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INFORMATION TECHNOLOGY FOR THE INTEGRATED ASSESSMENT OF EXPERT COMPETENCY

The **subject** matter of the study is the processes of selecting and assessing the competency of experts. The **goal** of the study is to increase the objectivity of expert assessment by developing and applying a model and information technology for the integrated assessment of the competency of experts, which will enable selecting experts for participation in expert groups on a high qualitative level. The following **tasks** were solved: methods and models for assessing the quality and competency of experts were reviewed; a model for the integrated assessment of the competency of experts was developed; an applied information technology for a comprehensive assessment of the competency of experts was designed and implemented in software. The methodology of the study was based on the following **methods:** methods of heuristic, test and statistical evaluation were used to develop the model for the integrated assessment of the competency of experts; principles of system analysis and methods of object-oriented design were used to develop the applied information technology for the integrated assessment of the competency of experts. The following **results** were obtained: the problem of assessing the quality of experts was considered; based on the authors' practical experience and analysis of literature sources, the structural diagram of the properties of experts and their assessment was developed; five main groups of existing methods for assessing the quality of experts were analyzed; existing models of an integrated assessment of the competency of experts were reviewed; a two-stage method for the integrated assessment of the competency of experts was developed by integrating the methods of heuristic, test and statistical assessment; the main groups of users and functional requirements to the information system for assessing the competency of experts were identified; the database and user interface of the information system were developed; the developed information technology of the integrated assessment of the competency of experts was tested on actual data for selecting an expert group to choose the methodology of project management. **Conclusions.** The problem of selecting and assessing the competency of experts is one of the most difficult in the theory and practice of expert surveys. It cannot be solved by applying singular methods of assessment; its solution requires that complex methods, including both quantitative and qualitative methods for assessing the competency of specialists should be applied. The applied information technology was developed for this purpose; it can be used at various enterprises, institutions and organizations that are interested in automating the process of expert survey and in building quality expert groups.

Keywords: information technology; complex assessment; expert competency; group of experts; methods for assessing the quality of experts.

Problem statement

Expert surveys are an integral part of the process of project assessment and decision-making and they are applied at all stages of these processes, from problem statement to the evaluation of implementation.

While managing technical and social processes, there is always a need to find out expert opinions about complex problems that are difficult to formalize. Expert surveys are aimed specifically at studying estimates specialists make across a wide range of issues and forecasts for the development of complex non-standard situations. In some cases, an expert survey is the efficient and the only possible way to obtain the necessary information and choose a course of action for solving non-standard tasks.

At the same time, there is a problem of objectivity of information obtained from experts; this problem can be solved due to the proper selection of specialists to participate in the work of expert groups since the reliability of their assessments is largely determined by the competency of experts [1].

The use of singular methods to assess the competency of an expert does not always enable taking into account all the characteristics of a candidate. Therefore, it is important to formulate and apply complex methods which include both quantitative and qualitative methods of assessing the competency of specialists.

The analysis of recent studies and publications

Selecting experts is an extremely complex process in which a large number of different qualities of a candidate [2] should be taken into consideration, for example awareness and competency in the subject area, practical experience and length of work, professional status, creativity, independence of mind, systematic thinking and the comprehensive vision of the problem, interest in expert study and so on.

On the basis of the analysis of literary sources [1–6], the structural diagram is developed and presented (fig. 1).

The diagram shows that taking into consideration the specificity of activities, the quality of an expert is determined by such properties as competency, specialization, independence, personal features of an expert, age and temperament.

It should be noted that the quantitative assessment of the quality of an expert consists of an assessment of individual properties this quality depends on.

In the scientific literature, the suggested methods of assessment of the quality of experts are divided into five groups [5]:

- heuristic assessments – those that are given by a human;

- statistical assessments – those that are obtained after the opinions of experts about the object of the assessment have been processed;

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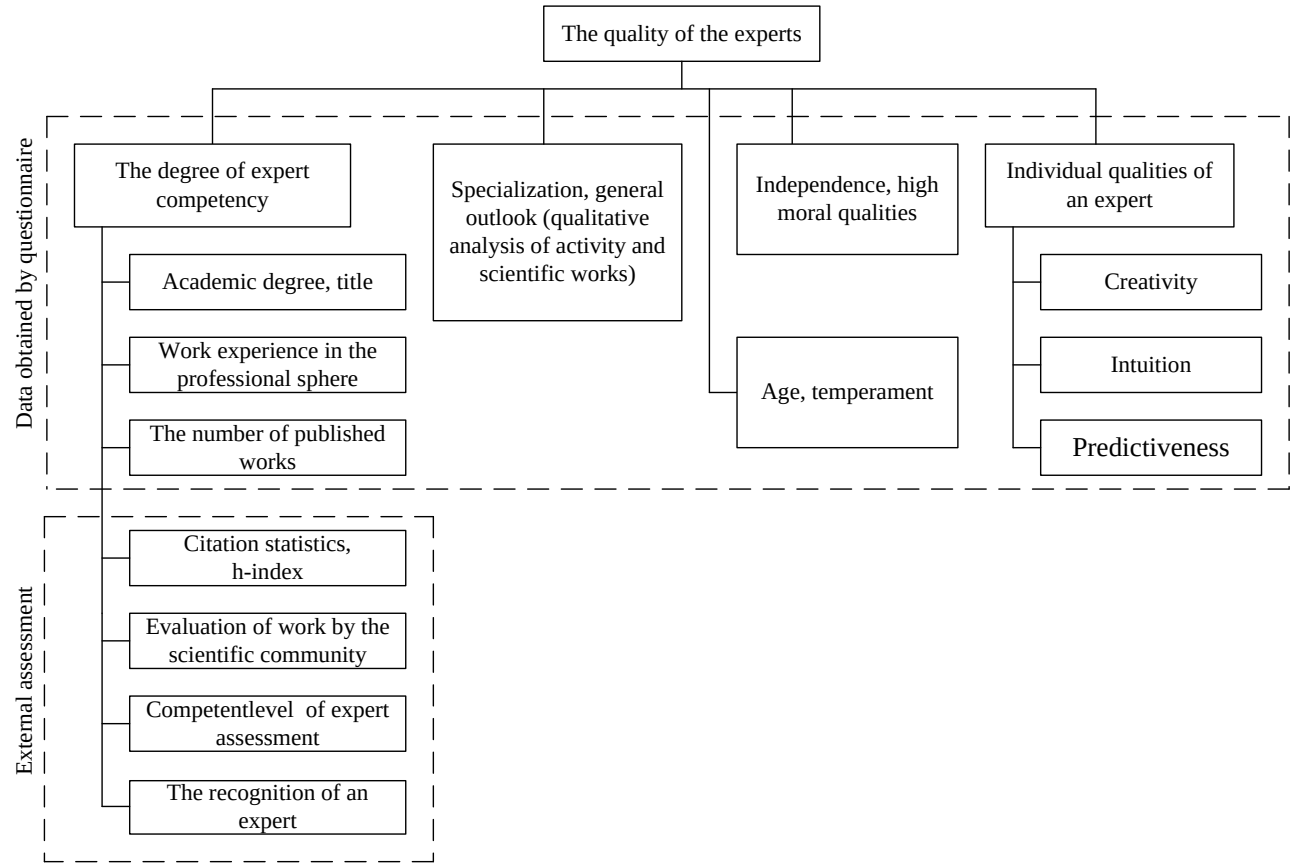

Fig. 1. Structural diagram of the basic features of experts

- test assessments – those that are obtained as a result of special tests conducted by experts;
- documentary assessments – those that are based on the analysis of documentary data about experts;
- integrated assessments – those that are obtained due to any combination of the listed methods.

