Selection of the optimal subsea production system using original software

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Abstract: Due to the high relevance of the offshore oil and gas fields' development, the authorsexaminethe technology of subsea mining, which is gaining popularity in the Russian Federation. The main types of subsea production system constructions were analyzed and a number of factors, which affect the development of offshore oil and gas fields, were proposed. An algorithm for the software product was created which allows after geological exploration and the discovery of industrial oil and gas recourses to optimize the planning process and to save time and material costs for the company at the preliminary stages of planning. The software product algorithm based on such factors asdepth and size of the field, duration of ice season of the region, remoteness of the field from the coast, the level of development of transport infrastructure and the complexity of geological structure.

1 Introduction

In the Russian Federation, one of the promising directions in engineering and technology for the development of offshore oil and gas fields is the use of subsea hydrocarbon production systems. The subsea hydrocarbon production system allows not only to extract petroleum in complicated climate conditions but also to involve previously unavailable fields or to increase the profitability of their development. As it was pointed by Speight J.G., subsea processing is an emergent application to increase production from mature or marginal fields [1].

To select the optimal subsea production system type, which will fit the conditions of the current field, an algorithm for the software product was developed.It allows determining the subsea hydrocarbonproduction system type according to a number of factors such as depth, size of the field, ice season, the remoteness of the field from the coast, the level of development of transport infrastructure, and the complexity of the geological structure of the field. The researched factors were chosen by using a standardized interviewing method among experts in this area. The implementation of the developed software product at the preliminary stages of planningwill help to optimize the planning process and to reduce the risk in choosingthe wrong type of subsea production system construction in accordance with the considered factors. Besides, saving time and material costs at the preliminary stages of planning will have a kind of cumulative effect at further stages of project realization, which may be found in cost reduction.

2 Literature review

Despite alargenumberof existing papers in the development of offshore oil and gas fields by using offshore oil production platforms, there are relatively few papers devoted to the topic of using subsea production systems in the Russian Federation. Theexistingliteratureisdevoted to the research of technologies of subsea production systems [2,3], the main areas of science and technology in the field of offshore development by using subsea production systems [4], the methodology of modeling subsea hydrocarbon production systems [5], the selection and justification of the concept of developing oil and gas fields on the shallow shelf of the Arctic [6].

In world practice, the research of the development and management of subsea production systems is more common. The subject of study is engineering and management of subsea hydrocarbon production systems [7,8]. The prospect of developing and deploying offshore oil and gas fields by using subsea production systems has also been discussed in the literature [9-10]. Technological and constructional features of subsea production systems are regulated by standards [11]. Existing papers also consider the optimization of operation processes of subsea hydrocarbon production systems [12,13].

In general, the implementation of such projects has great significance for the Russian economy, and the profitability of the offshore oil and gas fields is caused by using effective technologies in the extraction and preparation of oil and gas.

3 Methodology

The following research methods were used:

1. Critical analysisof domestic and foreign literature sources about main problems, trends, and forecasts in the complex management of oil and gas fields projects by using subsea production systems.

2. Statistical method, which includes the processing of obtained results in the study of the dependence of factorsaffecting the choice of the optimal type of subsea hydrocarbon production system.

By Potasheva G.A., the main purpose of project management is the final result, which involves setting goals, preparing a clear action plan, setting and implementing tasks, monitoring results [14]. Referring to this information, the purpose of introducing a software product is to reduce time and cost at the preliminary stages of planning. Thus, a solution that changes the approach to managing such projects, namely using the developed software product before the planning process begins, was proposed. At this stage of the study, the software product considers 6 factors, each of which has a defined value range, and is assigned to the appropriate type of subsea production system.

4 Analysis

Today the subsea production complex is a combination of subsea equipment located at the bottom of the sea and designed for extraction, preparation, and transport of hydrocarbons from wells to the point of connection with the production pipeline [2,15]. Subsea production systems can vary from a single well to several wells on the bottom plate or grouped near the manifold [5,16]. The research considers four main types of subsea production systems [11] in accordance with Figure 1, which were designed schematically using a 3D modeling program. All four types of subsea production systems, which are shown in Figure 1, differ only in the location of subsea equipment at the bottom of the sea, but the principle of operation remains the same for all [5].

