Methodology for selecting objects for reverse engineering at oil and gas industry enterprises

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Abstract. The basic methods of reengineering and the possibility of their application at the enterprises of both oil and gas industry and enterprises of defense-industrial complex under the conditions of ensuring technological independence are presented. The methodology of justification of selection of objects for reverse engineering at the presented enterprises has been developed, including the following criteria: participation of the reverse engineering object in the production of special products, reduction of unit production costs when implementing the reverse engineering object, the share of revenue from products containing the object in the total revenue of the enterprise, the level of import-independence provided by the reverse engineering object. For each criterion, verbal-numerical scales are developed, a complex coefficient is proposed, the values of which are used in making managerial decisions justifying the choice of objects for reverse engineering.

1 Introduction

A significant reduction in the supply of high-tech products to Russia by foreign suppliers has aggravated the problems in the sphere of import independence and technological sovereignty. Both oil and gas and defense industry enterprises have to solve not only the problems of scaling up the production of special equipment, but also the problems of diversification, technology transfer, development of markets for high-tech products for dual and civil purposes.

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Every world power must develop, strengthen and modernize its production regardless of the impact (positive, negative or uncertain) that spending on specialty products may have on economic development [1-3].

In the current situation, the key issues that need to be addressed in order to reduce import dependence are:

- the need to simultaneously design, modernize and master production of new military and civilian products;
- the need to master new methods of management and production organization, intensification of digitalization processes taking into account the existing limitations on all types of resources;
- increasing the efficiency of utilization of the existing and scientific and technological and production backlog of enterprises;
- formation of new logistic chains of supply of raw materials, materials and components;
- development of basic and critical technologies for the production of products needed to replace imported supplies;
- rapid introduction of best practices and product samples.

Under the current conditions, it is necessary to quickly adapt domestic enterprises of the defense industry to ensure the production of products capable of meeting the needs of domestic markets for high-tech products for dual and civil purposes, which have increased manifold as a result of the cessation of foreign supplies.

Within the directions of overcoming the import dependence of the domestic economy, reverse engineering occupies a significant place, especially the issues of introducing reverse engineering methods in the defense industry.

In scientific and business literature along with the concept of reverse engineering the following are used: reverse engineering, reverse engineering, reverse engineering, reverse development, reverse engineering, reverse engineering, reverse engineering.

Reverse engineering is a process of research of a finished device (mechanism), the purpose of which may be to recreate a copy of the object, its modernization and/or restoration of technical and technological documentation for the copied product. Reverse engineering is used to produce various parts, products, devices, which, in turn, can be applied to restore the performance of obsolete equipment and in the design of a new one on the basis of the existing one [1, 4-10].

Reverse or reverse engineering in industry is the reverse engineering of a competitor's product in order to learn its device, operating principle and assess the possibility of creating an analog [2]. Reverse engineering refers to the process of creating technical documentation based on an existing part or design [11-15].

Reverse engineering method differs from traditional development in that first the product is made, and only then its drawing and other necessary design documentation (CD) in accordance with the unified system of design documentation. In fact, the CD is not developed "from scratch", but is reconstructed according to the sample by taking its dimensions and studying its other parameters. The task of reverse engineering is to obtain a set of technical documentation in the shortest possible time (compared to a new development), which can be used to manufacture products at any production [4, 16].

Reverse engineering is also used when it is necessary to obtain a 3D model of a finished product, for example, to develop its modernized version. In this case, the physical prototype is "digitized" using a 3D scanner. Then, the digital geometry is created using the point cloud obtained as a result of scanning [5].

In the field of reverse engineering, 3D digitization equipment is used: 3D scanners, tomographs, measuring tools and computers with special software.

Reverse engineering is the study of some ready-made device or program, as well as documentation on it in order to understand the principle of its operation; for example, to discover undocumented features (including software bookmarks), to make changes or reproduce a device, program or other object with similar functions, but without direct copying. Copying various mechanisms and machines without actually developing them [6, 17-20].

Reverse engineering is often used today by domestic defense industry enterprises at the stage of product design development, allowing them to study analogs of a new product and the possibility of copying it.

2 Reverse engineering

Examples of reverse engineering applications may include analyzing program code to determine its algorithms and methods of operation, disassembling electronic devices into components to study their functions and properties, analyzing communication protocols to determine how to transfer data, etc. [2, 4, 6].

The stages of reverse engineering are:

- preliminary design;
- search for technical solutions;
- 3D modeling;
- production of design documentation;
- production of a prototype;
- testing and finalization of design documentation.

