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DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR EVALUATING INVESTMENT PROJECTS TAKING INTO ACCOUNT MULTI-FACTORITY BASED ON THE METHOD OF HIERARCHY ANALYSIS AND GAME THEORY

The paper describes the developed software product-the decision support system (DSS) "DSS Invect 2020"and its module "IT INVESTMENT which can be used both independently and as part of the DSS "DSS Invect 2020". The DSS is designed to make recommendations to the DSS during the selection of rational financial strategies by investors. When solving problems in poorly structured subject areas, the task of choosing rational investor strategies can be explained by increasing the relevance of the subject model to increase the reliability of proposals developed with the help of the DSS. The computing core of "DSS Invect 2020"is based on the method of hierarchy analysis, as well as on the mathematical solution obtained for the first time, which is based on the tools of bilinear multistep quality games with multiple terminal surfaces. "DSS Invect 2020"allows you to evaluate the attractiveness of investment projects in the field of digitalization of enterprises. The DSS "DSS Invect 2020"is implemented on a modular basis. The modular paradigm used during development makes it possible to supplement the DSS with other modules as necessary to expand the functionality of the DSS.

Key words: decision support system, investment project, software product, module.

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Иерархиялар мен ойын теориясын талдау әдісі негізінде көп факторлы ескере отырып, инвестициялық жобаларды бағалаудағы шешім қабылдауды қолдау жүйесін әзірлеу

Жұмыста әзірленген бағдарламалық өнім - "DSS Invect 2020"шешімдерді қабылдауды қолдау жүйесі (ШҚҚЖ) және оның "IT INVESTMENT"модулі сипатталған, оны өз бетінше де, "DSS Invect 2020"ШҚҚЖ құрамында да пайдалануға болады. ШҚҚЖ инвесторлардың ұтымды қаржылық стратегияларын таңдау кезінде ШҚТ ұсыныстарын жасауға арналған. Нашар құрылымдалған пәндік салалардағы мәселелерді шешу кезінде инвестордың ұтымды стратегияларын таңдау міндетін ШҚҚЖ көмегімен жасалған ұсыныстардың сенімділігін арттыру үшін пәндік модельдің өзектілігін арттыру арқылы түсіндіруге болады. "DSS Invect 2020"есептеу ядросы иерархияны талдау әдісіне, сондай-ақ бірнеше терминалды беттері бар көп сатылы сапалы ойындардың құралдарына негізделген алғаш рет алынған математикалық шешімге негізделген. "DSS Invect 2020"кәсіпорындарды цифрландыру саласындағы инвестициялық жобалардың тартымдылығын бағалауды іске асыруға мүмкіндік береді. "DSS Invect 2020"ШҚҚЖ модульдік қағидат бойынша орындалған. Даму барысында қолданылатын модульдік парадигма ШҚҚЖ функционалдығын кеңейту қажеттілігіне қарай ШҚҚЖ-ді басқа модульдермен толықтыруға мүмкіндік береді.

Түйін сөздер: шешім қабылдауды қолдау жүйесі, инвестициялық жоба, бағдарламалық өнім, модуль.

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Разработка системы поддержки принятия решений для оценки инвестиционных проектов с учетом многофакторности на основе метода анализа иерархий и теории игр

В работе описаны разработанный программный продукт - система поддержки принятия решений (СППР) "DSS Invect 2020"и его модуль "IT INVESTMENT который может использоваться как самостоятельно, так и в составе СППР "DSS Invect 2020". СППР предназначена для выработки рекомендаций ЛПР в ходе выбора рациональных финансовых стратегий инвесторами. При решении проблем в слабо структурированных предметных областях задача выбора рациональных стратегий инвестора может быть объяснена повышением актуальности предметной модели для повышения надежности предложений, разработанных с помощью СППР. Вычислительное ядро "DSS Invect 2020"базируется на методе анализа иерархий, а также на впервые полученном математическом решении, которое основано на инструментарии билинейных многошаговых игр качества с несколькими терминальными поверхностями. "DSS Invect 2020"позволяет реализовывать оценку привлекательности инвестиционных проектов в сфере цифровизации предприятий. СППР "DSS Invect 2020"выполнена по модульному принципу. Модульная парадигма, используемая в ходе разработки, дает возможность дополнять СППР другими модулями по мере необходимости расширения функционала СППР.

Ключевые слова: система поддержки принятия решений, инвестиционный проект, программный продукт, модуль.

