Information System for Quality Control of Polyethylene Production in a Circular Economy

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Abstract

A polyethene quality control system is a set of methods and means of controlling and regulating components that determine product quality and technical management at all stages of the production process. The first experience of polymerization of polyethene in the XIX century was received by the scientist Gustavson. For many years, polyethene was created in small quantities, but in 1938 the British mastered industrial production. At that time, the polymerization method was not yet perfect and required additional means of production control. Nowadays, each company uses different ways to control production. Still, given the complex chemical and technological processes, the need for a more efficient and integrated system that will maintain the quality of final products and at the same time save raw materials is relevant. The research aims to create a quality control system for notification, control, and management of automation systems using remote access and artificial intelligence systems. Study object: technical features of implementation of a quality control system for polyethene production enterprise. Scope of research: quality control system for polyethene production with elements of artificial intelligence technology. The bachelor's thesis deals with creating an information system for quality control of polyethene, which will provide effective and safe management of the production process, high functionality and cross-platform with the help of web technologies and artificial intelligence. The work consists of an introduction, five chapters, conclusions and a list of sources used. In the first section, the theoretical and methodological bases of research of quality control system are considered. The article provides a systematic analysis of the object of study, compares and selects the means of implementing strategies, describes the created software and the software product's economic characteristics, and calculates the cost of the software product. According to the study, an information system for quality control of polyethene production was created. The work is to establish compliance of products and processes with the requirements of regulatory and technical documentation, standard samples, provide information on the production process and maintain its stability, protect enterprise data, identify defective products in the early stages, and prevent the production of substandard products.

Keywords 1

Quality control system, control panel, web technology, means of artificial intelligence, polyethylene, Chemical Industry, quality control, production process, information system, artificial intelligence, raw material, polyethene production, detailed analysis, system user, management system, product quality, logical structure, web application, software tool, polyethene quality control, quality control information, control information system, express application, operator panel, user data, human factor, web development, source data

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1. Introduction

Since today, the problem is quality control in production. In addition, saving of raw materials is still not fully resolved. There is a need to build a quality control system using elements of artificial intelligence technology, which will help not only to report problems in advance but also to control the technological process, to maintain quality at a certain level constantly. Today, quality control systems are widespread for high-pressure polyethene production as they include complex chemical processes, prevention of breakdowns of technological equipment, reducing production costs, and improving occupational safety at the enterprise. The introduction of such systems in the production process brings many benefits to the chemical industry, solving problems related to quality control, raw material savings and production management. The quality control system of polyethene production allows increasing the reactor's productivity, ensuring high process speed, reducing the harmfulness of the production area, reducing the cost of polyethene, increasing the yield of the finished product, and improving its production quality. The use of systems that, based on artificial intelligence, control highly complex chemical-technological processes, sensitive to any deviations, makes the production of polyethene manageable, predictable and controlled. The purpose is to create a quality control system for the tasks of notification, control, management of automation systems using remote access and artificial intelligence systems. Research objectives:

- To consider the main elements of the essential quality control system and existing systems and to determine the possibility of their use in creating a comprehensive quality control system;
- Consideration of engineering and software solutions to create a quality control system for polyethene production, without reference to the platform;
- Defining the necessary functions and commands of the system;
- Description of system requirements for the development of quality control system;
- Determining the required software to system implementation.

The object of study is technical features of introducing the quality control system for the enterprise on polyethene production. The subject of research there is a quality control system for the production of polyethene with elements of artificial intelligence technology. The novelty of work is to develop a fundamentally new quality control system for polyethene based on web technologies, which with the help of artificial intelligence elements will independently control the production process to create a quality product and save raw materials. In addition, the system will not be tied to a specific user's workplace, which will give it increased mobility. The practical significance of the obtained results is that they are of both scientific and theoretical and practical interest. The materials of the analysis will be helpful for further study of the specifics of the involvement of information technology in the chemical industry. In turn, the developed information system will be effective for further optimising the production process, improving product quality and saving raw materials. This system can also be used in conjunction with other systems or to train relevant professionals.

