Decision-Making Support for Strategic Planning

Vitaliy Tsyganok
Institute for Information Recording of
National Academy of Sciences of Ukraine,
Kyiv, Ukraine
Email: tsyganok@ipri.kiev.ua

***Abstract*—New methods of decision-making support based on the most complete usage of knowledge (both formal and expert) in a certain subject domain are proposed for long-term planning. An innovative approach to construction of a strategic plan is proposed. It is based on hierarchical decomposition of the problem by remotely working group of experts under the supervision of a knowledge engineer, provides an opportunity to use estimation scales with different number of grades, and allows increasing the reliability of the results of group examinations. The proposed approach features such methods as target dynamic evaluation of alternatives, as well as an original method of optimal allocation of resources. Application of the approach is illustrated by an example, related to planning of information operation counteraction.**

***Keywords*—Decision-Making Support, Weakly-Structured Domain, Strategic Planning, Resource Allocation, Expert Estimating.**

I. Introduction

It is known that in a general sense a strategy is a non-detailed action plan, designed for a long-term period and aimed at achievement of a certain main goal. At the same time, the plan should be flexible, constructive, resistant to uncertainties of environmental conditions; is should also provide an opportunity for concretization through decomposition of the main goal.

In weakly structured subject domains, which include management, environmental protection, production, social sphere and others, the problem of building long-term non-detailed plans of action extremely relevant. There is no doubt that creation of such strategic plans should be based on all available knowledge in a given subject domain. Since knowledge in any such area is not completely formalized and, therefore, mostly, “stored” within in the minds of professionals, it would be unreasonable not to use the information obtained from experts in the planning process. Moreover, one cannot take into account only quantitative (e.g., financial) indicators. In order for long-term plans to be realistic, they need to adapt to imminent changes in the current situation and take into account the availability of resources, required for their implementation at any particular moment. Therefore, strategic plans can be rational only at a certain time interval.

The purpose of this research is to create a technology that would include formal mechanisms of building strategic plans in weakly structured subject domains, involving groups of experts and knowledge engineers.

With the above-mentioned requirements to strategies in mind (namely the need for realistic and dynamic plans), we suggest using decision-making support (DM) tools, capable of performing distribution of limited resources among specific activities, for strategic plan construction. Resources are allocated at a given moment in time, depending on potential contribution of certain activities to achievement of strategic goal. In essence, the approach should provide an answer to the question: "Which activities should be implemented under current conditions for the most effective achievement of the strategic goal?".

II. Strategy-building technology

Considering the above, the developed strategy-building technology involves several stages:

A. Stage: "Building of a Knowledge Base"

This stage is implemented using a web-based software system that allows the decision-maker, knowledge engineers and experts to work remotely to create a Knowledge Base (KB), without the need to come together.

This stage includes a number of sub-stages:

1) Selection of expert group for the examination. The problem of expert selection is, generally, the responsibility of decision-makers and knowledge engineers. Moreover, under the examination intended for resolving of different issues different groups of experts (most competent specialists in each specific area) are formed.
2) Construction (through dialogue with the experts) of goal hierarchy, which describes the subject domain. At this sub-stage the decision-maker formulates strategic goal, which is subject to decomposition into local goals (factors) that significantly influence its achievement (through examinations conducted by knowledge engineers). In the process of decomposition, the experts (working remotely in a web-centric system "Consensus" [1]) coordinate their judgments on the composition of the set of influence factors for a particular goal, and gradually reach agreement on every issue. For decomposition of each local goal knowledge engineers, working as examination organizers, form a separate group of experts. The software system allows different expert groups to work simultaneously, while every expert can be included into different groups. The advantage of the remote approach is that experts in the group can collaborate and provide their knowledge (while they might be incompatible at the direct personal contact,

remote work ensures anonymity of the experts and this, in turn, eliminates the influence of any "dictator's" judgment). The range of specialists involved to the expertise can be significantly expanded with the ability for each user to choose (in the system) the most suitable language for communication, i.e., the examination may involve specialists, who have not even been able to work and communicate with each other without an interpreter.