1 Introduction

The problem of effective financial investment in advanced information technologies is one of the most important in the field of digitalization of industrialized countries. Such investment projects are usually characterized by a high degree of uncertainty and risk. Many researchers note that in order to increase the effectiveness and efficiency of evaluating such large investment projects related to the digitalization of enterprises, it is advisable to use the potential of various computerized decision support systems (DSS). This is especially true for the analysis of different variant strategies of investors. That is, the number of options for investment strategies can be quite large.

The "DSS Invect 2020"program allows you to:

1. balance in accordance with the method of hierarchy analysis, set expert estimates of the comparison of options in the form of a matrix of paired comparisons. Estimates can be set not only in numerical form, but also in graphical representation, which makes it easier for experts to work. The program implements the receipt of final estimates and the construction of the resulting diagrams;

2. find rational strategies for investors with visualization of calculation data in tabular and graphical form.

2 Main material

The use of the hierarchy analysis method in "DSS Invect 2020"allows you to include in the hierarchy all the knowledge and intuition available to the expert group on the problem under consideration. This method is simple and gives a good correspondence to intuitive ideas [1]. The first stage in solving the problem of decision-making is the decomposition of the problem through the definition of its components and the relationships between them (Fig. 1).
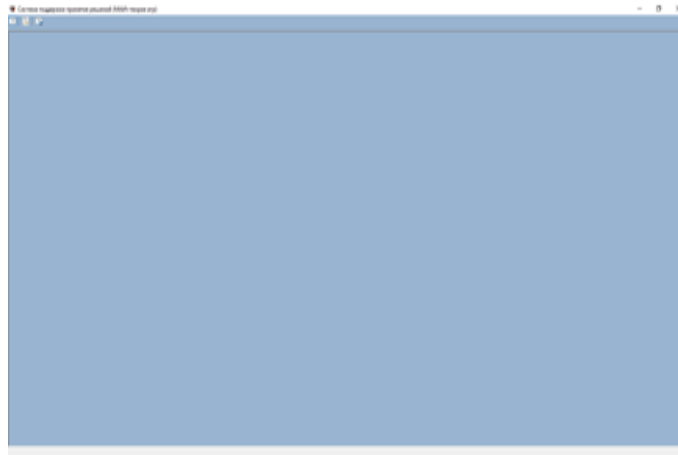

Figure 1: General view of the DSS "DSS Invect 2020"

If the computing resources of the computer are insufficient, for example, the number of criteria and alternatives exceeds 10, then the DSS issues a corresponding warning, see Fig. 2
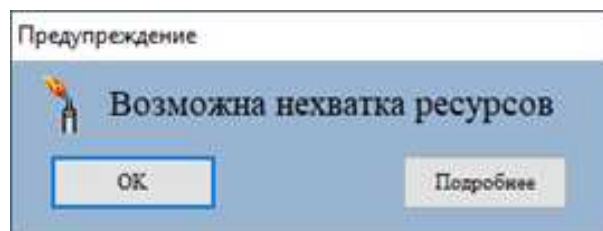

Figure 2: DSS alert "DSS Invect 2020"

When working with the DSS "DSS Invect 2020", the expert must fill out the forms proposed by the system in the interactive mode. After that, the corresponding hierarchies will be automatically formed for the subsequent evaluation of the investment project, see Fig. 3

The DSS "DSS Invect 2020" system has a well-developed menu, which makes working with it very convenient even for an unprepared user.