According to A. Nikulina and M.Kruk, the significance of the offshore development projects for the Russian economy justifies the need for a multilateral assessment of their quantitative and qualitative indicators, including the possibility of achieving economic, social, political, and innovative effects [16]. This way, the main factors that affectthe development of offshore oil and gas fields were selected by using a standardized interview method, and arepresented in Table 1. The interview was conducted according to a pre-prepared questionnaire, which was drawn up in such a way as to quickly identify the problem of the topic, to clarify the main factors and possible risks that have the greatest impact on the subsea production system [17]. As it was noted by A. Cherepovitsinet al., special attention should be paid to identifying the factors that restrain the development of the Arctic territories (technological, economic, natural, social, and environmental factors) [17]. Thus, specialists of majorRussian oil and gas companies, whose activities are related to the production of hydrocarbons on the shelf, were interviewed. To obtain more universal results, specialists from various departments (both technical and design and management) were interviewed.

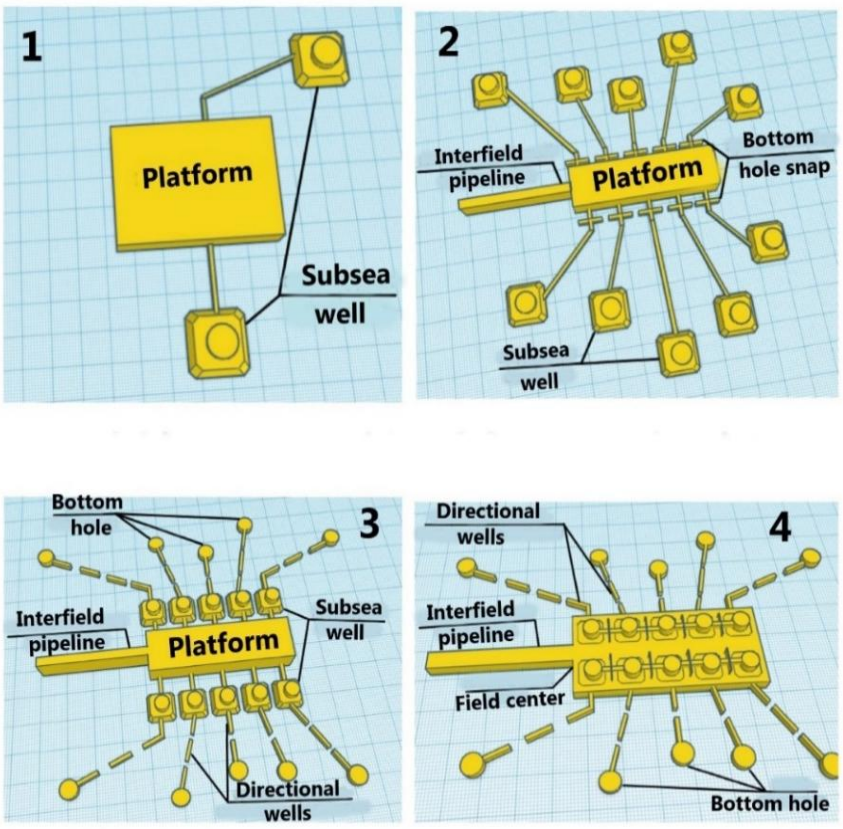

Fig.1. Types of subsea production systems, where: 1 is a typical construction of the subsea production system with one satellite well; 2 is a typical construction of the subsea production system with multiple satellite wells; 3 is a typical construction of the subsea production system with a cluster of wells; 4 is a typical construction of the subsea production system with the presence of underwater field center [1,2].

According to the Order dated 14.06.2016 "On approval of the Rules for the development of hydrocarbon deposits" (as amended on September 20, 2019) [19] and the Order No. 477 of 01.02.2016"On approval of guidelines for the application of the classification of reserves and resources of oil and combustible gases," approved by order of the Ministry Natural Resources and Environmentof the Russian Federation dated 01.11.2013 [20], each factor, presented in Table 1, has its classification.