Advantages of reverse engineering:

- reduction of financial and time costs for designing, testing, manufacturing, maintenance and operation of the product;
- possibility of multiple reproduction of engineering objects, including the use of additive technologies;
- Reduction of dependence on suppliers of products, reduction of risks of non-fulfillment of the production program, reduction of import dependence;
- possibility of product modernization taking into account changes in customer needs.

To stimulate the work on the development of reverse engineering at the state level, the RF Government Resolution No. 209 dated February 18, 2022 "On granting grants in the form of subsidies from the federal budget for the implementation of projects to create and (or) develop engineering development centers on the basis of educational organizations of higher education and scientific organizations implementing projects related to the development of components" was adopted [7]. Within the framework of this resolution the requirements for the development of critical components are presented.

Critical components - critical components, including spare parts, tools and accessories, representing individual components, including raw materials and materials, or their complex, used as components of products, classified in accordance with the All-Russian Classifier of Products by Economic Activity according to the list determined by the interdepartmental commission for the development of production of critical components, in accordance with the Regulations on the interdepartmental commission for the development of production of critical components, in accordance with the Regulations on the interdepartmental commission for the development of production of critical components.

The implementation of the program to stimulate the development of technical documentation by the Agency for Technological Development within the framework of the RF Government Resolution No. 209 dated February 18, 2022 includes more than 100 projects and stimulates the interaction of defense industry enterprises and developers of design and

technological documentation for products, the production of which is absent or limited in Russia [8].

The introduction of reverse engineering methods will facilitate the introduction of artificial intelligence technologies at defense industry enterprises, such as: 3D-modeling, work with big data (Big Data), development of additive technologies.

3D modeling works include: development of mathematical models of parts, assemblies, components and other objects, formation of virtual objects, prototyping. On the basis of 3D-modeling, digital twins are created, allowing virtual testing of objects, collection of data on objects, allowing to simulate their behavior in real conditions, which significantly reduces costs and accelerates the process of design and development of design and technological documentation.

Based on 3D models using additive technologies, the process of manufacturing parts, assemblies, and products by "growing" them from raw materials is significantly accelerated.

3 A system of criteria for ranking objects for reverse engineering

The objects of reverse engineering can be:

- equipment or its components (assemblies, separate elements and parts);
- software;
- products and parts used in the production of products;
- materials and chemical compounds.

Under the conditions of the necessity of simultaneous implementation of several re-engineering projects, the enterprises of the defense industry face the task of selecting the most priority ones, which implies the use of selection criteria and ranking methods.

To use the proposed criteria in practice, they should satisfy the following conditions:

- criteria should reflect the main information aspects used in management decision making;
- the criteria should use available information;
- the labor intensity of criteria calculation should be minimal.

On the basis of the study of actual tasks of defense industry enterprises, the system of criteria for ranking objects for reverse engineering is proposed:

- participation of the object in the production of special-purpose equipment, k_{SPE};
- reduction of unit production costs when implementing the object, k_C;
- the share of revenue from products containing the object in the total revenue of the enterprise k_R;
- level of import-independence provided by the object, k_{II}.

In order to ensure practical application of the proposed criteria, the verbal-numerical scales are presented in Tables 1-4.

Table 1. Verbal-numeric scale of values of the criterion "Participation of the object in the production of special equipment".

Criterion value	Numerical value of the criterion k_{SPE}, score
The facility is involved in the production of specialty equipment	3
The facility is not involved in the production of specialty equipment	0

Table 2. Verbal-numeric scale of values of the criterion "Reduction of unit production costs when implementing the facility".

Criterion value	Numerical value of the criterion k_C, score
Average unit production costs will be reduced by more than 15% when the facility is implemented	3
Average unit production costs will be reduced by 5 - 15% when the facility is implemented	2
Average unit production costs will be reduced by more than 5% when the facility is implemented	1

Table 3. Verbal-numeric scale of values of the criterion "Share of revenue from products containing the object in the total revenue of the enterprise".

Criterion value	Numerical value of the criterion k_R, score
The share of revenue from products containing the facility in the total revenue of the enterprise is more than 30%	3
Share of revenue from products containing the facility in the total revenue of the enterprise from 10 to 20%	2
Share of revenue from products containing the facility in the total revenue of the company is less than 10%	1

Table 4. Verbal-numeric scale of values of the criterion "Level of import independence provided by the facility".

Criterion value	Numerical value of the criterion k_{II}, score
Implementation of the facility based on the results of its reverse engineering will result in a fully import-independent product	3
Implementing a facility based on the results of its reverse engineering will not result in a fully import-independent product	0

A comprehensive coefficient is calculated for each facility:

$$K_{\text{P}} = k_{SPE} \times a_1 + k_C \times a_2 + k_R \times a_3 + k_{II} \times a_4 \quad (1)$$

where a_1, a_2, a_3, a_4 are the weight coefficients of each criterion when $a_1 + a_2 + a_3 + a_4 = 1$.

