, including 50 specialists from the educational institutions and 35 from other sources, have come in 2014. 45 pers have left this field of professional activities for various reasons. 30 IS practitioners have been enrolled in these positions for 2014, and 20 IS practitioners have left them.

Then the regional DfISP is 1,700 pers by the end of 2024.

Using these data, it is necessary to identify all the key indicators for the respective demand for IS specialists with the higher education (DfISS) for the region for the next 10 years.

We assume that the IS specialists and IS practitioners incoming’s intensity throughout the forecast period will be the same as in the initial period. In this case, one year is taken as such a period. Of course, the average data for a few previous years would be more reliable. An account of incoming intensities’ trends and their forecast for the future could give even greater accuracy. However, the application of these specifying methods would be possible only for a survey for several years and while using more labor-intensive calculations. In this case, the degree of forecast’s accuracy achieved could not justify sharply increasing labor and time costs to conduct a survey and perform calculations.

The IS practitioners will exist in the foreseeable future, since many positions are often occupied by the skilled workers with the vocational training or higher education in the similar areas of training or even the university’s students. However, the number of IS practitioners in positions designed for the IS specialists with the higher education, should gradually decrease. The rate of this decrease should be determined by the experts in each particular case. In our example, it is assumed that in the forecast period the half of the outcoming practitioners will be reimbursed by the IS specialists with the higher education, and the other half will be again replaced by IS practitioners. This assumption seems to be very logical as it reflects the moderate gradual decrease in their numbers and the increase of the saturation coefficient for IS specialists with the higher education.

The outcoming coefficient (due to the small number of IS specialists and, accordingly, very small statistical sample) will be taken as the average outcoming rate for several similar groups of training directions.

Dfiss calculation example

Let us consider the real-world example of the perspective DfISS calculation, using the scheme of all the indicators calculation shown if Figure 2.

The nominal regional DfISS with the higher education is 1,700 pers by the end of 2024 (according to the organizations’ staff lists). But some of these positions (230 in the initial period) is occupied by the IS practitioners. The current intensity of their outcoming (the outcoming rate) is 8.9%*(20:(220+230)/2)*100.

Taking into account the accepted assumption that the half of outcoming IS practitioners will be replaced in the future by the IS specialists with the higher education, we can say that the number of IS practitioners will be reduced by 4.45% per year. Thus the number of IS practitioners at the end of the forecast period will be $230(1-0{,}0445)^{10}=230*0.9555^{10}=230*0.6343=146$.

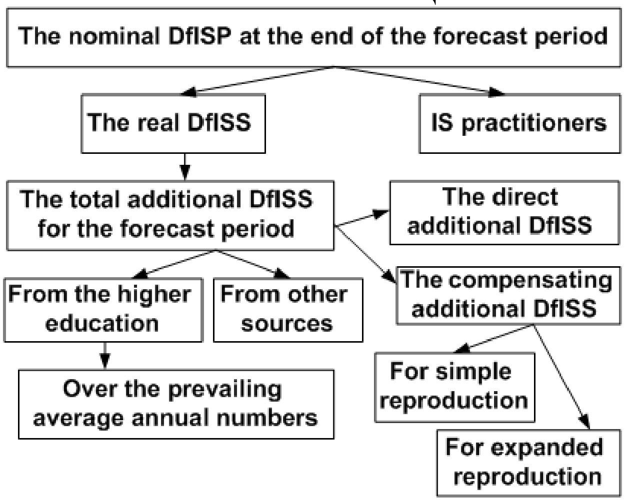

Figure 2. The perspective DfISS calculation scheme.

To determine the actual DfISS with the higher education at the end of 2024 the nominal DfISS at that moment should be reduced by the resulting expected number of IS practitioners: 1,700-146=1,554.

Next, we should determine the incoming of specialists of this speciality (direction) for 10 years that can provide the growth from 1,020 pers at the end of 2014 up to 1,554 pers at the end of 2024, while maintaining the current outcoming intensity.

Let us introduce the following notation: S_o is ane initial number of IS specialists; S_n is a perspective real DfISS; S is an average annual number of IS specialists; K_t is an average annual rate of growth of the number of IS specialists in %; K_o is an average annual coefficients of IS specialists' outcoming in %; n is a number of years in the forecast period.