Scientific paper [5] suggests the diagram of methods for obtaining private assessments of properties characterizing the quality of experts. Each group contains several private assessments and the methods used for obtaining them (fig. 2).

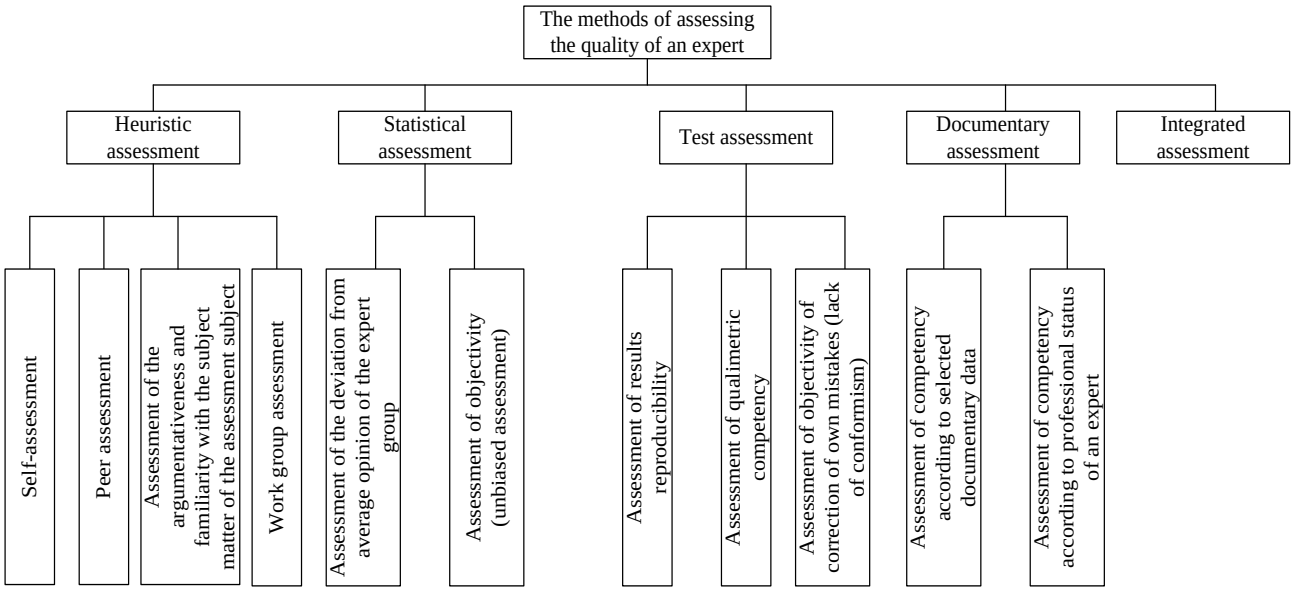

Fig. 2. Methods for obtaining private assessments of properties characterizing the quality of experts [5]

In scientific paper [1], the model of expert competency assessment was developed; it reduces the subjectivity of available heuristic methods of selecting experts and includes two stages of expert competency assessment – heuristic assessment and test assessment.

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Scientific paper [3] recommend that expert competency should be assessed by combining heuristic and statistical methods of expert competency assessment by using information on the scientific potential of experts that have been obtained in a documentary way.

It should be noted that except for the above methods, there are other methods to assess the quality of an expert. Scientific papers of many authors [7–18] deal with studies in this area.

Thus in the scientific paper [7], the competency of experts is proposed to be determined using the method of paired comparisons, and in [9] – by the method of peer assessment.

Scientific paper [8] suggests the technique that enables conducting the integrated assessment of expert competency taking into consideration the quality of an expert as well as the level of their arguments while assessing in the scientific and technological area.

Scientific paper [10] considers various procedures for determining the competency of experts.

Scientific paper [11] suggests the approach to formalizing the process of forming expert groups, that is based on the application of methods of combinatorics, the theory of sets and relations, the theory of matrices, metric algorithms for classification and logic of predicates.

Scientific paper [12] analyzes a great number of works on making managerial decisions and suggests considering the process of selecting the quantity and quality of expert group as a multistage process.

Scientific papers [13-14] suggest using the unified optimization framework based on the Facility Location Analysis, which is a well-known branch of the Operation Research for solving three types of problems to form a group of experts.

Scientific paper [15] presents a new approach for determining the weighting factors of experts in a group while solving problems. In this paper, the weighting factor of experts in a group is determined within the decision environment by using the projection method.

Scientific paper [16] considers how the expert group size affects the importance of expert competency while aggregating individual expert opinions.

Scientific paper [17] describes the Theory of Expert Competency that implies both analyzing experts and designing and using expert systems.

Scientific paper [18] deals with the approach to the complex assessment of the expert group competency. It considers an integrated approach to calculating the competency of the expert group in terms of the work complexity (types of work). The suggested approach extends the current methods and algorithms of assessment based on the proposed three-dimensional model which considers the professional knowledge in the given field of expertise, expert competency and sociometric status of the expert in the group.

The goal and objectives of the study

The goal of the study is to increase the objectivity of the expert assessment by developing and applying a model and information system of an integrated assessment of the expert competence, which enables selecting quality specialists to participate in the work of expert groups.

The tasks that are solved to achieve the goal of the study are as follows:

- to review methods and models of assessment of the quality and competency of experts;
- to develop a model of integrated assessment of the quality of experts;
- to design and implement in software applied information technology for the integrated assessment of expert competency.

Materials and methods

The model of the integrated expert assessment of experts is proposed; this model is based on the combination of heuristic, test and statistical assessment methods. The developed model includes the following stages (fig. 3).

Stage 1 is implemented by the test method. An expert does the competency test in a specified speciality, for example in Project Management. The test has 40 questions, each one scores 2.5 points and the total score is 100. The passing score is 80–100, that means that an expert should answer correctly at least 32 questions from 40 ones.