The "DSS Invect 2020" includes a module that allows you to take into account the degree of disparity of the compared alternatives when making decisions during the process of investing in digitalization objects, taking into account the multi-factor nature. Fig. 5 describes
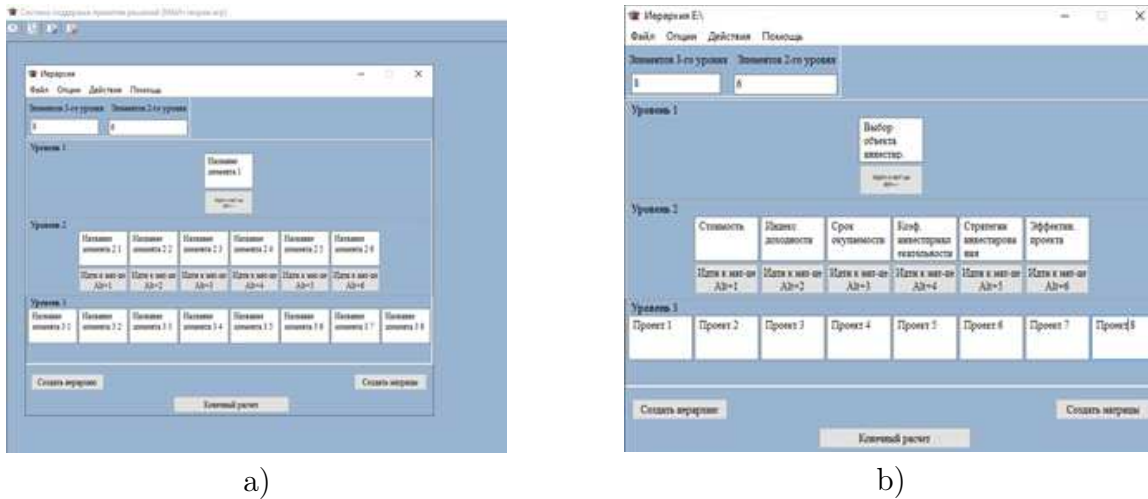
a)   b)

Figure 3: Example of creating hierarchies in the DSS "Invect 2020 DSS"
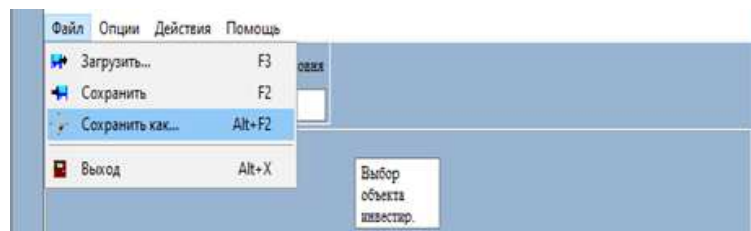

Figure 4: The main menu of the DSS "DSS Invect 2020"

in more detail the stages of filling in the matrices by experts in the context of the problem being solved. Fig. 5 (a) shows all the matrices in the child forms of the application, and the criteria were set at the last step of the project evaluation. Fig. 5 (b) shows an example of the criterion matrix already filled in by the expert – "Selection of the investment object".

In the lower part of the form, each of the criteria is automatically calculated and controlled by such indicators as: λ_{max} (or L_{max} – the eigenvalue of the matrix); ИС (the consistency index); ОС (the consistency ratio).

For clarity, the results can be visualized, for example, in the form of a bar chart, see Fig. 6.

Fig. 7 shows the resulting matrix for the initial selection stage of the project that can be selected for investment.

Also, for convenience, you can keep a history of evaluation procedures, which is convenient when you need to perform several evaluations by different experts or groups of experts. The rating history file is stored in its own format (see Fig. 8) of the "DSS Invect 2020" project, so it cannot be opened without the corresponding software. The latter circumstance can be useful to prevent unauthorized access to the calculation data, for example, by unscrupulous competitors.

The "IT INVESTMENT" module is described below, which can be used both independently and as part of the DSS "DSS Invest 2020".
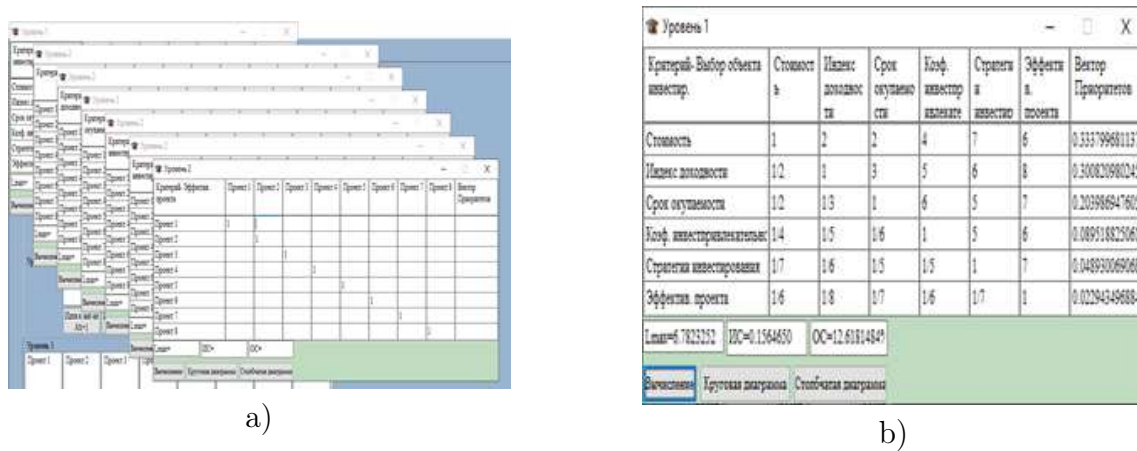
a)

b)