Based on the results of the standardized interview method, an analysis was carried out that allowed us to assign certain values of the considered factors to each of the 4 types of subsea production system. As it was pointed by IlinovaA.andChanysheva A., statistical methods serve mainly to collect data by registering pre-planned essential features to obtain generalizing characteristics [21].This study is strictly statistical: after conducting standardized interviewing and processing the results, the dependence of factors, considered in the research, was investigated when choosing the appropriate type of subsea production system construction.

Table 1. The researched factors of choosing the optimal type of subsea production system [7,19,20]

Factor	Value range
1. Depth of the developed field, m	1. Shallow water (up to 20 m) 2. Shallow depth (from 20 m to 60 m) 3. Medium depth (from 60 m to 100 m) 4. Deep (from 100 m to 150 m) 5. Extremely deep (from 150 m to 300 m) 6. Deepwater (more than 300 m)
2. Gradation of oil and gas fields by recoverable reserves, million tons / billion m^3	1. Unique (oil reserves – up to 300 million tons, gas – over 300 billion m^3) 2. Large (from 30 to 300 million tons / billion m^3) 3. Medium (from 5 to 30 million tons / billion m^3) 4. Small (from 1 to 5 million tons / billion m^3) 5. Very small (up to 1 million tons / billion m^3)
3. Ice season duration, months	1. Up to 3 months 2. From 3 to 6 months 3. Over 6 months
4. Remoteness of the field from the coast (remoteness from supply bases), km	1. Coastal (distance up to 2 km) 2. Remote (distance from 2 to 60 km) 3. Far (distance more than 60 km)
5. The level of development of coastal transport infrastructure, km	•Up to 100 km •From 100 to 300 km •From 300 to 600 km •From 600 to 1000 km •More than 1000 km
6. Complexity of geological structure of the field	1. Simple structure (single-phase, associated with undisturbed or slightly disturbed structures; productive formations are characterized by the persistence of thicknesses and filtration-capacitive properties by area and section)

	2. Complex structure (single and two-phase, characterized by inconsistency of thickness and filtration-capacitive properties of productive formations by area and section or by the presence of lithological substitutions of reservoirs by impermeable rocks, or tectonic disturbances) 3. A very complex structure (single and biphasic, characterized by the presence of lithological substitutions or tectonic disturbances, as well as the incontinence of thicknesses and filtration-capacitive properties of productive formations)

According to P. Shcherban&V.Ivanova, when developing a deposit, it is important to take into account such parameters as time and resources (material costs), as sufficient knowledge about thatgives a complete conception of each stage of the field development (in case of geological exploration it is data on the structure of the deposit) [22].This is why much attention was paid to thefactor ofthe complexity of the geological structure of formation, as sufficient knowledge about it includes information about the density of wells spacing, on which technological development indicators depend, including rates of hydrocarbon extraction [10,11]. This will allowto enter hydrocarbon field into industrial development more quickly and to reduce errors probability in decision-making and implementation of development systems, to make the development process more flexible and controlled [15]. Besides, having sufficient information about geological structure will help to avoid possible mistakes in the selection and installation of the appropriate type of subsea production system, which, in turn, will allow predicting the possible cost of funds for the implementationof such projects [6,9]. As it was noted by A.Cherepovitsin, each Arctic project is unique, and combined with extreme mining conditions, requires unique technologies [18]. Thus, based on the research, an operation algorithm of a software product was developed by using the combinatorics method and is sketchily presented in Figure 2. This algorithm is conditionally divided into 6 blocks, each of which carries a certain range of values for each of the 6 factors considered in the research. The blocks are interconnected sequentially, and the final result of a software product takes into account the significance of each of the factors. The main path of the algorithm begins with such a factor as the depth of the developed field. However, the sequence of factors does not matter when obtaining the result at the output, as all the factors are interconnected. As the main objective of introducing this program is to reduce time and material costs at the preliminary stages of planning, it is proposed to slightly change the management approach, namely to use the developed software product before the planning process begins.