Stage 2 lies in calculating the integrated assessment that comprises self-assessment of own competencies, which is calculated according to the formula suggested in [3]:

$$K_{self}^{ij} = \frac{\varphi_{ij}}{\varphi^{\max}}, \quad (1)$$

where φ_{ij} is the value of the qualification in accordance with the position i and the academic degree j (the academic title of expert, registration in the state register of experts) of an expert ($\varphi_{ij} \in [1,\ldots,12]$). The specific value of the indicator φ_{ij} is determined according to the data presented in table 1 [4];

$\varphi^{\max}$ is the maximal value of the qualification indicator.

Peer assessment within the specified speciality is conducted via questionnaires.

The competency coefficient of the l-th expert is a relative number of votes for including an expert in the group and is calculated by the formula [1]:

$$K_{peer,l} = \frac{\sum_{j=1}^{n} x_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}}, \left(l = \overline{1,n}\right), \quad (2)$$

where $K_{peer,l}$ is the competency coefficient of the l-th expert that is determined by the method of peer assessment; x_{ij} is the assessment which is equal to 1 if the j-th expert added the i-th expert to the list or is equal to 0 in any other case.

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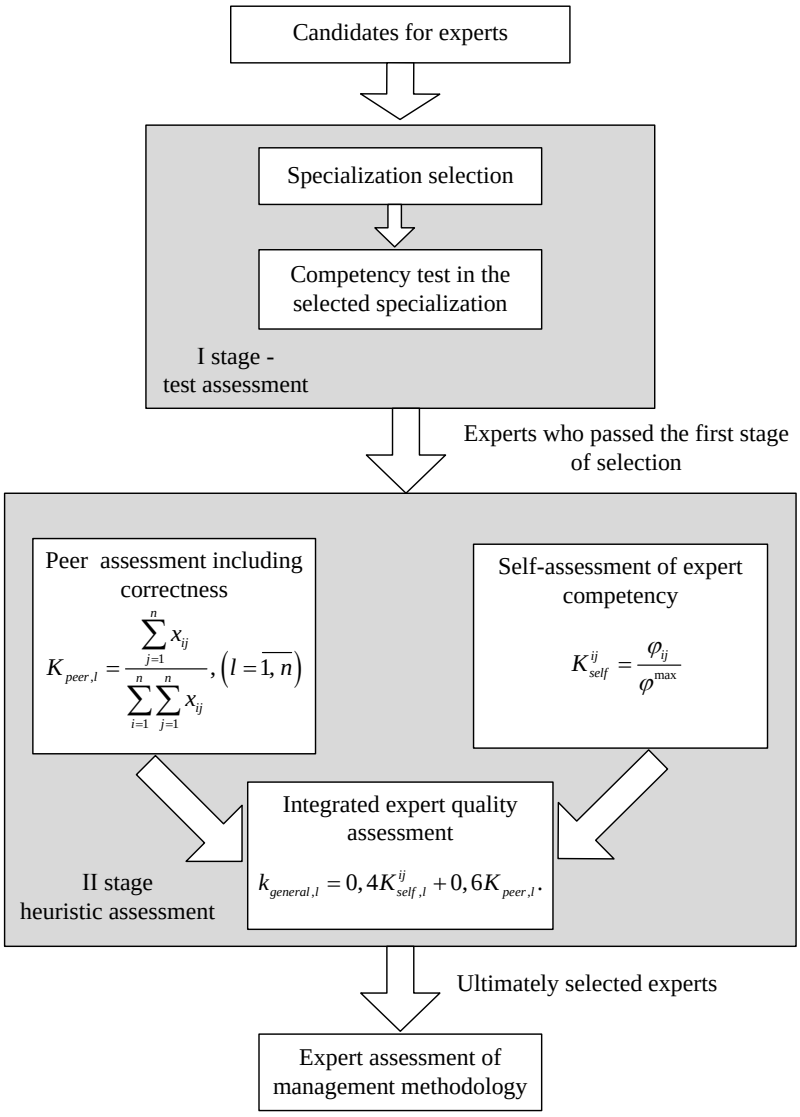

Fig. 3. The method of integrated assessment of expert competency while selecting the methodology of management

Table 1. *Verbal-numerical assessment scale of experts* φ_{ij} [4]

Position	No scientific degree	PhD	PhD, associate professor / PhD, state expert	Doctor of Science	Doctor of Science, associate professor	Doctor of Science, professor / Doctor of Science, state expert	Doctor of Science, professor, state expert	Member of the Academy/ Corresponding Member
Junior research scientist (research scientist)	1	1,5	1,75	2	2,25	2,75	3	4
Senior scientific researcher	1,5	2,25	2,5	3	3,5	4	4,5	5
Head of laboratory	2	2,5	3	3,5	4	4,5	5,5	6
Leading researcher (deputy head of department)	2,5	3	3,5	4	4,5	5	6	7
Head of department (chief researcher)	3	4	4,5	5	5,5	6	7	8
Chief of Bureau	3,5	4,5	5	6	7	8	9	10
Head of the Institute (center)	4	5	6	7	8	9	10	12

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On the basis of two stages, the integrated assessment of an expert competency is calculated according to the formula [1]

$$k_{general,l} = 0,4K^{ij}_{self,l} + 0,6K_{peer,l}. \quad (3)$$

Weighting factors are assigned taking into consideration the fact that the assessment of results reproducibility specifies the professional competency of an expert concerning issues that are of great significance for further expert assessments of objects.

The discussion of the results of the study

As a result of a detailed analysis of the subject area, the main users of the information system for the integrated assessment of expert competency were identified. Two types of users were specified, these are "Administrator" and "Expert". For each type of user, the basic functional capabilities were identified for dealing with the information system. All functional capabilities are presented as a diagram of use cases that are shown in fig. 4.