The examination organizers determine the sufficient level of detail, and, therefore, the moment of termination of the strategic goal decomposition process in the case when the lower level of the hierarchy features only the goals (factors), which are "ready" for implementation, i.e. specific activities (projects).

The result of this stage of strategy construction process is a hierarchical structure, which, in accordance to the aggregate opinion of this expert group, fully describes the subject domain.

General view of a goal hierarchy in the decision support system (DSS) "Solon" [2] is shown on Fig. 1. The DSS demo version is available at the website of DSS lab ($http://dss-lab.org.ua/$).

3) Expert estimation of relative influences of goals in the hierarchy. The relative influence of each goal in the goal hierarchy graph is determined by the knowledge engineer (in the case of availability of reliable knowledge about the level of influence of some sub-goal upon a specific goal), or (otherwise) by the expert group by means of paired comparisons of the goal (factor) influences.

   To improve the reliability of the examination results, a special software tool is developed, that provides an expert with the ability to perform each individual pair-wise comparison in the verbal scale, which most adequately reflects the knowledge of the expert about the issue under consideration and the level of his / her confidence in this own knowledge [3], [4]. This software tool allows to gradually increase the level of detail of the scale, and then to perform a final estimation in the most appropriate scale (Fig. 2).

   The results of this sub-stage are: the relative values of mutual influences of goals, resulting from aggregation of individual expert estimates, performed in different detail scales, and presented in the form of incomplete group pair-wise comparisons matrices (PCM) of influences. For aggregation we propose using the combinatorial method [5], which is more efficient in comparison to other methods (efficiency advantage is confirmed by the relevant experimental study [6]).

   This aggregation method has several advantages over existing approaches to processing of PCMs:

   - In the combinatorial method the informational redundancy is used as fully as possible.
   - The method allows for determining of alternative weights in cases when some elements of the PCM are missing (not specified). That is, the presence of all paired comparisons in the matrices is not a mandatory requirement for determining the weights of alternatives. The only necessary condition is the connectivity of the graph corresponding to the generalized PCM.
   - The method has only one stage (in contrast to well-known approaches, used for calculation of weights in the group methods of estimation [7]). Aggregation of paired comparisons in such group DM methods is a two-stage procedure: either (1) initially the individual PCMs element-wise are aggregated, and then – on the basis of the generalized matrix the weight vector of alternatives is calculated , or (2) at first for each PCM the weight vector is calculated, and then all the vectors are aggregated. In case (1) consistency of all corresponding elements from the individual PCMs does not guarantee the consistency of the resulting PCM. In case (2) consistency of each individual PCM does not guarantee the consistency of the weight vectors calculated for each PCM. The two-stage procedure makes it impossible to organize feedback with experts for improvement of consistency, if its level is insufficient for aggregation and for the weight calculation. When using of combinatorial method, there is no need for gradual achievement of the desired level of consistency and, therefore, a conflict between the two successive processes of consistency and mutual compatibility improvement is not occurring. If you want to increase consistency of paired comparisons, certain elements of individual PCM are adjusted (under consent of the experts who built the respective PCM).

   We should note that aggregation is acceptable only under sufficient consistency of expert judgments. To evaluate consistency level of paired comparisons we suggest using the Double-entropy consistency index [8], which determines consistency degree based on the spectrum of the expert estimates of weights for each of the influences. In comparison to other known indices, it reflects (more accurately and correctly) the properties of the consistent set of expert estimates. In the case of insufficient consistency, the method provides an opportunity to improve its level by feedback with experts.

At this point the KB construction is finished. The next stage of building of optimal strategy, based on the knowledge, incorporated in the KB, starts.

B. Stage: "Determination of the optimal strategy"

Obviously, the greater the weight of a specific project or activity, the more considerably it influences the achievement of strategic goal. Therefore, allocation of resources to the project will bring more tangible and measurable results. At the same time, there is no sense to allocate lesser resources to the project, than it requires for launching and implementation. Consequently, we define optimal strategy as the optimal variant of resource distribution between projects (i.e. the one that provides the most effective achievement of the strategic goal).