Based on the above considerations, we have for total incoming $I = \Sigma_1^n I_n = nS\,(\sqrt[n]{S_n/S_o} - 1 + 0.01K_o) = 10*1{,}287\,(\sqrt[10]{1{,}554/1{,}020} - 1 + 0.01*4.5) = 12{,}870\,(\sqrt[10]{1.5235} - 1 + 0.045) = 12{,}870\,(1.045 - 1 + 0.045) = 12{,}870*0.09 = 1{,}158$ (n=10), $S = (1{,}020+1{,}554)/2 = 1287$ (where $K_o = 45*100/1000 = 4{,}5\%$).

The coefficient of total growth $K_t=K_i-K_o$. As K_i *is* I/S in percents and n=10, then $I=\Sigma_1^{10} I_n$ is the number of incoming of specialists for the forecast period. It will provide the actual presence of IS specialists by the end of the forecast period equal to the real DfISS at that moment, while maintaining the current outcoming intensity.

This part of incoming, in turn, consists of the incoming, compensating the outcoming to preserve the initial number of IS specialists (nS_o*0.01K_o), and the incoming, compensating the outcoming of aggregate values, providing the direct additional demand ($\Sigma_1^n I_n$- S-nS_o*0.01K_o).

The value $\Sigma_1^{10} I_n$=1,158 consists of the direct additional demand S=S_n–S_o=1,554-1,020=534 and the compensating additional demand 1,158–534=624, including the compensating demand for preserving simple reproduction of nS_oK_o=10*1,020*0.045=459 pers and for expanded reproduction of 165 IS specialists.

In other words, 1,158 pers are the total additional DfISS for all 10 years. 534 pers are required for the direct transition from the initial to forecast value by the end of the forecast period. 459 pers are required to compensate the possible outcoming of the initial number (1,020 pers) for ten years. 165 pers are required to compensate the possible outcoming of the totality that provides a direct transition from the initial to the designed number and are equal to the direct additional DfISS.

However, the value of the total additional DfISS does not mean that 1,158 pers of this training direction should be employed in the region for ten years from the existing educational institutions over the prevailing numbers of employ contingents. From our assumption 85 pers, including 50 IS specialists from the educational institutions and 35 from other sources (maybe form other regions and another sectors of the economy of this region), have came for this region in 2014. If the volume of incoming will remain at the same level for the forecast period, then for 10 years we will have 850 pers, including 500 IS specialists from the educational institutions and 350 from other sources, in the region. That means that the higher education should provide inflow of not 1,158, but only 800 pers (1,158-350) to the region for 10 years, including 308 pers over the prevailing average annual numbers in the initial period (808-500).

Thus, the total additional DfISS is determined approximately as 116 pers on average per year for 2014-2024. 80 pers should come from the higher education, including about 30 pers over the prevailing average annual numbers in the initial period.

The saturation coefficient expressing the percentage of the number of IS specialists with the higher education to their numbers provided by the staff list, will increase from 81.6% at the initial period to 91.4% at the end of 2024.

Further we will determine the total additional DfISS for next 10 years as $\Sigma_1^n I_n = S_n - S_o + nS_oK_o + ½*[(n-1)(S_n - S_o)]*K_o =$ 1,554-1,020+10*1,020*0.045+[(10-1)(1,554-1,020)/2]*0.045 = 534+459+108=1,101 (n=10).

The direct additional DfISS $S_n - S_o$ and incoming, compensating the outcoming for preserving the initial number of IS specialists nS_oK_o, are defined similarly. The number of incoming, compensating the outcoming from the numbers providing direct additional demand can be defined as $½*[(n-1)(S_n - S_o)]* K_o$.

From the total additional DfISS constituting 1,101 pers, 751 pers should be employed from the higher education (1,101-350), including 251 pers (751-500) over the prevailing average annual numbers in the initial period.

The average annual values of the found indicators are 110, 75 and 25 pers correspondently.

Thus, we have obtained different results: for the entire ten-year period the difference is 57 pers (about 5% for the total additional DfISS) and 5-6 pers when calculating the annual average indicators for the forecast period.

If the real DfISS at the end of the forecast period remains at the initial actual number of IS specialists ($S_n = S_o$), then the total additional DfISS will exist. However, it will be composed of one (not 3) component, namely, the compensating additional DfISS that will compensate the possible outcoming of the initial number to preserve the simple reproduction. The direct additional DfISS and the part of compensating additional demand, which should provide the expanded IS specialists reproduction are absent or more precisely are equal to 0 in this case.

In our example for $S_n = S_o = 1{,}020$ the total additional DfISS $\Sigma_1^{10} I_n$ is 459 pers. Taking into account the current level of incomimg, we can conclude that for 10 years the total DfISS can be achieved by 109 pers from the higher education (459-350), or about 11 pers per year. Since the existing annual average numbers of incoming of such specialists in the region are 50 pers, it would be necessary to adjust these levels decreasing them to the amount determined by the forecast calculation.