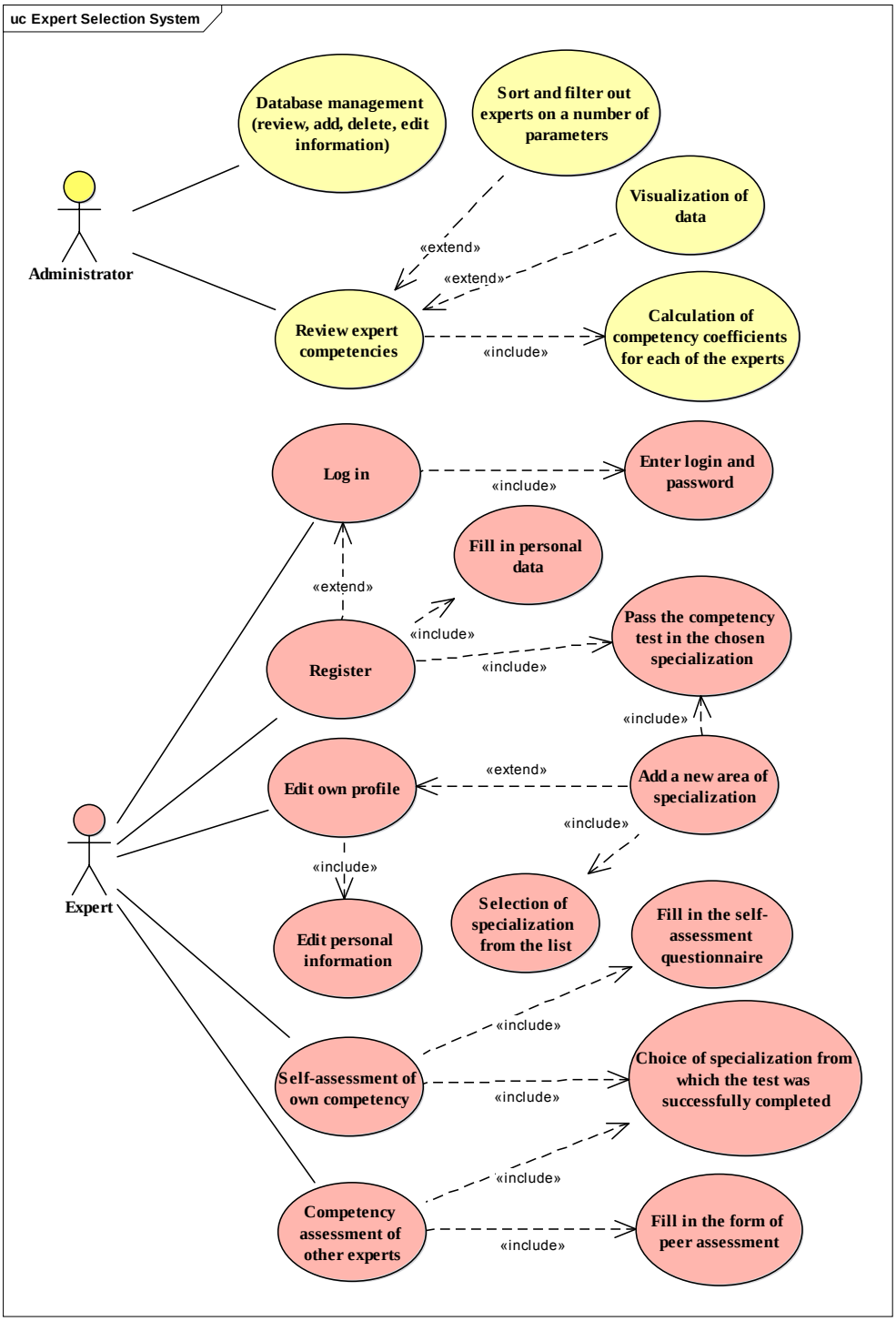

Fig. 4. The diagram of information system use cases

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The diagram shows that the administrator has the following two basic functionalities – he can manage the information system database and review expert competencies.

As part of database management, the administrator can review, add, delete and edit any information including personal data of experts. When viewing the numerical values of expert competence, the administrator can sort or filter out experts by a number of parameters as well as visualize the calculations. Thus, sorting is possible according to the expert's surname and various components of competencies of an expert. Experts can be filtered out according to the organization, position, academic title/degree. It should be noted that the assessment of the competence of each expert is represented by four indicators – the coefficients of competence based on the results of self-assessment and peer assessment, integrated and complex coefficients of competency.

An expert within an information system can register or log in to the system, edit own profile (any personal information), carry out a self-assessment of own competency and assess the competency of other experts.

To log into the system, the expert must enter a login and password. If an expert is not registered in the system, he can do this by filling in personal data (name, position, organization, etc.), then he should create own login and password and successfully pass the test for any specialization. It should be noted that self-assessment and peer assessment are possible only in the list of specializations in which experts have successfully passed the competency test. In the case of an unsatisfactory result in the competency test for any specialization, re-testing is blocked by the system.

On the basis of the above described functional use cases of the information system, a conceptual (logical) and physical data model was developed. In total, 14 entities were specified in the data model, whose descriptions are given in table 2.

Table 2. *Descriptions of Data Model Entities*

Code	Entities	Descriptions
E-1	Expert	Detailed information about experts (full name, position, organization, photo, e-mail address, etc.)
E-2	Academic title	The list of all academic titles an expert can have (professor, senior scientific researcher, associate professor, no title)
E-3	Academic degree	The list of all academic degrees an expert can have (doctor of science, PhD, no degree)
E-4	Organization	Information of the organization (name, address, city) where experts work
E-5	City	The list of the cities where there are the organizations in which experts work
E-6	Competency self-assessment	The results of expert self-assessment according to a number of factors in the areas of his specialization
E-7	Self-assessment factor	A list of factors according to which the self-assessment of experts is conducted in various areas of specialization
E-8	Area of specialization	A list of the experts' areas of specialization
E-9	Factor assessment	A list of probable assessment values for each factor of self-assessment
E-10	Expert competency	The results of the calculation of four competency coefficients (self-assessment, peer assessment, integrated, complex) on each expert according to the areas of specializations
E-11	Competency peer assessment	The results of peer assessment according to the areas of specializations
E-12	Competency test	Information about the competency tests which experts have passed in the areas of specializations to prove the expert title in the specified area
E-13	Test questions	A list of competency test questions according to the areas of specializations
E-14	Variants of answers	The list of answers to the questions of competency tests and the designation whether the answer is correct or not

The physical data model is presented in fig. 5. The types of data for each attribute of the entities of the physical model are specified taking into account the use of the Microsoft SQL Server as a database management system.

The developed information system refers to the type of client-server architecture. The information system database was implemented using Microsoft SQL Server Express relational database management system. The information system was developed using C# programming language, Microsoft Visual Studio was used as a development environment.

The basic screenshots of the developed information system are presented in fig.6–9.