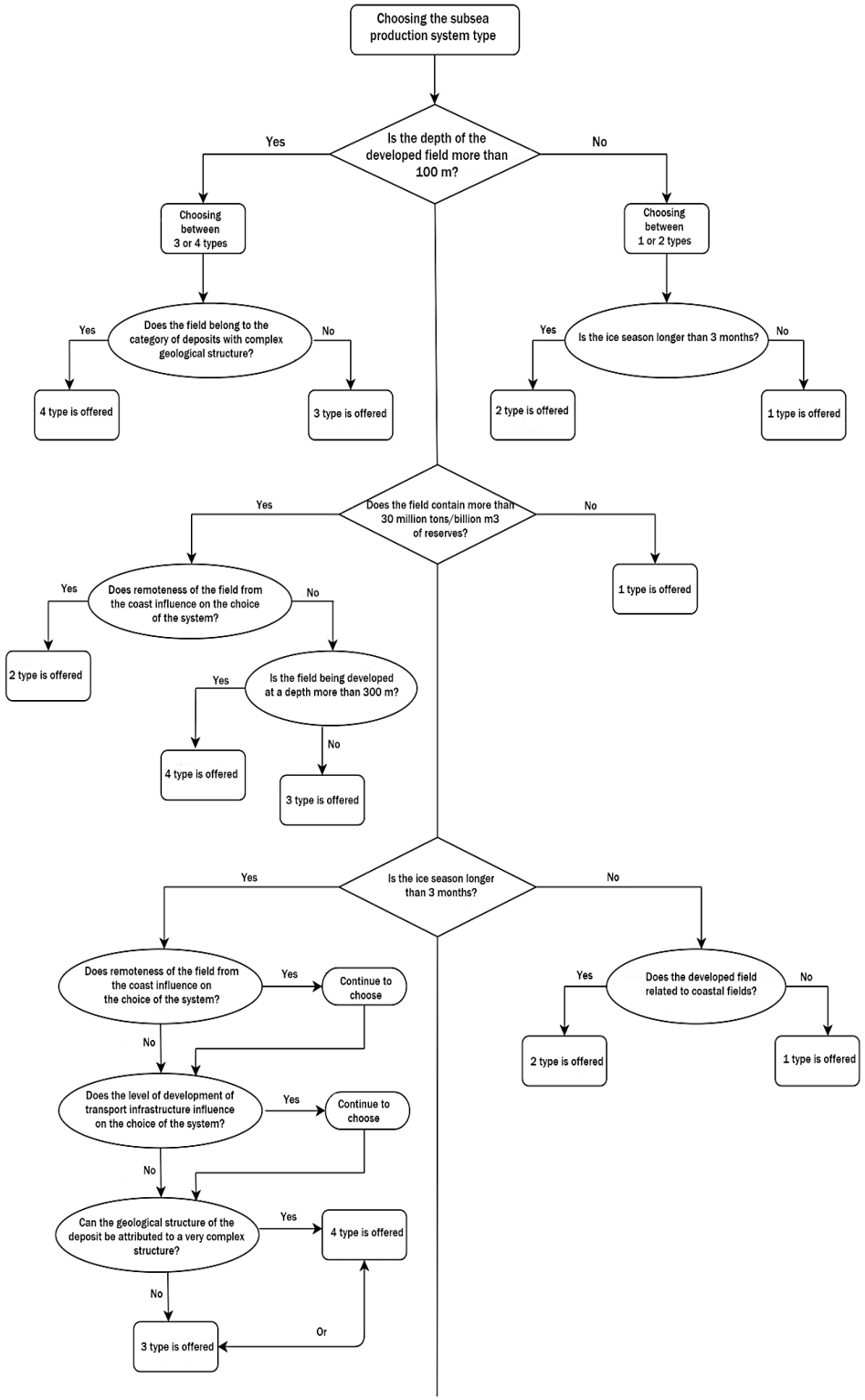

Fig.2. An operation algorithm of a software product.