2. Related works

2.1. Basic principles of research

The quality control system is a holistic set of processes, resources, relevant procedures, organizational, providing opportunities to maintain strong links between all levels of management and operating enterprises at all levels of sales and production and the overall quality management of products and services. To ensure the required high quality of products or services, you need a transparent management system of this quality, which will include scientific and technical advances, focus on market demands and stimulate the conscientious work of the entire team at the enterprise [1].

The quality control system is a general term for several types of systems. There are different approaches to the construction of quality control systems in production, namely: a system built on the principle of a light signal panel using mechanical control devices (switches, buttons, signal lamps, beacons), a method using an operator panel (combined use of automatic control devices and panel computers), as well as a system that is an NMI based on automated workstations (AWP), which is a personal computer, phone or tablet with a comprehensive quality control system. This paper will

consider developing a quality control system for polyethene on the principle of HMI systems, with support for multiplatform and the use of web technologies [2-3].

There is a lot of work devoted to developing and researching quality control systems and remote control systems both in the international space and in the national segment.

The article [4] describes supervisory quality control and data collection, interface requirements, discusses new and open technologies and their impact on increasing SCADA / HMI development capabilities. Finally, it introduces practical SCADA / HMI programs for DCAI [4].

An article [5] provides an overview of SCADA functions and the basics of SCADA systems, including a brief description of the critical human-machine interface. Several key issues and problems of modern SCADA systems are discussed: messaging standards, system performance testing, and system obsolescence. An analysis of current trends is in distributed processing, improvements in the human-machine interface, standard systems, smarter RTUs and standard software [5].

The article [6] focuses on product quality. However, it does not have an evaluation criterion but is a specific advantage and depends primarily on the qualifications of staff and their knowledge of production technologies. Quality forms the reputation and business image of both the specialist and the company he represents [6]. Article [7] conducts a precise, detailed analysis of the current state of organization of product quality control in enterprises. It provides the need to analyze the entire organizational process of product quality control, system research, and detailed study of information flows of quality control of products manufactured at the enterprise. All the works mentioned above have an unsolved problem of quality monitoring and running power of the production process without the involvement of personnel, reducing the cost of raw materials and financial costs, and reducing the complexity of training to work with these systems. In addition, based on these works, system development is relevant. It is not tied to a specific device or panel and is built on the principle of multiplatform, which provides mobility in the work of the system operator.

2.2. Analysis of known means of solving the problem

To ensure the required quality of products or services, an effective quality management system is needed, which will take into account all scientific and technical achievements and focus on market demands. Beginning in the 1950s, the world started introducing product quality management systems at enterprises in various industries. One of the first systems was the Saratov system of defect-free production (GDP). The purpose of the plan was to create the necessary conditions for production, according to which the products complied with all these regulations and surrendered from the first submission. One of the main criteria for assessing quality was the percentage of products that were delivered from the first time. Accordingly, the higher the rate of offered products, the greater were the moral and, most importantly, material incentives [8]. The Lviv system of defect-free labour (SBP) was more progressive than the Saratov system. This system aimed to produce the most defect-free product of excellent quality. It is worth noting that the system encouraged the work of all employees: from production worker to management employee. The design took into account the quality of work and the miscalculations of each employee of the enterprise. Nowadays, quality control systems are used in various fields of human activity. They are actively used to automate individual units, installations or the entire process [9]. A modern HMI system is a specialized software or a microprocessor device with a display. It comes with a pre-installed production process and a user environment for the HMI user. It distinguishes the operator panel from industrial panel computers, which require additional software packages and other applications - usually paid. To better understand all the advantages and disadvantages of different ways of implementing quality control systems, it will be advisable to get acquainted with the primary means of implementing strategies and highlight the most popular designs on the market. And also to compare them with systems which on the principle of realization are similar to mine. Among the most effective and popular systems used in the chemical industry are the following:

2.2.1. SIMATIC PP button panels

SIMANTIC pushbuttons can be used wherever buttons and lamps are needed, such as control panels, machines and installations. They can also be used in the design of special devices to develop standard

operator panels, which can be quite flexibly and modularly expanded using additional buttons and LEDs that connect to the built-in board of digital inputs and outputs.