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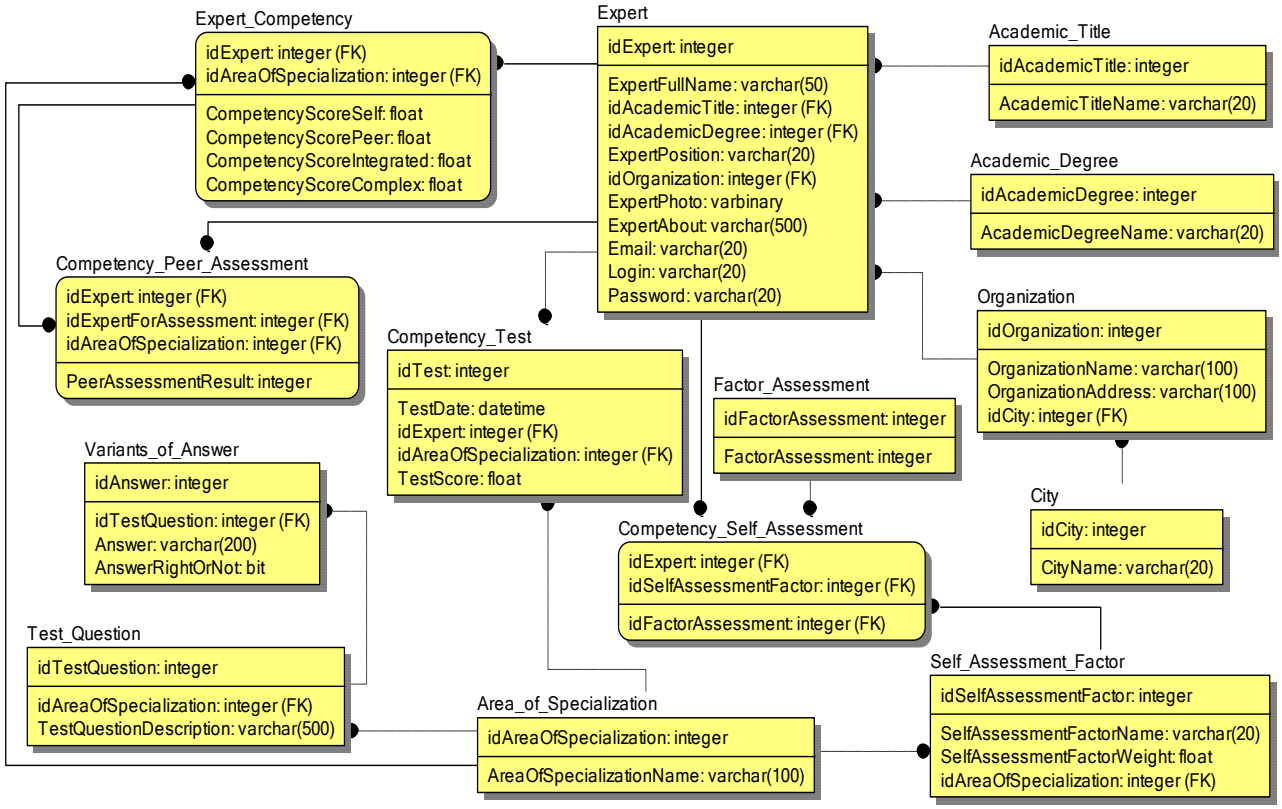