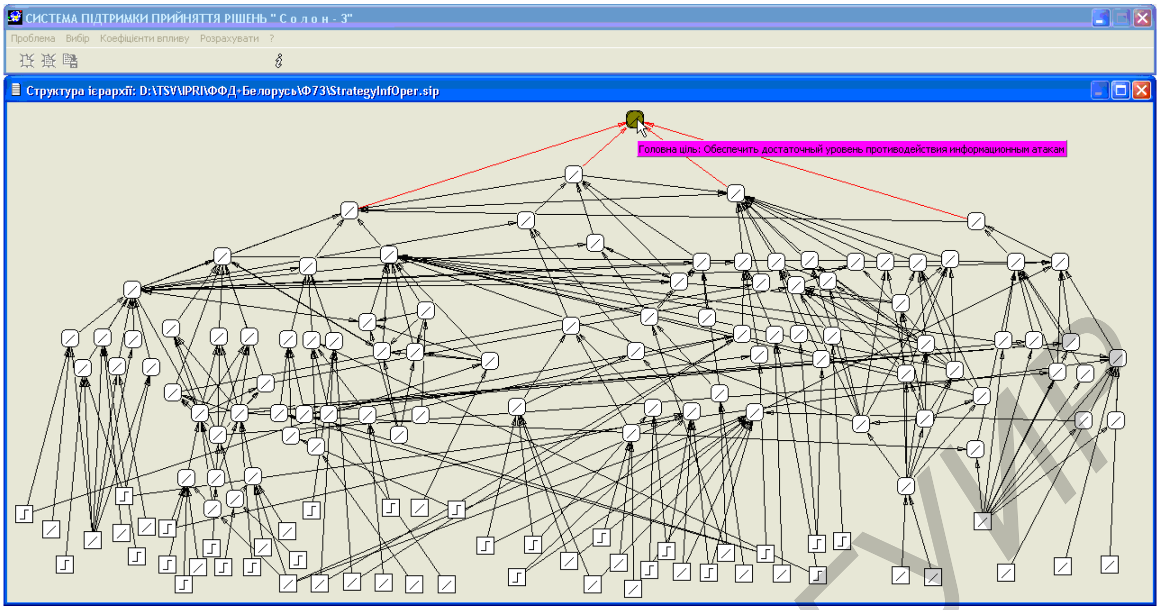


Figure 1. The DSS "Solon" interface and the view of the goal hierarchy

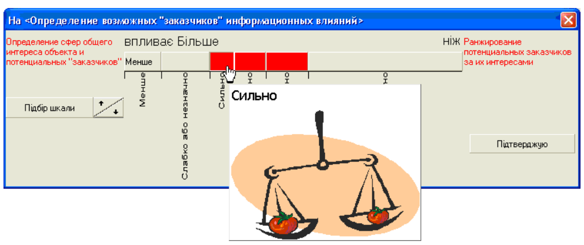


Figure 2. Expert choice of a detail level of the paired comparison scale

The task of choosing the optimal allocation of resources to projects is the subject of a separate study. It should be noted that (since the projects can be characterized by different terms of realization and, in addition, goals can have different delays of influence upon the main goal) optimal resource allocation is relevant only for a given point in time. Through the use of the method of targeted dynamic of estimation of alternatives [9], [10] within a given strategic plan, it is possible to evaluate and compare quite diverse projects / activities: those that provide the immediate effect and those, whose effect may be witnessed in the distant strategic perspective. Another important parameter that characterizes the projects is the range of necessary resource volumes. For example, if the minimum required amount of funding for the project is 1 million UAH, and requested – 2 millions UAH, it makes no sense to allocate amount, which does not belong to this range, to the project.

Given these features, the most efficient way to solve the problem of resource allocation to projects during a given time period can be considered as targeted search of an optimal allocation among all possible resource allocations with a given accuracy (say, up to 10 thousands UAH), for example, using genetic algorithm [11].

Depending on the complexity of the subject domain and the formulated goal to be achieved, strategic plan construction process can be easier or more difficult. However, the proposed mathematical apparatus and the developed DM software tools allow to create rather extensive, meaningful, and most importantly, realistic long-term plans (based on all available knowledge about the domain). In subsequent sections of this paper some of the stages of technology implementation are illustrated by an example: formation of a confrontation strategy in the information war.