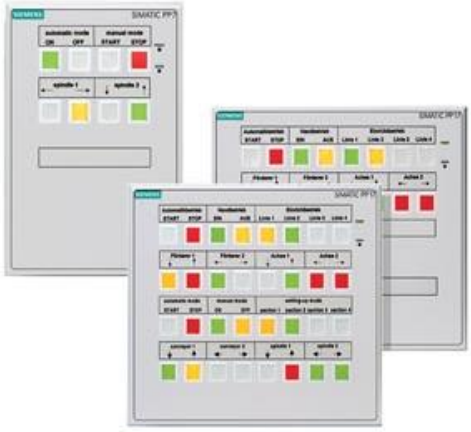

Figure 1: SIMATIC PP button panel

Ready-to-use pushbuttons are connected to SIMATIC controllers via MPI, Profibus DP or Profinet networks. The standard configuration guarantees immediate readiness for use immediately after connection and design, thanks to which up to 90% of the time can be saved compared to the standard installation. Changing the settings can activate various PP options. Operating the machine becomes more accessible and faster for the development engineer, operator and end-user [10].

Advantages of SIMATIC PP. The Button Panel (PP) provides the standard features required for a traditionally designed operator panel plus the following:

- Fully or partially "customized" buttons simplifies the deployment of the system in the enterprise;
- Two-colour LEDs in all buttons;
- Additional digital inputs and outputs for system extensions;
- Other blanks for standard 22-mm different elements such as button, lamp, etc.;
- Centralized entry to prevent unauthorized access;
- Built-in check of lights and controls, selected through parameters;
- High reliability of system management, which plays a significant role during production;
- Ease of maintenance and repair of the system.

Disadvantages of SIMATIC PP. The disadvantages of SIMATIC push-button control panels, as well as other electronic-mechanical panels, are:

- The significant influence of the environment and the human factor on the wear and tear and failure of the elements of the system;
- Lack of reliable means of prevention and elimination of errors of the operator's actions when working with the system;
- The need for constant presence around the operator's system;
- Binding of the control panel to one location at the enterprise, which prevents its mobility;
- Lack of saving reports on the system;
- Lack of output of graphic information, which in turn complicates the work with the system, reduces its productivity and the level of input to work with it;
- The need for constant adjustment of the quality of the process by the operator, which creates additional threats based on the human factor;
- Provide the system with only the warning functions and change the input data with the user's permission lack of direct involvement in control and self-learning.

2.2.2. Yokogawa touch panels

The operator's touchpad is a human-machine interface that allows the user to communicate with the equipment efficiently. The simple and intuitive graphical interface will enable you to manage industrial

units easily. Modern Yokogawa panels have virtually no physical elements - buttons, switches, toggles, indicators, etc. [11].

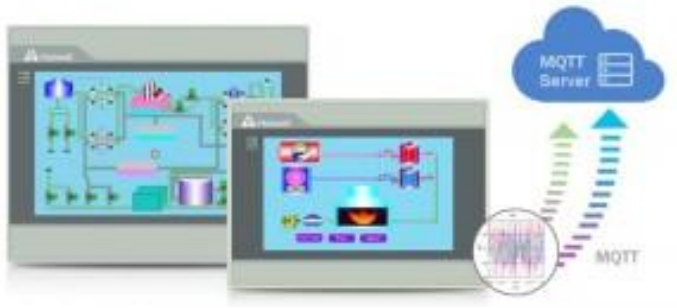

Figure 2: YOKAGAWA touch panel

The interaction takes place through the touch screen. It also displays all the information needed by the operator. This technology allows quick and convenient control of the equipment and eliminates the need to use additional electrical connections present in traditional push-button control systems. The reliability of such links is often in doubt, so they can fail at the most crucial moment. With touch control, the risk of such a situation is minimized.