Fig. 5. The physical data model

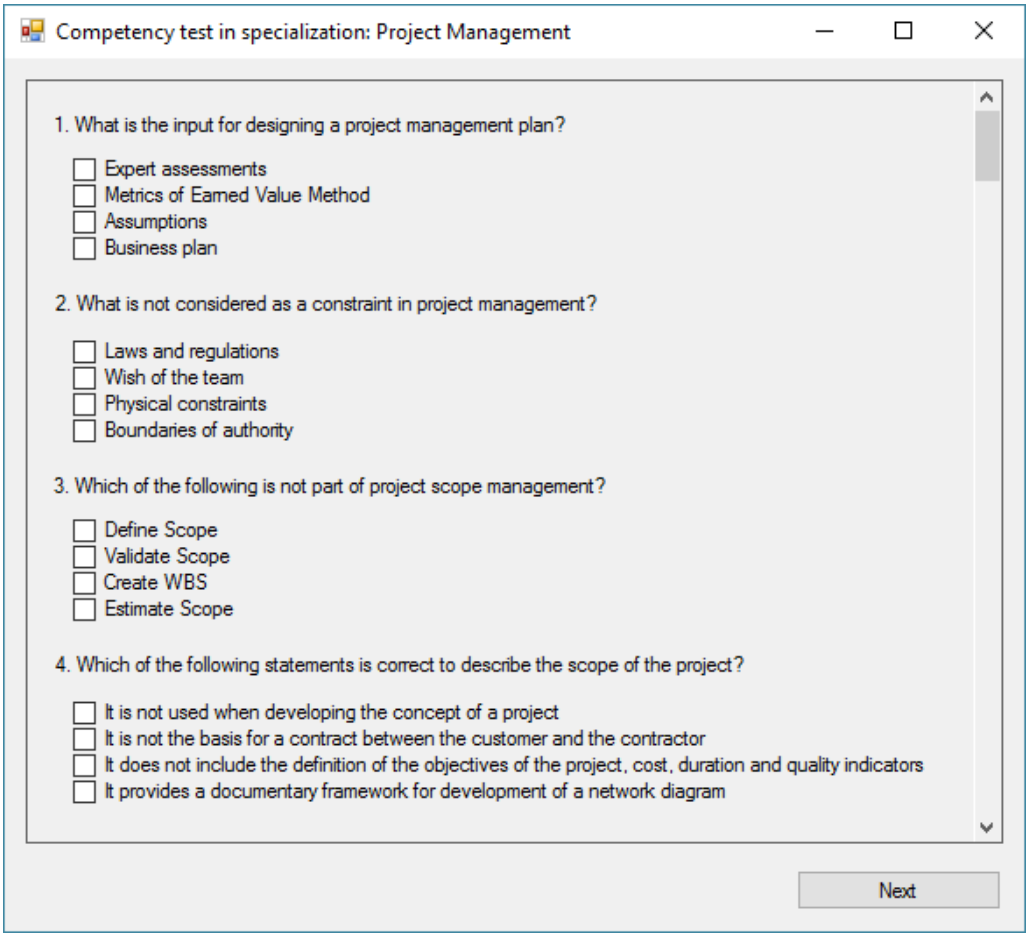

Fig. 6. The competency test for the selected specialization

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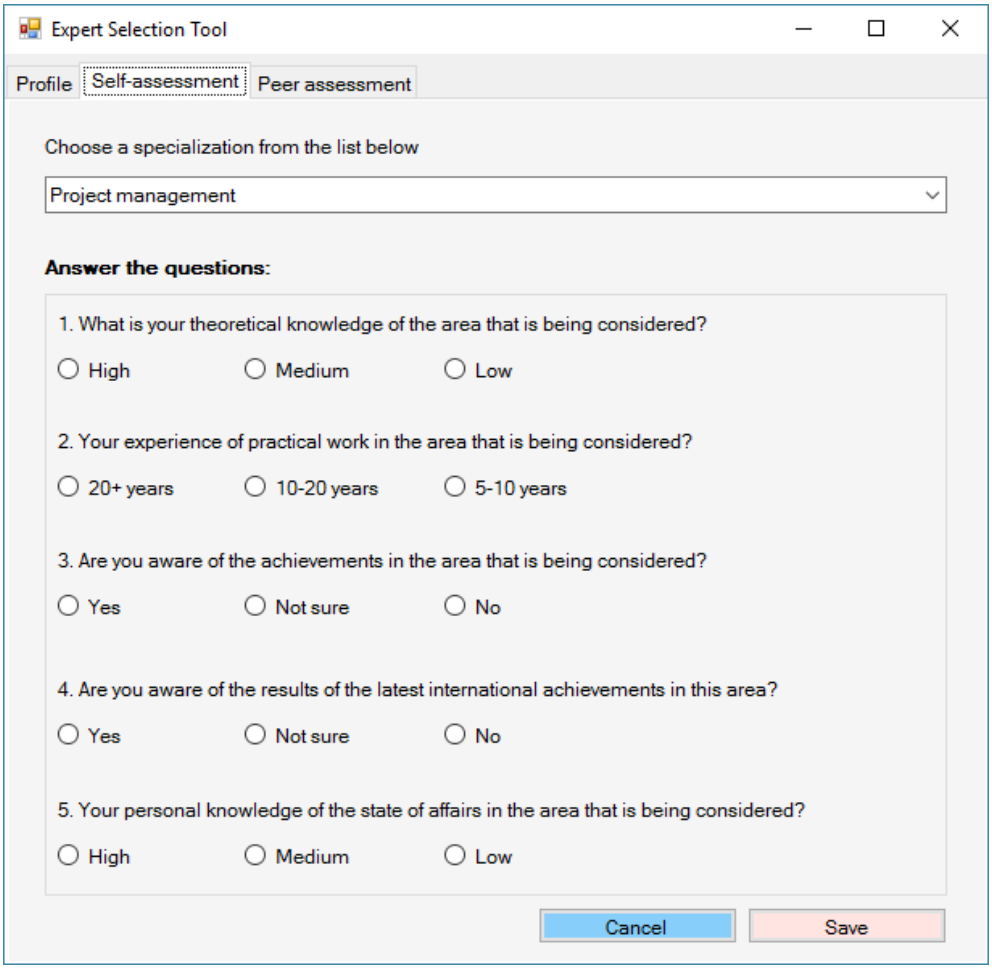

Fig. 7. Self-assessment of an expert for the selected specialization

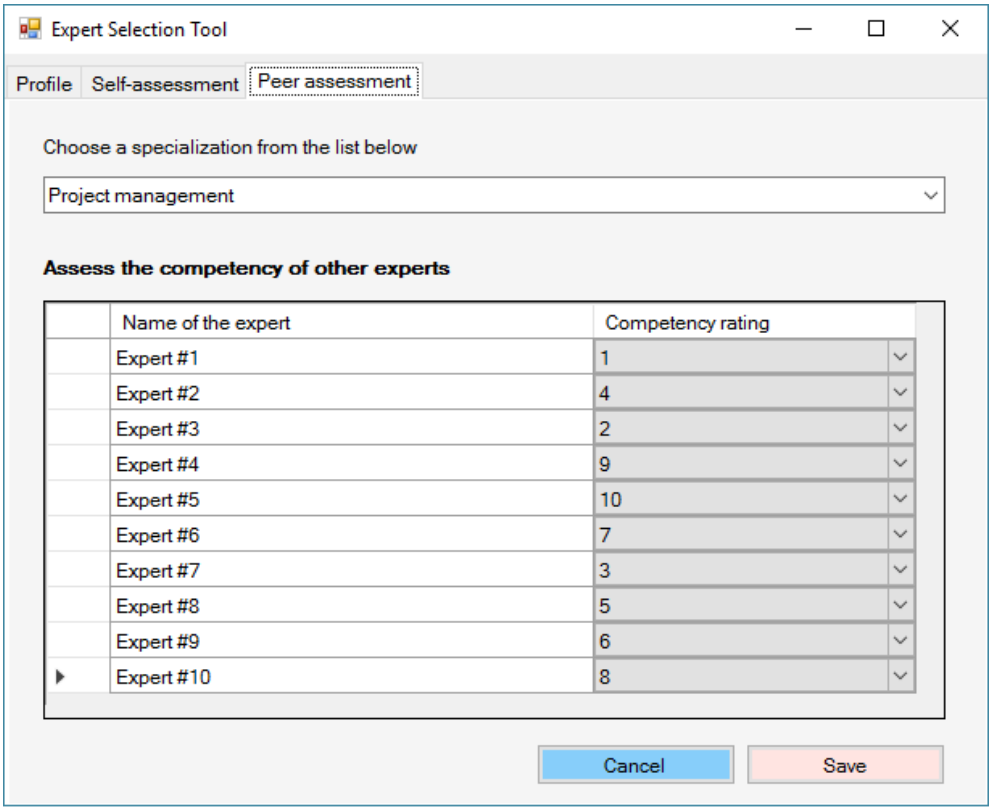

Fig. 8. Peer assessment for the selected specialization

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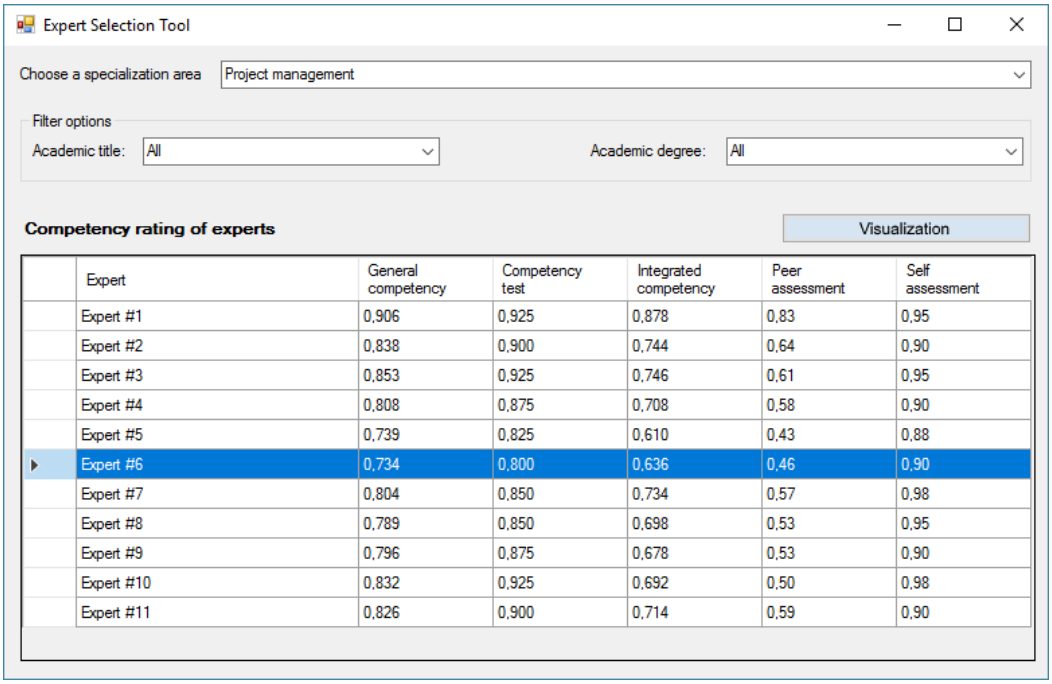