The term "information operations" (IO) in the modern-world environment gained considerable popularity in the beginning of this century, when the information has become an important strategic resource, lack of which leads to significant losses in all spheres of life. It is probable that the term became popular after the declassification of a number of the US Department of Defense documents, where IO is defined as "actions aimed at influencing the enemy's information and information systems, protection of one's own information and information systems." Then, in the "road map of information operations" [12] the term was clarified: "The integrated implementation of the core capabilities of Electronic Warfare, Computer Network Operations, Psychological Operations, Military Masking and Security Operations, within the concept of supporting and associated capacities, in order to influence, disrupt, corrupt or usurp adversarial human and automated decision-making, while protecting one's own facilities". The meaning of the term IO covers and explains informational influence on public consciousness (both adversarial and friendly), the impact on the information available to the enemy and necessary for him to make decisions, as well as on information and analytical system of the enemy [13]. In the modern conditions IO, being an inseparable part of the information war, is viewed as a new kind of combat action, active counteraction in the information space, and the information in this case is viewed as a potential weapon and as a target for attack.

The two main types of IO (according to general convention) are offensive and defensive operations. However, in practice most IO are mixed, and the majority of their constituent procedures are simultaneously offensive and defensive. A distinguishing feature of an offensive IO (information attacks) is that the objects of influence of such operations are identified and the planning is based on fairly accurate information about these objects. The information attack often calls for detection or creation of an informational occasion (for defensive IOs the occasion may be the information attack of the enemy itself), the “promotion” of the occasion i.e. propaganda (in contrast to the counter-propaganda activities during a defensive IO), as well as for measures to counteract the information exposure. Thus, IO, regardless of its type, can be divided into the following phases: assessment, planning, implementation, and final phase. Now, following the purpose of this research, let us consider in greater detail a defensive IO, corresponding to doctrines of the majority of progressively developing countries.

Typical defensive IO covers the following basic phases:

- Estimation:
  - Analysis of possible vulnerabilities (goals);
  - Collection of information about possible operations;
  - Identification of possible requesters / "customers" of the information influences:
    - definition of areas of common interest of the object and the potential "customers";
    - ranking of potential customers by their interest;
- Planning:
  - Strategic planning of defensive operations (explicit or implicit):
    - Defining the criteria of information influences;
    - Information Modeling effects, taking into account:
      - object relations;
      - dynamics of the influence;
      - «special» (critical) points of the influence;
    - Forecasting of the next steps;
    - Calculation of the consequences;
  - Tactical planning of counter-operations;
- Execution - implementation of informational influence:
  - Identification and "smoothing" of information occasion;
  - Counter-propaganda;
  - Operational intelligence;
  - Evaluation of the information environment;
  - Adjustments to the information counteraction;
- The final phase:
  - Analysis of effectiveness;
  - The use of positive results of the information influence;
  - Counteraction to negative results.

As we can see from the proposed detailed plan of a defensive IO, strategic planning is a fundamental component of IO. Obviously, there is no uniform "standard" plan for IO. We can only consider an exemplary sequence of actions on IO implementation, obtained by generalization of some already realized IO. Moreover, the choice of an optimal set of such actions depends, primarily, on the availability of resources to perform them at a given time, as well as on the results of execution of previously selected activities. Optimality should be considered here in terms of effectiveness of achievement of goals of one or another defensive IO.

A separate objective of this study is improvement of the existing DM apparatus, taking into account the peculiar features of strategic planning process in weakly structured domains. The following example demonstrates the formal IO strategy construction, involving a group of competent specialists in this area.

III. Numerical Example

A hypothetical example, presented here, shows the final stages of the process of optimal strategic plan construction for counteraction to the information operations within a 5-year term, under condition of availability of financial resources in the amount of 200 million UAH. Within the example we assume that the hierarchy with the main objective "Ensure sufficient level of counteraction to information attacks" has already been built and presently we are at sub-stage 3 of strategic plan construction – estimation of relative influences of the projects upon a certain goal from the goal hierarchy graph.