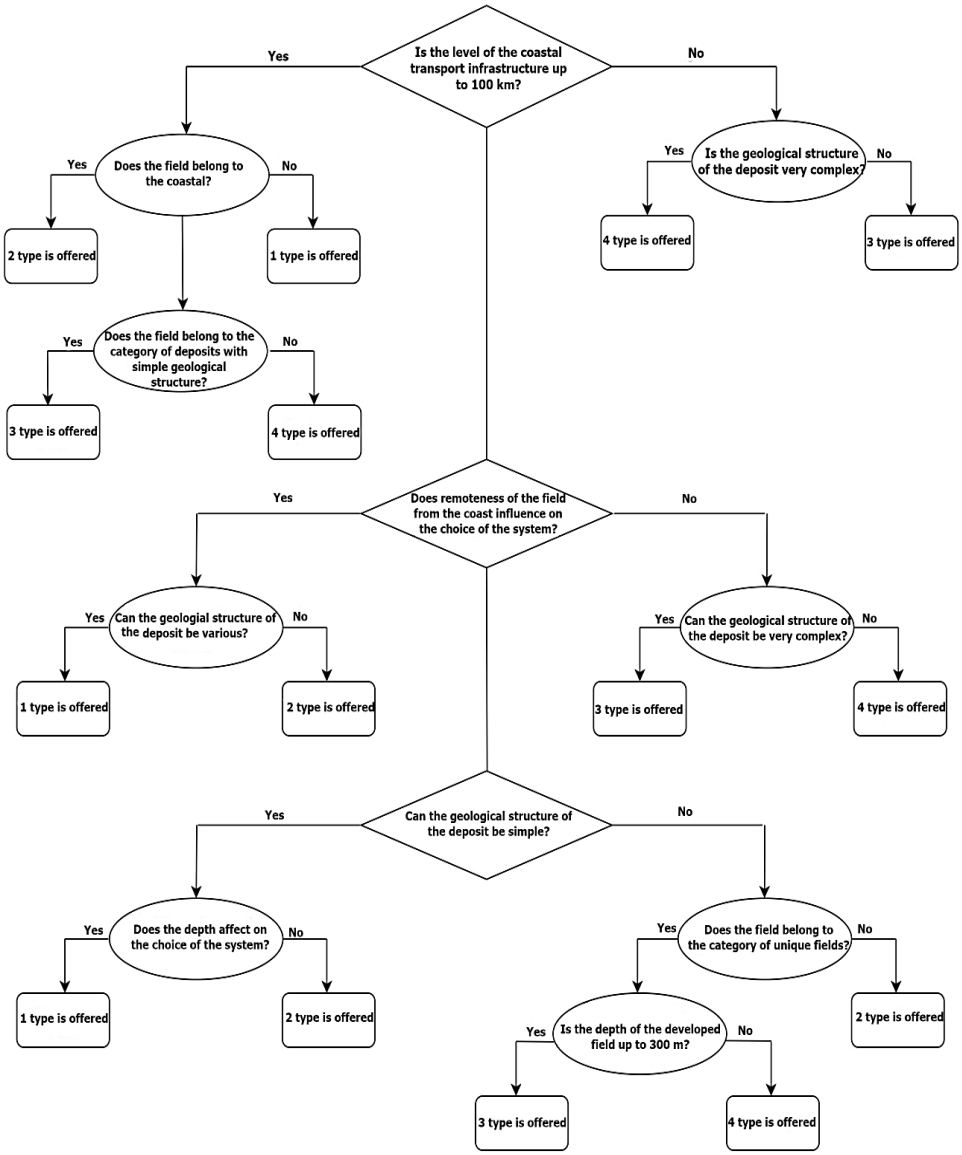

Fig. 2. An operation algorithm of a software product

The most common problem in project management is the lack of clear distribution of responsibilities in making strategic and operational decisions at each stage. BerezikovS. also points, that in the Arctic regions of the Russian Federation, the innovation sphere is associated preliminary with the lack of motivation among corporations to introduce new technologies in the real sector of the economy [23]. This may keep with great uncertainty of the initial data of the field [13], which will require a lot of time of project documentation development, as a result, a long process of determining further action program at the subsequent stages of project implementation [2]. Moreover, as A.Ilinova and D. Dmitrieva noted, the more complex are the conditions for resource exploration and extraction, the more scientific research and innovations are required [24]. Thus, the proposed approach will al-

low not only to avoid possible errors when choosing an inappropriate type of subsea production system for the field but also to reduce the time for further work at the subsequent stages of project development.