The values of the criterion coefficients are determined on the basis of the scales presented in Tables 1-4.

Stages of the methodology:

- determination of a set of objects for which reverse engineering is necessary;
- ranking of objects by criteria;
- making a management decision.

The main constraints in the course of prioritization of reverse engineering objects are related to the budget, the total cost of reverse engineering of all products should not exceed the planned volume:

$$\sum_{i=1}^{n} C_i \leq C_{reengineering\ budget} \quad (2)$$

Reverse engineering can be treated as a system of interconnected dependent events. By using this concept an organization can build a standardized workflow with the necessary integrated linkages for increased success in both execution and scaling of projects. Utilizing a pull (downstream stakeholders assist with upstream execution) vs. push (independent

execution and forward handoff) system promotes clear communication among functions to prevent rework, shorten flow time, and increase quality. Reverse engineering, like traditional forward engineering, is set up as an interactive multifunctional process with organized information sharing, compromise, and iteration.

The scheme of the methodology of justification of the choice of objects for reverse engineering at the enterprises of the defense industry is presented in the Figure 1.

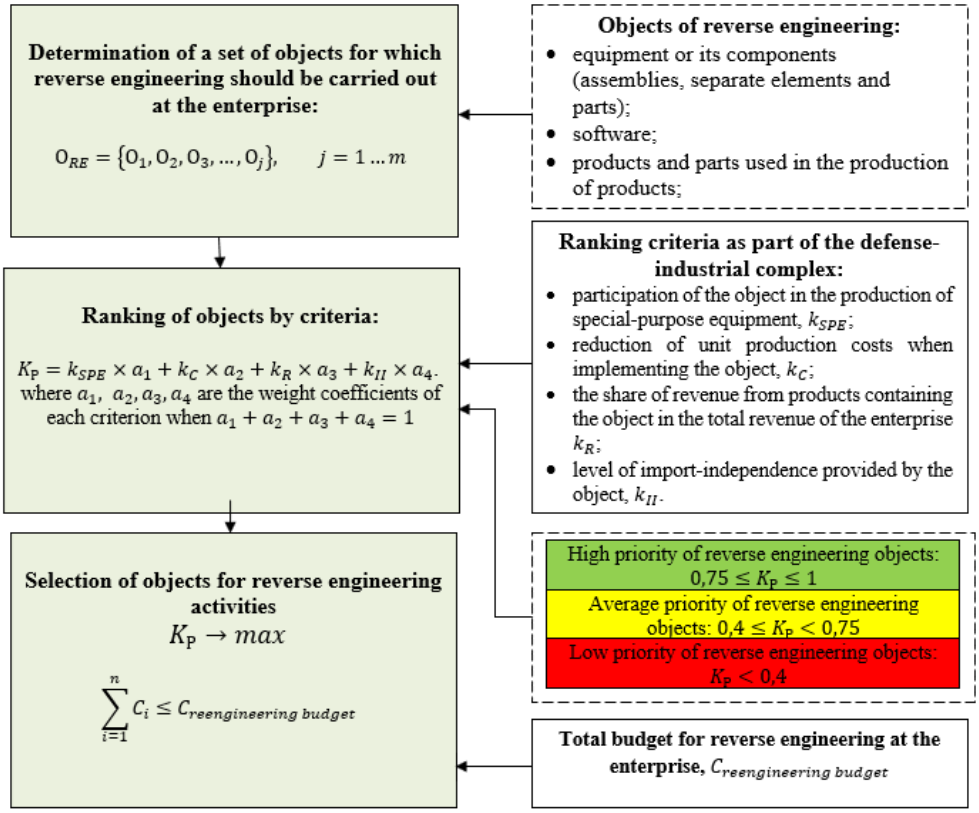

Fig. 1. Scheme of the methodology of justification of the choice of objects for reverse engineering at defense industry enterprises/

4 Conclusion

The developed methodology of substantiating the choice of objects for reverse engineering at the enterprises of the defense industry allows to formalize the process of evaluation of re-engineering measures, analyze the dynamics of the effectiveness of measures, develop management decisions aimed at improving the efficiency of reverse engineering in the defense industry, which contributes to the intensification of diversification processes in the defense industry, reducing import dependence in the production of military, civilian and dual-use products.

This also allows the company to focus on highest priority projects or statements of work that match their existing expertise. On the other hand, out sourcing can promote dependencies on suppliers once in-house knowhow or capability is lost or lagging. These dependencies can

become a risk to the company and require a proactive step to mitigate potentially negative downstream impact.

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