Let us assume that estimation at this stage is performed by a group of three equally-competent experts. Each expert is formally given the opportunity to determine the domination degree in each pair of 4 projects – to perform an ordinal comparison (">" - more; "<" - less), decide on verbal estimation scale, select the number of points (grades) of the scale and, finally, select the number of a particular point (grade).

Table I shows the data of the expert estimation of the importance of activities that are part of the goal of "Implementation of information influence": C_1 – Revealing and "smoothing" of information occasion; C_2 – Counter-propaganda; C_3 – Operational Intelligence; and C_4 – Evaluation of the information environment. The asterisk symbol "*" in the matrices denotes the elements (pair comparisons) on which the experts (due to one reason or another) have not provided information.

Based on the pair-wise comparisons of unified values (bottom row of matrices in Table I) we calculate the relative weights of project influences (Table II).

To construct the optimal strategy for the 5-year term, we use the resource allocation tools of the DSS "Solon" (see. Fig. 3).

On the screen form we can see that the following expert estimates are entered for each project, which claims to be funded: the minimum necessary number of resources for the project (R min), the percentage of completion of the project under minimal funding (% min), the amount of resources that is requested (R max) and the planned percentage of the project completion (% max, usually, 100%). After calculations (<Distribute> button), the amounts of allocated resources are displayed in the "allocated" column.

A list of recommended actions for decision-makers in the form of a set of projects with the calculated funding volumes

Table I. EXAMPLE OF EXPERT ESTIMATION OF PROJECTS' RELATIVE INFLUENCES

		Expert 1				Expert 2				Expert 3			
		C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
Ordinal Comparison	C_1	1	>	>	>	1	>	<	>	1	*	>	>
	C_2		1	<	>		1	<	>		1	<	<
	C_3			1	>			1	*			1	>
	C_4				1				1				1
The number of scale points	C_1	1	5	9	9	1	5	5	9	1	*	8	9
	C_2		1	5	9		1	7	9		1	9	3
	C_3			1	7			1	*			1	9
	C_4				1				1				1
Point number	C_1	1	2	3	5	1	3	2	5	1	*	4	8
	C_2		1	2	2		1	4	5		1	2	2
	C_3			1	5			1	*			1	3
	C_4				1				1				1
Scale number	C_1	1	1	3	1	1	3	4	1	1	*	2	3
	C_2		1	2	1		1	4	2		1	3	5
	C_3			1	2			1	*			1	1
	C_4				1				1				1
Unified values of pair-wise comparisons	C_1	1	2.500	1.732	5.000	1	2.615	0.833	5.000	1	*	2.011	6.839
	C_2		1	0.739	2.000		1	0.574	2.333		1	0.760	0.726
	C_3			1	3.138			1	*			1	3.000
	C_4				1				1				1

Table II. THE CALCULATED RELATIVE WEIGHTS OF PROJECTS' INFLUENCES

Marking a project	Normalized value of the weight
C_1	0.4455
C_2	0.1743
C_3	0.2919
C_4	0.0883

will provide the basis for an optimal strategic plan for ensuring a sufficient level of information attack counteraction in a 5-year prospect, under the limitations on the amount of financial resources supplied.

IV. CONCLUSIONS

A strategic planning technology in weakly structured subject domains, based on the use of decision-making support apparatus, is proposed. The advantages of the technology are: the ability to use all available knowledge about the subject domain (including knowledge of experts), opportunity to consider both quantitative and qualitative factors influencing the achievement of strategic goal, high reliability of group expert examinations (resulting from availability of a mechanism to ensure sufficient consistency of expert data, including incomplete data and estimated, provided in different scales), as well as opportunity to consider time frames of project execution and the limitations on available resource volumes.

This technology allows to define the rational (for a given moment in time) allocation of resources among the initial set of activities, which ensures the most effective achievement of the strategic goal. Subject domain is described by an expert-built knowledge base, and targeted resource allocation variant search is performed by Genetic algorithm.

Above-mentioned features make the technology a universal, convenient and flexible tool for strategic planning. As an example of technology application we have considered the estimation of specific activities aimed at counteraction to potential information operations.