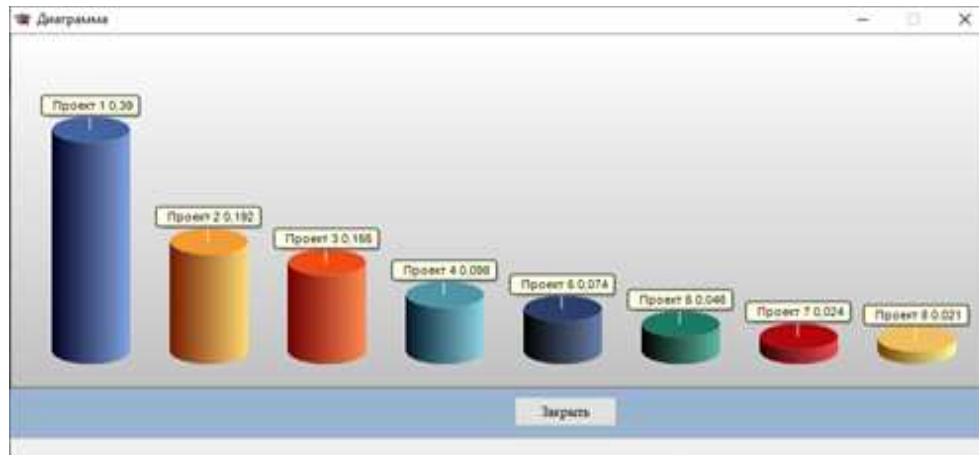Figure 5: Examples of matrices filled in by experts

Figure 6: Bar chart obtained during the selection of strategies for investing in digitalization objects, taking into account the multi-factor nature

Конечная матрица

	0.333799681137	0.300820980245	0.203986947605	0.089518825061	0.048930069068	0.022943496884	Общие веса
Проект 1	0.270283675824	0.279589585288	0.389870197534	0.305669145798	0.295643891449	0.357207018788	0.303880046416
Проект 2	0.245478294759	0.259128503075	0.192464619397	0.250610756862	0.286946036541	0.213903805465	0.240534508237
Проект 3	0.183145816128	0.151436048505	0.154785637890	0.184344998595	0.133572206334	0.159588802192	0.164962975534
Проект 4	0.119362896903	0.118505112191	0.097605246451	0.108502334081	0.110286617878	0.098366509399	0.112768522228
Проект 5	0.083972726943	0.075718024252	0.073713016917	0.061917089175	0.044276734697	0.068122336449	0.075116306450
Проект 6	0.048186897693	0.061919582961	0.046482201326	0.047456776483	0.052018565803	0.044215888269	0.052001257078
Проект 7	0.033693739275	0.030321822372	0.024300736525	0.026971094226	0.060680272770	0.036343202963	0.031542783591
Проект 8	0.015875952475	0.023381321354	0.020778343959	0.014527804780	0.016575674528	0.022252436476	0.019193600465

Figure 7: The resulting matrix for the initial evaluation of investment projects
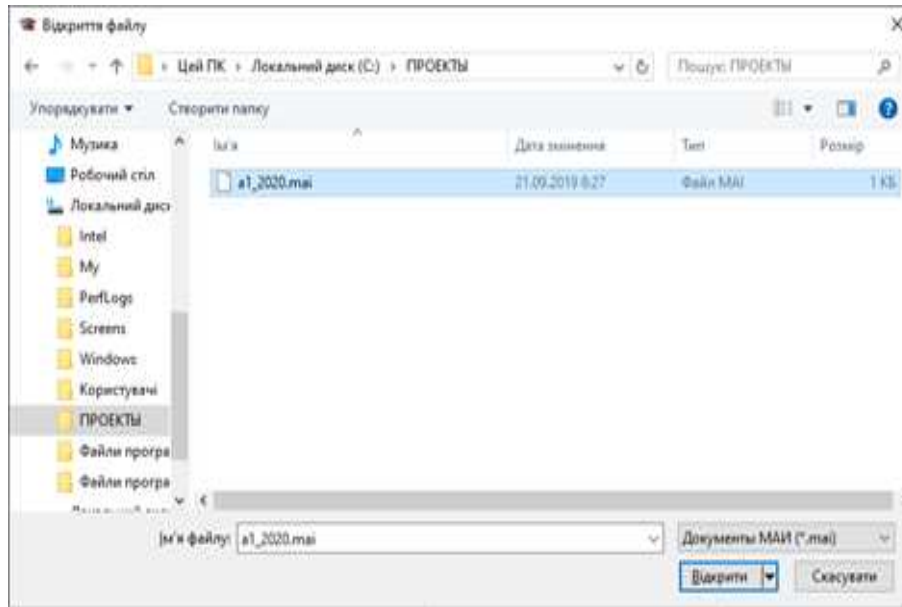
Figure 8: File with the history of expert assessments of investment projects