By reducing the prospective real DfISS compared to the actual number of IS specialists in the initial period, the total additional DfISS will be reduced or completely absent.

Conclusion

We would like to emphasize once again the role of IS personnel in solving the problems of global information society. With a difficult demographic situation in the world as a whole and a general decrease in youth's interest in activities associated with the solution of engineering problems, the staffing support of this critical sector is of paramount importance. It is clear that its solution requires substantial data and financial costs.

Thus, the consideration of peculiarities of education's impact on production suggests three possible directions of determining the effectiveness of spending on education in modern conditions. Firstly, the cost of workers' education should be considered along with the other costs in determining the effectiveness of capital investments in economy-wide or for individual sectors and objects. Secondly, the most important general indicator of relation between the development of production and education is the result of comparing the production volume with the sum of cumulative social costs on necessary training for the employees involved in the production. This indicator is similar to the indicator of capital intensity (capital ratio), expressing the effectiveness of the basic production goods. Thirdly, the practical definition of the cost-effectiveness of education is also possible on the basis of calculation of losses to society from a lack of personnel qualification in specific production sectors of the economy.

The paper presented the conceptual approach to calculate DfISS and thus to forecast DfISP at the country level. To achieve the goal we used the informal heuristic methods and introduced some important indicators for DfISP forecast. As a validation of the conceptual approach proposed we showed how to apply it on the regional level of one country on one real-world example.

Further work is aimed at narrowing down all the reasoning and calculations the DfISS forecasting within one corporation or IS professionals of a specific profile (e.g., IS analytics, security administrators).

REFERENCES:

1. Malyuk A. Information Security Staffing. The State Service, 2011, Vol. 5 (In Russian).
2. Malyuk A., Tolstoy A. Personnel Training for Information Security Maintenance in Russia. Proceedings of the 1st World Conference on Information Security Education (WISE1), Sweden, Kista, 1999.
3. Malyuk A., Miloslavskaya N., Tolstoy A. The Russian Experience Information Security Education. Proceedings of the 2nd World Conference on Information Security Education (WISE2), Perth, Western Australia, 2001.
4. Malyuk A., Miloslavskaya N., Tolstoy A. Teaching Undergraduate Information Assurance in Russia. Proceedings of the 3rd World Conference on Information Security Education (WISE3), Monterey, California, USA, 2003.
5. Malyuk A. Forecast of Information Security Personnel Training. The State Service, 2012, Vol. 3 (In Russian).
6. National Infrastructure Protection and Computer Intrusion Program (NIPS). URL: http://memphis.fbi.gov/menipc.htm (access date 10.04.2015).
7. The International Association of Computer Investigative Specialists. URL: http://www.iacis.com (access date 10.04.2015).
8. US Government Opens $9m Cyber Security Center, TG-daily. URL: http://www.tgdaily.com/security-features/44495-us-government-jpens-9m-cyber-security-center) (access date 10.04.2015).
9. DoD Directive 8579.1. URL: http://www.isc2.org/ dodmandate/default.aspx (access date 10.04.2015).
10. Economic and Statistical Analysis and Forecasting Demand for Specialists. Golovach A.V. (edt). Kiev, Visha shkola, 1985 (In Russian).
11. Analytical Research on IT Personnel for the Russian Economy. URL: http://www.apkit.ru/files/ITstaffdemant2007.pdf (access date 10.04.2015) (In Russian).
12. Marcinkiewicz V.I. Education in the United States: economic importance and effectiveness. Moscow, Nauka, 1967 (In Russian).
13. Zhamin V.A. Education Economy (theory and practice issues). Moscow, Prosvezhenie, 1969 (In Russian).
14. Volkov F.M. Reproduction of Skilled Labor in the USSR. Moscow, Sochekgiz, 1961 (In Russian).
15. Tolypin Y.M. The Impact of the Law of Time Economy and a New Methodology for its Mathematical Analysis. Moscow, MGU, 1964 (In Russian).
16. Gomberg J. Labor Reduction. Moscow, Economica, 1965 (In Russian).
17. Research and Information Centers on the Higher Education Management Problems: the Scientific and Research Institute for the Higher Education of the USSR. University Management. 1998. N 3(6). Pp. 31-34. URL: http://ecsocman.hse.ru/univman/msg/144985.html (access date 10.04.2015) (In Russian).
18. The Theory of Forecasting and Decision-Making. Sarkisian S.A. (edt.). Moscow, Vishaja shkola, 1977 (In Russian).