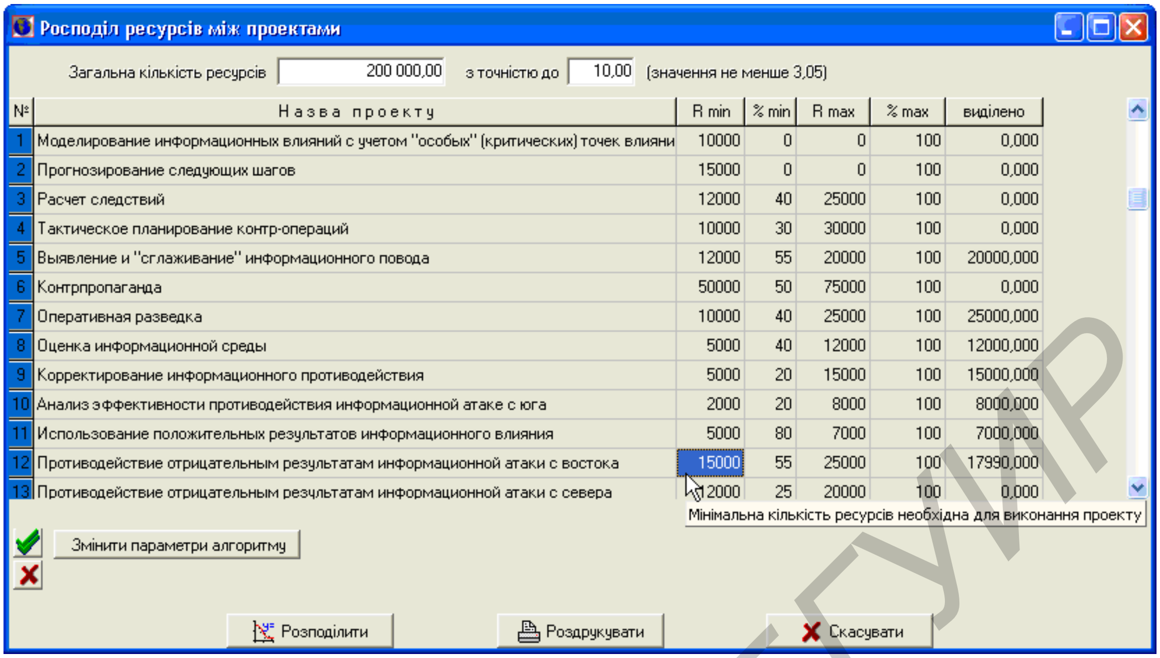
Further research in this area can be dedicated to development of new algorithms for determination of optimal resource allocation variant in the context of a given strategic goal.

Research carried out in the project F73 / 23558 "Development of methods and tools for decision-making support at revealing of information operations" supported by State Fund for Fundamental Research of Ukraine and Belarusian Republican Foundation for Fundamental Research.

REFERENCES

[1] Свідоцтво про реєстрацію авторського права на твір №45894 Держ. служби інтелект. власності України. Комп'ютерна програма „Система розподіленого збору та обробки експертної інформації для систем підтримки прийняття рішень – «Консенсус»" / В.В.Циганок, П.Т.Качанов, О.В.Андрійчук, С.В.Каденко // від 03/10/2012.

[2] Свідоцтво про держ. реєстрацію автор. права на твір №8669. МОН України Держ. деп. інтелект. власності. Комп'ютерна програма "Система підтримки прийнят-



№	Назва проекту	R min	% min	R max	% max	виділено
1	Моделирование информационных влияний с учетом "особых" (критических) точек влияни	10000	0	0	100	0,000
2	Прогнозирование следующих шагов	15000	0	0	100	0,000
3	Расчет следствий	12000	40	25000	100	0,000
4	Тактическое планирование контр-операций	10000	30	30000	100	0,000
5	Выявление и "сглаживание" информационного повода	12000	55	20000	100	20000,000
6	Контрпропаганда	50000	50	75000	100	0,000
7	Оперативная разведка	10000	40	25000	100	25000,000
8	Оценка информационной среды	5000	40	12000	100	12000,000
9	Корректирование информационного противодействия	5000	20	15000	100	15000,000
10	Анализ эффективности противодействия информационной атаке с юга	2000	20	8000	100	8000,000
11	Использование положительных результатов информационного влияния	5000	80	7000	100	7000,000
12	Противодействие отрицательным результатам информационной атаки с востока	15000	55	25000	100	17990,000
13	Противодействие отрицательным результатам информационной атаки с севера	12000	25	20000	100	0,000