A general view of the form for setting the source data in the "IT INVESTMENT" module is shown in Fig. 9

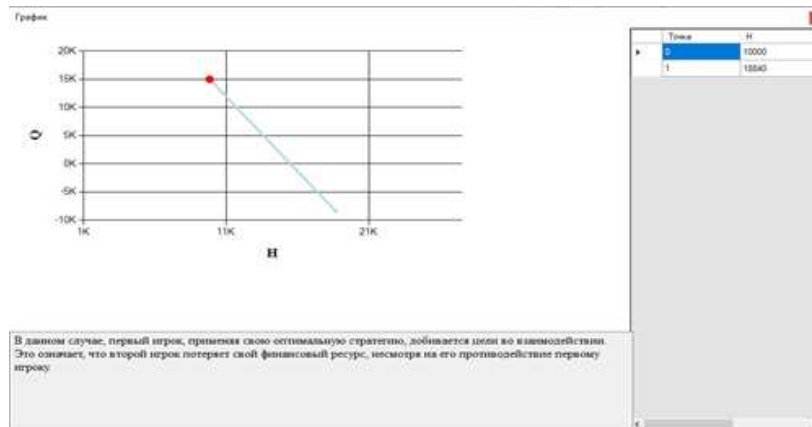The "IT INVESTMENT" DSS module is implemented in the Visual Studio 2019 programming environment.

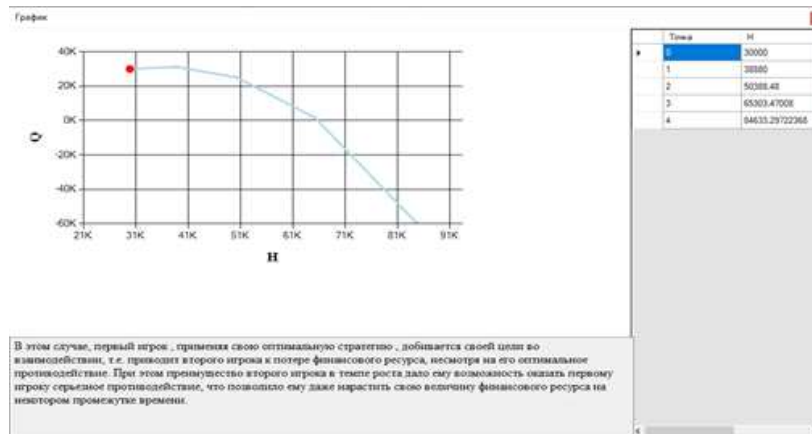Figure 9: General view of the "IT INVESTMENT" module

All text fields on the main form are used for setting initial values and coefficients. By default, an empty field contains 0.

3 Results

The "Build 2D" and "Build 3D" buttons allow you to perform calculations.

a)

b)

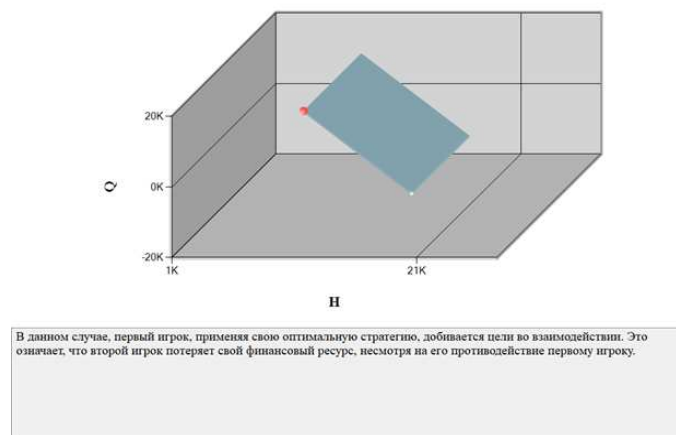Figure 10: 2D graph output and solution interpretation in the "IT INVESTMENT" module

