System approach to modeling of industrial technologies

V S Toropov, E S Toropov

Industrial University of Tyumen, 38 Volodarskogo St., Tyumen, 625000, Russia
E-mail: vladimir.s.toropov@gmail.com

Abstract. The authors presented a system of methods for modeling and improving industrial technologies. The system consists of information and software. The information part is structured information about industrial technologies. The structure has its template. The template has several essential categories used to improve the technological process and eliminate weaknesses in the process chain. The base category is the physical effect that takes place when the technical process proceeds. The programming part of the system can apply various methods of creative search to the content stored in the information part of the system. These methods pay particular attention to energy transformations in the technological process. The system application will allow us to systematize the approach to improving technologies and obtaining new technical solutions.

1. Introduction
At present, it is customary to perform design and creation of complex systems from positions of system engineering.

A system engineer is a specialist who can combine knowledge fields from different technical and scientific areas in one system and use this interdisciplinary, integrated approach to solve a wide range of technical and other problems when implementing a large complex project [1].

No matter how trivial it sounds, the Russian Federation lags behind developed countries for decades in training of this kind of specialists [2]. The situation would not be so critical if these human engineering resources were not leading doers in implementing the largest and most significant projects, both technical and non-technical, from the creation of the Large Hadronic Collider to the organization of the European Union [3].

Thus, today there are a large number of specialists in various subject areas, which need to be taught to systems thinking to be able to use a systematic approach for solving problems in their field and related fields.

It is clear that such task cannot be solved in a short time, without strong support at a high level, especially taking into account the fact that in Russia few people know what a system engineer is, and what is difference between an ordinary engineer and system engineer. But something can be done.

2. Research object
It is proposed to solve this problem by the introduction of an intuitively understandable, easy-to-use software and information tool, which will be possible to answer several categories of tasks at once.

In general, system engineering solves a vast range of problems, the description of which is beyond the scope of this paper. However, it is necessary to note the following. In the past, engineering began with the fact that there were no standards. Then the appearance of standardized drawings, diagrams,
charts, and other formalized information was noticed. Today one cannot imagine modern engineering without a system of technical standards, unified rules, text and graphics documents.

So, engineering as such is now in some transition stage. For a long time, the methods of machine processing of all this engineering information are studied [4]. Thus, until now, one has had no such opportunities. System engineering proposed standards for the design, creation, maintenance of systems and other activities with them. At the same time, a large number of so-called unified formal languages for system creation (modeling) appeared [5] to process this information.

Many of them have practical application only in information systems, but there are universal languages. As a rule, they represent a set of graphic symbols with a specific semantics tied to each character. A single standard for these languages is not available at the moment.

The emergence of formal languages for system engineering did not in itself lead to explosive growth of the industry and was not a panacea for solving the problems facing scientists and engineers. Therefore, it is advisable to go in a slightly different way.

One need a tool which includes not only modeling rules but also the content itself. The working title of the project is "Technology constructor."

3. Methods
It is advisable to create a tool for system engineering using methods of system engineering. By the postulates of system engineering, it is necessary to determine the requirements for the system at the very beginning. Moreover, it is essential to answer the question, who are its stakeholders, i.e., interested persons, users and other persons and organizations having direct or indirect relation to the project.

Table 1 lists the main stakeholder groups and the reasons for their interest in the developed tool.

| Stakeholders | Reasons for interest                                                                 |
|--------------|---------------------------------------------------------------------------------------|
| Students     | Availability and ease of studying the features of technics and technologies application. The system provides correct submission of information. |
| Teachers     | The ability to competently provide students with information about technological processes using a system approach. The ability to quickly find data to improve their skills. |
| Scientists   | The possibility of creating a unified system for publishing and reviewing scientific papers using information part of the system as a basis. The possibility of applying various mechanisms of scientific search to the information part of the system. Systematization and centralized accounting of information on scientific novelty. The system provides suppression of plagiarism attempts. |
| Engineers    | The system can be used to solve engineering problems and improve technology using a wide range of methods. These can be methods of creative search intensifying (morphological analysis, functional analysis, TRIZ methods and others), statistical methods of data science, etc. The use of these methods will provide new technical solutions. |
| Businesses   | This system is a convenient tool for complete and detailed modeling of the production process and further technical and economic analysis of the model |
obtained to reduce production costs and improve the technological chain. The system enables one to promote products and services within its framework and to solve identified problems and eliminate weaknesses in the technological process.

State structures
The possibility of developing unified standards for registration and verification of plagiarism and scientific novelty in academic and technical information.
The possibility of using the system for reverse engineering to solve import substitution problems.

Each of these stakeholders can put forward their requirements for the developed system. In general, "Technology constructor" capabilities can meet these demands. They are as follows:

1. The system creates a complete picture of the studied technology. This figure includes both primary materials and equipment, and operation principles, physical and chemical effects on which the process is based, as well as energy and labor costs both in individual sections of the cycle and for the entire technological process as a whole.

2. The method information structured allow one to use it in two ways: both for working with it and for machine processing, the ease of which is ensured by uniform structuring according to a single template. Methods for processing can be very diverse.

3. All information is entered into the system and stored simultaneously in several languages, including international English, thus providing the opportunity for broad access to the project for specialists from different language spaces.

Figure 1. Technology groups classification in the "Technology constructor" system.

Let us note that overcoming the language barrier is one of the most urgent tasks for Russian scientists and engineers. So far no solution would suit everyone. "Technology constructor" will solve this problem in the following way. The system is initially formed as multilanguage and does not require further translation. At the moment, this is a secure and reliable way to provide the project with a broad audience coverage.