Figure 3. The calculated allocation of resources among the projects

тя рішень СОЛОН-3"(СППР СОЛОН-3) / В.Г.Тоценко, П.Т.Качанов, В.В.Циганок // зареєстровано 31.10.2003.

[3] Циганок В.В. Агрегація групових експертних оцінок, що отримані у різних шкалах / В.В.Циганок // Реєстрація, зберігання і обробка даних. – 2011. – т.13. – №4.– С.74-83.

[4] Tsyganok V.V. Using Different Pair-wise Comparison Scales for Developing Industrial Strategies / V.V.Tsyganok, S.V.Kadenko, O.V.Andriichuk // Int. J. Management and Decision Making. – 2015. – Vol. 14, No.3. – pp.224-250.

[5] Циганок В.В. Комбінаторний алгоритм парних порівнянь зі зворотним зв'язком з експертом / В.В.Циганок // Реєстрація, зберігання і обробка даних. – 2000. – Т.2, №2. – С.92-102.

[6] Tsyganok V.V. Investigation of the aggregation effectiveness of expert estimates obtained by the pair-wise comparison method / V.V. Tsyganok // Mathematical and Computer Modelling. – 2010. – Vol.52(3-4). – pp. 538-544.

[7] Forman E. Aggregating individual judgments and priorities with the analytic hierarchy process / E. Forman and K. Peniwati // European Jouranl of Operational Research. – 1998. – Vol.108. – pp.131-145.

[8] Olenko A. Double Entropy Inter-Rater Agreement Indices / Andriy Olenko & Vitaliy Tsyganok // Applied Psychological Measurement. – 2016. – v.40(1). – pp.37-55.

[9] Тоценко В.Г. Об одном подходе к поддержке принятия решений при планировании исследований и развития. Часть 2. Метод целевого динамического оценивания альтернатив / В.Г.Тоценко // Проблемы управления и информатики. – 2001. – №2. – С.127-139.

[10] Циганок В.В. Удосконалення методу цільового динамічного оцінювання альтернатив та особливості його застосування / В. В. Циганок // Реєстрація, зберігання і обробка даних. – 2013. – Т. 15, № 1. – С. 90-99.

[11] Holland J.H. Adaptation in natural and artificial systems. An introductory analysis with application to biology, control, and artificial intelligence / J.H.Holland; London: Bradford book edition. – 1994. – 211 p.

[12] Information operations roadmap. – DoD USA, 30 october 2003. – 78 p. Retrieved 20/11/2016 from *http://nsarchive.gwu.edu/NSAEBB/NSAEBB177/info_ops_roadmap.pdf*.

[13] Горбулін В.П. Інформаційні операції та безпека суспільства: загрози, протидія, моделювання // В.П. Горбулін, О.Г. Додонов, Д.В. Ланде; – К.: Інтертехнологія, 2009. – 164 с.

ПОДДЕРЖКА ПРИНЯТИЯ РЕШЕНИЙ ПРИ СТРАТЕГИЧЕСКОМ ПЛАНИРОВАНИИ

Цыганок В.В.

Современные методы поддержки принятия решений, основанные на наиболее полном использовании знаний в определенной предметной области (как формализованных, так и экспертных) предлагаются к применению при долгосрочном планировании. Предложен подход к построению стратегических планов в слабо-структурированных предметных областях. Подход включает иерархическую декомпозицию проблемы группой удаленно работающих экспертов под руководством инженера по знаниям. Предлагается возможность использования разных шкал оценивания, позволяющая повысить достоверность результатов групповых экспертиз, целевое динамическое оценивание альтернатив, а также, метод оптимального распределения ресурсов. Применение подхода описывается на примере планирования противодействия информационным операциям.