Figure 11: Example of a three-dimensional graph for two calculation points and interpretation of the solution in the "IT INVESTMENT" module

The cases when the players' strategies lead them to the corresponding terminal surfaces were modeled. On the plane, the abscissa axis is the financial resources of the first investor. The ordinate axis is the financial resources of the second investor.

In the lower part of the window, Fig. 10, shows the output generated in the "IT INVESTMENT" module during the search for rational strategies by investors, as well as the intersection area of the first investor's preference set. The rational strategy of the investor in Figure 10 a), b) is shown by a gray-blue line for a 2D chart or a plane for a 3D chart. The starting point is shown in red. The right part of the visualization form shows a table with the calculated values of the points that make up the trajectory of the optimal strategy of the investor.
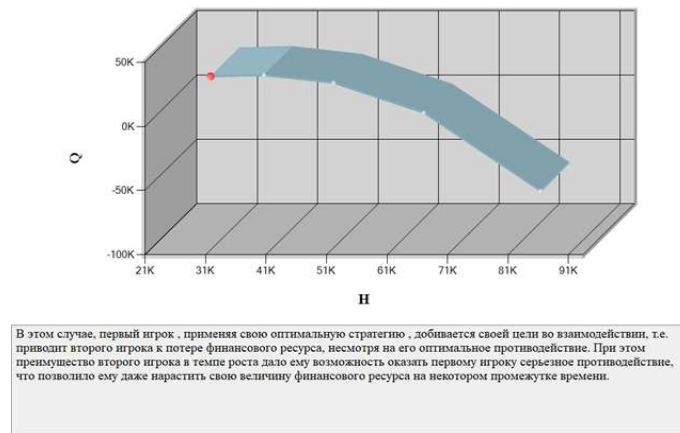
Figure 12: Example of a three-dimensional graph for five calculation points and interpretation of the solution in the "IT INVESTMENT" module

On the central part of the form there is a graph. It can be two-dimensional or three-dimensional, depending on the user's choice. The starting point of the graph is always marked in red. On the right is a table with the coordinates of each point. A text description of the result obtained during the calculations is placed at the bottom. The "History"button displays a table containing information about all previous calculations.

During the testing of the model and the "IT INVESTMENT" module, the correctness of the results was established.
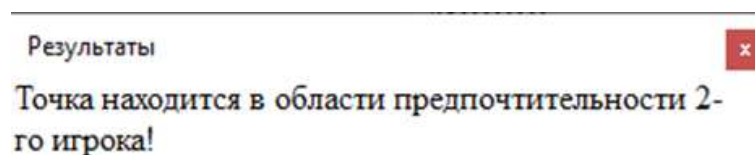
Figure 13: Example of generating the DSS output if the point on the graph is in the preference area of the 2nd player

In order to facilitate the work of experts or PLRs, the main form of the "IT INVESTMENT" module has a "History" button, which allows you to view the history of evaluation procedures.

DSS "DSS Invect 2020" allows you to collect expert information, and after processing with the help of integrated modules, present the results in a convenient format, either graphic or text. In addition, the DSS "DSS Invect 2020" allows you to find the optimal solution not only on the basis of the traditional and well-proven MAI, but also on the basis of new approaches based on bilinear quality games. The evaluation of the investment project performed with the help of "DSS Invect 2020" allows not only to determine the most attractive projects for the investor from the set of possible ones, but also to analyze and predict investment strategies more deeply, taking into account the multi-factor approach, using the apparatus of bilinear differential equations.

4 Conclusion

A software product has been developed – the decision support system "DSS Invect 2020". The DSS is designed to make recommendations to the DSS during the selection of rational financial strategies by investors. "DSS Invect 2020" allows you to evaluate the attractiveness of investment projects in the field of digitalization of enterprises. The "DSS Invect 2020" is implemented on a modular basis. This makes it possible to supplement the DSS with other modules. In particular, the DSS module "IT INVESTMENT" has been implemented, which allows to reduce the discrepancies between forecasting data and the real return on investment in enterprises in the field of digitalization.

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