Advantages of YOKAGAWA:

- Thanks to the high-speed USB interface, you can quickly download and download work programs. You can use a USB flash drive or SD card to copy and back up data and transfer it from one panel to another.
- The Yokogawa brand offers many bright and colourful displays with high resolution, up to 65,535 colours. They allow you to reproduce a clear and realistic picture.
- The PLC program can be serviced and updated via the panel. It ensures efficient and convenient operation of the PLC with fewer cables and connections.
- The panels can be connected to different types of inkjet and dot matrix printers via a USB port.
- There are many opportunities for communication through different communication interfaces.

Disadvantages of YOKAGAWA:

- The higher cost of the device is compared with button options or with panels that do not have controls.
- Some touch screens cannot work effectively in negative temperatures, making the device underused at temperatures below 0°C.
- When working with the system, it is always necessary to monitor the cleanliness of the display to ensure high reliability.
- System mobility, which leads to partial quality losses, and the speed of solving problems or preventing them, is still unresolved.
- Provide the system with only the functions of warning and changing the input data with the user's permission, lack of direct involvement in control and self-learning.

2.2.3. Schneider Electric Harmony STW6 web touch panels

The panels of the Harmony ST6 operator range in size from 4.3 to 15.6 inches and combine exceptional quality with good graphics in 16 million colours, have a stylish design thanks to the metal front panel of the case. Harmony ST6 is programmed using the new EcoStruxure Operator Terminal Expert software, which is part of the EcoStruxure Machine offering and combines key technologies for product connectivity, local management, and cloud technologies analytics and digital services. The constant development of EcoStruxure Machine functionality helps offer its customers more innovation and additional benefits throughout the life cycle of the equipment [12].

Figure 3: Schneider Electric Harmony STW6 web touch panel

Advantages of Schneider Electric Harmony STW6:

- The metal basis provides the case with a rigidity that, in combination with a qualitative lining of a sealant on the perimeter of the case, provides a guaranteed high degree of protection from the front panel - IP65.
- The Harmony ST6 housing has additional locking hooks that prevent the terminal from falling out of the mounting window until it is fully closed. Complete clamps allow installation of the operator's panel without the use of the additional tool.
- All Harmony ST6 models have a QR-code on their body. With its help, you can get a quick link to the documentation for maintaining the operator panel using a smartphone with Internet access.
- All Harmony ST6 terminals feature high-resolution displays with high resolution, providing 16 million colours, improved graphics using TrueType fonts, gradient, transparency and anti-aliasing.
- Harmony ST6 models meet IIoT requirements at the product connectivity level, providing secure connectivity, connectivity, and efficiency for the required software and applications.
- The built-in WEB browser with HTML5 support allows you to use the menu access capabilities to configure various servers and web terminals.

Disadvantages of Schneider Electric Harmony STW6:

- High purchase price of the system and its deployment;
- The need for qualified personnel to correct software errors in the operation of the system;
- The need for additional means of communication for secure data transmission;
- Lack of system support on popular platforms (smartphone, tablet, personal computer);
- Attachment of the system software to the web panel;
- Provide the system with only the warning functions and change the input data with the user's permission. Lack of direct involvement of the system in control and its self-learning.

As can be seen from the above description of quality control systems, their main problem is the lack of self-training of the system, leading to high financial costs for purchasing raw materials and additional wages to employees. Also among the main disadvantages are the high cost, the need for skills to work with similar systems and the binding of approaches to a single device or location.