Expert	General competency	Competency test	Integrated competency	Peer assessment	Self assessment
Expert #1	0,906	0,925	0,878	0,83	0,95
Expert #2	0,838	0,900	0,744	0,64	0,90
Expert #3	0,853	0,925	0,746	0,61	0,95
Expert #4	0,808	0,875	0,708	0,58	0,90
Expert #5	0,739	0,825	0,610	0,43	0,88
Expert #6	0,734	0,800	0,636	0,46	0,90
Expert #7	0,804	0,850	0,734	0,57	0,98
Expert #8	0,789	0,850	0,698	0,53	0,95
Expert #9	0,796	0,875	0,678	0,53	0,90
Expert #10	0,832	0,925	0,692	0,50	0,98
Expert #11	0,826	0,900	0,714	0,59	0,90

Fig. 9. Expert rating for the selected specialization

Let us consider the use of the technique of the integrated assessment of the expert competency while selecting the methodology of project management [19] or selecting team members for the project team [20–21]. The group of 11 people is considered. These people have successfully passed the test in the specialization Project Management. The results are given in table 3. The names of actual experts who have been tested are not shown for ethical reasons.

The results of the self-assessment of each expert according to the previously described method (see formula (1) and table 1) are given in table 4.

Competency peer assessment is presented in table 5. Thus, each expert according to his own free choice, ranked the other ten experts, assigning everybody a position from 1 to 10, where the first position is the best and the tenth one is the worst.

Table 3. *The results of testing the expert group*

Expert	1	2	3	4	5	6	7	8	9	10	11
The percentage of correct answers	0,925	0,9	0,925	0,875	0,875	0,8	0,85	0,85	0,875	0,925	0,9

Table 4. *The results of expert self-assessment*

Expert	1	2	3	4	5	6	7	8	9	10	11
Self-assessment	0,95	0,90	0,95	0,90	0,88	0,90	0,98	0,95	0,90	0,98	0,90

Table 5. *Expert peer assessment (rating positions)*

Expert	1	2	3	4	5	6	7	8	9	10	11
1		2	1	9	10	7	6	5	8	4	3
2	3		2	4	1	10	7	6	5	8	9
3	1	6		2	3	4	5	10	9	8	7
4	4	1	9		8	7	6	5	4	3	2
5	2	3	4	5		1	10	9	8	7	6
6	5	6	7	2	1		3	4	5	9	10
7	2	10	9	1	8	7		3	4	6	5
8	3	4	5	6	7	8	9		1	2	3
9	4	6	7	8	9	4	3	2		5	1
10	2	4	3	6	10	9	1	8	7		5
11	1	4	2	9	10	7	3	5	6	8	

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For each position from 1 to 10 experts were given the appropriate number of points. thus, for each first position, 10 points are given, for the second one – 9 points and so on. The results of the calculation are presented in table 6. The total sum of points scored by each expert as a result of peer assessment is the sum of all the points in the corresponding column of the table. Peer assessment is calculated as the sum of the points scored divided by 100.

Table 6. *Expert peer assessment (score)*

Expert	1	2	3	4	5	6	7	8	9	10	11
1		9	10	2	1	4	5	6	3	7	8
2	8		9	7	10	1	4	5	6	3	2
3	10	5		9	8	7	6	1	2	3	4
4	7	10	2		3	4	5	6	7	8	9
5	9	8	7	6		10	1	2	3	4	5
6	6	5	4	9	10		8	7	6	2	1
7	9	1	2	10	3	4		8	7	5	6
8	8	7	6	5	4	3	2		10	9	8
9	7	5	4	3	2	7	8	9		6	10
10	9	7	8	5	1	2	10	3	4		6
11	10	7	9	2	1	4	8	6	5	3	
Total	83	64	61	58	43	46	57	53	53	50	59

The integrated competency of experts was calculated as a weighted sum of self-assessment and peer assessment. The overall competence was calculated as a weighted sum of the test assessment and integrated assessment. The calculation results are presented in table 7.

Table 7. *The results of the calculation of the competency of experts*

Expert	General competency	Competency test	Correct answers	Integrated competency	Peer assessment	Self-assessment
1	0,906	0,925	37	0,878	0,83	0,95
2	0,838	0,900	36	0,744	0,64	0,90
3	0,853	0,925	37	0,746	0,61	0,95
4	0,808	0,875	35	0,708	0,58	0,90
5	0,739	0,825	33	0,610	0,43	0,88
6	0,734	0,800	32	0,636	0,46	0,90
7	0,804	0,850	34	0,734	0,57	0,98
8	0,789	0,850	34	0,698	0,53	0,95
9	0,796	0,875	35	0,678	0,53	0,90
10	0,832	0,925	37	0,692	0,50	0,98
11	0,826	0,900	36	0,714	0,59	0,90

The table shows that the most competent is the first expert. Then in a descending mode, the third, second, tenth and eleventh ones come. That is, the initial group of eleven experts can be reduced to a group of 5 specialists to select the methodology of project management. The visualized calculation is presented in fig, 10.

Conclusions

The article deals with the problem of assessing the quality of experts. On the basis of the authors' practical experience and the analysis of literary sources, the structural diagram of the properties of experts and their assessments was developed. Five main groups of existing methods for assessing the quality of experts were analyzed. Existing models of integrated assessment of experts were reviewed and a two-stage method of integrated expert assessment of experts was developed based on the combination of heuristic, test and statistical methods of assessment. The main groups of users and functional requirements for the information system for expert assessment were specified. The database and the user interface were developed. The information technology for the integrated assessment of expert competency was tested using actual data to select an expert group for choosing the methodology of project management.