Of course, the instrument itself cannot claim to cover all stages of creating complex systems. But it can flawlessly perform the functions of an information resource that is convenient for machine processing by various methods.

They can be methods of creative search intensifying, such as morphological, functional analysis, any tricks in the framework of TRIZ, up to the methods of mathematical statistics [6], or as it is now commonly called - Data Science.
As for the last, one knows that Data Science ideally manipulates raw data after appropriate processing. But in our case, there is the opportunity to apply the methods of data science to a template filled with information. One should not be confused by an element of subjectivism, which will undoubtedly take place with this approach. It occurs when processing any raw data. Moreover, by the Data Science rules, the researcher should always ask the questions “What is the goal of our search? What patterns do we expect to find?”, but in this case, we are free to set the task quite individually.

![Figure 2](image1.png)

**Figure 2.** Generalized scheme of technology.

The development of "Technology constructor" raises questions of creating and reviewing content. A multidisciplinary professional team, which should expand as information about an increasingly wide range of technologies accumulates, can be best in content reviewing.

The way system information structured is as follows. All data include several categories, which in turn have a hierarchical structure. They are a software and information complex with the ability to process computer information stored in memory. This complex includes models of various technologies, as well as equipment, materials, and effects of diverse nature that occur when working with this particular technique.

![Figure 3](image2.png)

**Figure 3.** Input resources of industrial technology according to "Technology constructor" classification.

Thus, the central category of data is "Technology." This class in its turn has some daughter elements. One can scale the system. The technologies in question can be different. However, One does not try to cover everything. Let us deal exclusively with industrial technologies.

Within the framework of this project, the authors divided all industrial technologies into four categories:
1. Creation.
2. Operation.
3. Repairs.
4. Control.

Figure 1 explains a broad interpretation of these categories and what they include.
Further, one should keep in mind that any technology must have something at the input (specific resources), also the process itself, and something at the output (results). It follows from the very logic of the application of any technology (see Figure 2).

If one considers this scheme in more detail, then one comes to the fact that technology is a set of methods that make up the technological process, used to transform raw materials and energy through equipment and tools involving personnel of varying degrees of skill.

Thus, at the input, let us have the following set of categories of this scheme (see Figure 3).

Let us clarify in Table 2 what is meant by each of these categories, and what they included. As can be seen from the table, in the first group of "Systems" there is any equipment, which in its turn can be defined as a system or as a hierarchical structure of simple and complex systems from the point of system engineer’s view. In this case, this is convenient since one can disclose information about these systems to any level of detail.

If one cannot classify something as "Systems", one should put it into the category of "Materials." Some materials represent a fuel, so one should put them in the category of "Energy" to analyze information about the technological process regarding energy costs minimizing) [7].

### Table 2. Decoding of resource categories in the "Technology constructor" project

| Category | Content |
|----------|---------|
| Systems  | Any equipment and tools from a screwdriver to an industrial enterprise entirely [8]. |
| Materials| Consumables and raw materials themselves in various aggregate states, parts and components, oils and greases, combustible materials, if one uses them as raw materials, but not for fuel. |
| Energy   | All kinds of energy, including electrical, heat in the form of fuel, solar power, etc. |
| Staff    | It means specialists with a set of specific knowledge and skills. |

The category of "Energy" is fundamental to optimize costs and increase the energy efficiency of production. In general, the energy conversion in the system will look like this:

\[ E_{out} = E_{in} + E_d \]  

where \( E_{out} \) – energy received at the output of the process; \( E_{in} \) – energy at the input to the technological process. It can be represented both in the form of electrical, thermal energy and in the form of organic fuel; \( E_d \) – energy lost or dispersed during the process.

The indicator of \( E_{w} \) will determine the efficiency of the system and can serve as a criterion for the energy efficiency of technology.

### 4. Results and discussion

Technical systems are visualized within the "Technology constructor" to facilitate the search for and elimination of specific problematic technology sites for individual nodes [9].

The system adds data on the functions of individual nodes in a unified format for processing this information using functional analysis. Also, the "Technology constructor" stores information about the problematic locations of the technology, which is structured as follows:

a) Individual components problems of the equipment used;

b) The problems of technological process particular stages;

c) Common problems not attributed to a specific node or stage of technology, or temporarily unclassified issues [10].
Let us open "Result" category content. Here there are three critical positions, which can take place in this particular technology, and may be absent. In general, they are:

1. To create new systems or systems.
2. To change the properties of incoming resources (all or some of them).
3. To receive waste.

There is information about the technological process, which is the essence of this technology, in the "Technology constructor." There are also characteristics of technology that do not fall into the listed templates, but they are not less necessary for working with scientific and technical information. They include the central principle, the technological process based on (physical or chemical effect), tasks solved using technology, order and scope of application, process parameters calculations, and others.

5. Conclusion
In fact, the basis of any technology is the use of one or more physical or chemical effects. It is especially important for analyzing the various types of energy transformation that takes place when specific effects occur. This approach is a necessary element for modeling any industrial technology.

Thus, the system summarizes data on all essential parameters of the technological process. The method will finally allow answering many questions that arise before an engineer or scientist in the process of technical creativity.

The most important of these issues is technology improvement based on taking into account the direction of energy and material transformation, as well as the quantitative evaluation of these alterations. In the long term, this will allow us to approach the issue of engineering and scientific search by system modeling methods, providing the possibility of solving part of the tasks using computer systems.

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