The software product interface is presented in Figure 3. The left side of the program displays factors considered in the research, where a range of values is indicated under each of them. To the right side of the factors, user selects the desired value from the drop-down list. Further, by pressing the "Select the type of subsea production system" button down below, the program analyzes the input data and shows the result, which is displayed at the right side of the software product interface like one of the 4 types of subsea production system.

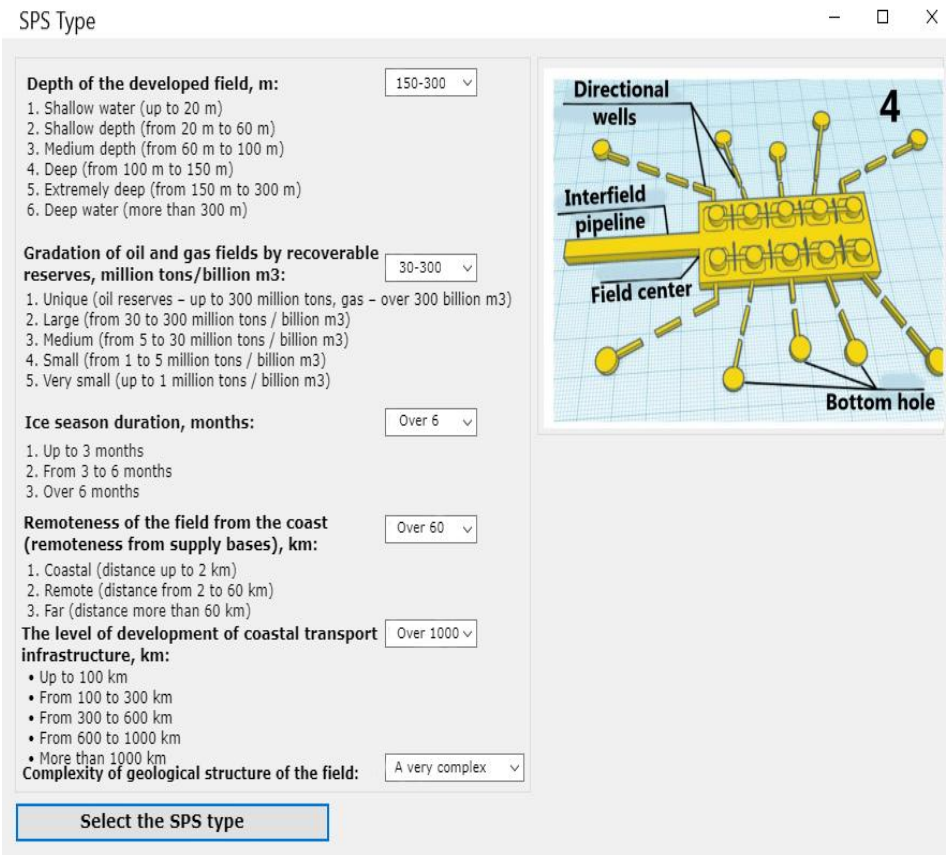

Fig. 3. The software product interface example

5 Conclusion

In the research, the main types of subsea production systems were investigated, and based on interviewing method, several factors that have the greatest impact on the development of offshore oil and gas fields were identified [14]. Based on the researched factors, we developed an operation algorithm of a software product, which can help toavoid the loss of time and material costs at the preliminary stages of planning. The developed software product will help to select the appropriate type of subsea production system construction for the current field, depending on the geological structure of the formation, the depth, size of the field, and other factors, considered in the research.

In this paper, we proposed to improvethe management process by using subsea production systems by introducingthe developed software product at the preliminary stages of planning, which will allow making managerial decisions more quickly and efficiently, and to increase the efficiency of ongoing operations [25]. This, in turn, will contribute to better adherence to schedules at future stages of the project [9]. Besides, this will allow us to avoid possible risks when choosing an inappropriate type of subsea production system and correctly develop a project plan, including the content, timing, cost, and ongoing work. In conclusion, this software will help to optimize the planning process, timely predict possible risks, and make the right choice in installing the optimal type of subsea production system, as well as saving material costs and time at the preliminary stages of planning. Thiswill also have a kind of cumulative effect at the stage of the project implementation, which maymean that the use of the developed software product can be implementedin further cost reduction in theimplementation of subsequent stages of the project.

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