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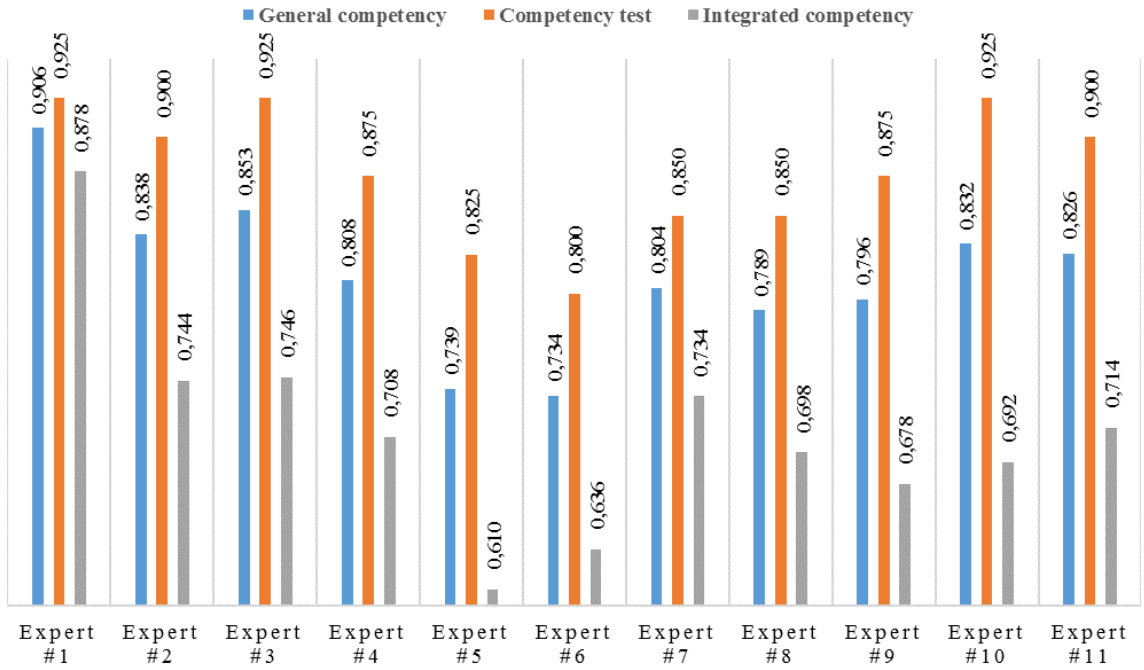

Fig. 10. Visualization of the comprehensive assessment of expert competence

Selecting and assessing the competency of experts is one of the most complex problems in the theory and practice of expert surveys, it cannot be solved by using singular assessment methods, it requires that complex methods that include both quantitative and qualitative methods of assessing the competence of experts should be used. The applied information technology developed for this goal can be used in various enterprises, institutions and organizations that are interested in automating the expert survey process and building quality expert groups.

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ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ КОМПЛЕКСНОГО ОЦІНЮВАННЯ КОМПЕТЕНТНОСТІ ЕКСПЕРТІВ

Предметом дослідження є процеси відбору та оцінювання компетентності експертів. **Метою** дослідження є підвищення об’єктивності експертної оцінки шляхом розробки та застосування моделі та інформаційної технології комплексної оцінки компетентності експертів, яка дозволить провести якісний відбір спеціалістів для участі в роботі експертних груп. **Завдання**, що вирішуються у роботі: провести огляд методів та моделей оцінки якості та компетентності експертів; розробити модель комплексної оцінки компетентності експертів; спроектувати та програмно реалізувати прикладну інформаційну технологію для комплексної оцінки компетентності експертів. В основу методології дослідження покладено наступні **методи**: методи евристичної, тестової та статистичної оцінки – при розробці моделі комплексної оцінки компетентності експертів; принципи системного аналізу та методи об’єктно-орієнтованого проектування – при розробці прикладної інформаційної технології комплексного оцінювання компетентності експертів. У результаті дослідження отримано наступні **результати**: розглянуто проблему оцінки якості експертів; на основі досвіду практичної роботи авторів і аналізу літературних джерел розроблена структурна схема властивостей експертів та їх оцінок; проаналізовано п’ять основних груп існуючих методів оцінювання якості експертів; здійснено огляд існуючих моделей комбінованої оцінки компетентності експертів; розроблено двоетапний метод комплексної оцінки компетентності експертів, який базується на поєднанні в комбіновану оцінку методів евристичної, тестової та статистичної оцінки; визначені основні групи користувачів та функціональні вимоги до інформаційної системи оцінки компетентності експертів; розроблена база даних та інтерфейс користувача інформаційної системи; розроблена інформаційна технологія комплексного оцінювання компетентності експертів протестована на реальних даних для відбору експертної групи для вибору методології управління проектами. **Висновки**. Проблема підбору і оцінки компетентності експертів є однією з найбільш складних в теорії і практиці експертних опитувань, вона не може бути вирішена шляхом застосування одиничних методів оцінки та вимагає для свого вирішення застосування комплексних методик, які включають в себе разом із кількісними і якісні методи оцінки компетентності фахівців. Розроблена з цією метою прикладна

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інформаційна технологія є актуальною для використання на різноманітних підприємствах, установах та організаціях, які зацікавлені в автоматизації процесу експертного опитування та побудови якісних експертних груп.

Ключові слова: інформаційна технологія; комплексна оцінка; компетентність експертів; експертна група; методи та моделі оцінки якості експертів.

ИНФОРМАЦИОННАЯ ТЕХНОЛОГИЯ КОМПЛЕКСНОГО ОЦЕНИВАНИЯ КОМПЕТЕНТНОСТИ ЭКСПЕРТОВ

Предметом исследования являются процессы отбора и оценки компетентности экспертов. **Целью** исследования является повышение объективности экспертной оценки путем разработки и применения модели и информационной технологии комплексной оценки компетентности экспертов, которая позволит провести качественный отбор специалистов для участия в работе экспертных групп. **Задачи**, решаемые в работе: провести обзор методов и моделей оценки качества и компетентности экспертов; разработать модель комплексной оценки компетентности экспертов; спроектировать и программно реализовать прикладную информационную технологию для комплексной оценки компетентности экспертов. В основу методологии исследования положены следующие **методы**: методы эвристической, тестовой и статистической оценки – при разработке модели комплексной оценки компетентности экспертов; принципы системного анализа и методы объектно-ориентированного проектирования – при разработке прикладной информационной технологии комплексной оценки компетентности экспертов. В результате исследования получены следующие **результаты**: рассмотрена проблема оценки качества экспертов; на основе опыта практической работы авторов и анализа литературных источников разработана структурная схема свойств экспертов и их оценки; проанализированы пять основных групп существующих методов оценки качества экспертов; осуществлен обзор существующих моделей комбинированной оценки компетентности экспертов; разработан двухэтапный метод комплексной оценки компетентности экспертов, основанный на сочетании в комбинированной оценке методов эвристической, тестовой и статистической оценки; определены основные группы пользователей и функциональные требования к информационной системе оценки компетентности экспертов; разработана база данных и интерфейс пользователя информационной системы; разработанная информационная технология комплексной оценки компетентности экспертов протестирована на реальных данных для отбора экспертной группы для выбора методологии управления проектами. **Выводы**. Проблема подбора и оценки компетентности экспертов является одной из самых сложных в теории и практике экспертных опросов, она не может быть решена путем применения единичных методов оценки и требует для своего решения применения комплексных методик, включающих в себя вместе с количественными и качественные методы оценки компетентности специалистов. Разработанная с этой целью прикладная информационная технология актуальна для использования на различных предприятиях, учреждениях и организациях, которые заинтересованы в автоматизации процесса экспертного опроса и построения качественных экспертных групп.

Ключевые слова: информационная технология; комплексная оценка; компетентность эксперта; экспертная группа; методы оценки качества экспертов.