2.3. Software system functionality

To represent the functioning of the polyethylene quality control system based on the HMI-interface, it is necessary to determine the main attributes and functions shown in Table 1, namely such as:

- Graphical interface - includes several visual aids to improve user navigation through the system and technical functions perform aesthetic, for the presentability of the system and its further promotion in similar enterprises.
- Messaging - is implemented for communication between employees of the enterprise for their further coordination of actions, sending reports and creating notes.
- Production mode with quality control - the function is implemented to monitor the production process, review the original data and evaluate the system. In this mode, the system user enters only

the necessary initial data required by the production technology and then performs only the role of observer. All operations for further quality control, error correction, and critical analysis are performed by analysing the initial parameters based on artificial intelligence and setting additional inputs.

- Database for authentication - performs a protective role of the system, restricts access to the system to unregistered users. It stores all information about the user and provides all the necessary functions associated with his ID.
- Diagnostic mode - is implemented to check the serviceability of equipment and sensors attached to them.
- A database for reporting on the sessions of the system - is necessary for the analysis of technological processes, the efficiency of each user, economic calculations, and further forecasts.

Table 1
Software system functionality

Attribute Function	Status	Priority	Labour intensity	Risk	Stability	Target version	Appointment	The decision is made
Graphical interface	Included v 1.0	Important	High level	Low	Average	v 1.0	Graphic representation of navigation functions system	Implement immediately
Messaging dumb	Proposed bath v 1.0	Useful	Average	Low	High	v 1.0	Exchange of messages between users	Implement immediately
Production mode with the use of quality control	Included v 1.0	Important	High level	High	Average	v 1.0	Control of the production process and the quality of the final product	Implement immediately
Database for authentication	Included v 1.0	Critical	High level	Average	Average	v 1.0	Database for registration and authentication	Realize immediately
Diagnostic mode	Included v 1.0	Useful	High level	High	High	v 2.0	User control of equipment and sensors	Implement immediately
Database for reporting on system sessions	Included v 1.0	Useful	Low level	Low	High	v 3.0	The output of all available information for each of the system sessions	Consider possible implementation options

After analyzing this area, the main research principles were considered, which show that this area is in high demand, but it still needs modernization and improvement. Having studied in detail the work of leading people in this field, we got a general picture of the target audience, their needs, compliance with what users expect from the system, and what it can provide in this technical development of the industry.

In addition, to gain an in-depth understanding of the need for quality control systems, a brief analysis of the creation and implementation of the first enterprise systems was conducted. Comparing the most popular quality control systems, a general picture of the functionality of these systems were obtained. It is not clear the perfection of each design, as increasing the functionality directly increases the cost of the system and does not allow the use of these systems. The lack of artificial intelligence for quality control in production makes the system more complex and requires more staff and raw materials. From the above, creating a system that combines mobility, low cost and reliable functionality, and all complex chemical processes and quality control of the original product will be carried out by a plan with elements of artificial intelligence to eliminate errors based on human factors.

3. Materials and methods

3.1. System analysis of the object of study

For the design of an information system for quality control of polyethene production, one of the critical requirements is to provide recommendations based on building a decision support system and methodology of system analysis [13]. Among all the principles are the following:

- The principle of the ultimate (global) goal - is the definition of the goal and is characterized by absolute priority, i.e. defines a specific main goal for the system - to provide tools to solve the problem of quality control of polyethene production;
- The principle of unity -provides a joint consideration of the system as a set of components (elements, subsystems, system-building relations). In the latter case, it is a subsystem that provides the ability to enter the necessary information into the program (new input data); recommendation subsystem based on entered data; subsystem of independent control of initial data; a subsystem that provides the ability to output all the original data in a pre-created appropriate form (output system);
- The principle of connectivity - contains the necessary generated data based on the entered and stored data in the database;
- The principle of modularity -provides for the implementation of decomposition into components (modules) of varying degrees of generality and considers the system as a set of modules and connections between them. The designed system can be divided into the following modules: the main module of logical output, the module of analytical control of initial data; module for outputting the formed system of recommendations, a module for entering system user data;
- The principle of functionality - is to ensure the overall functionality of the system, namely, the functionality of entering the necessary user data, saving user reports;
- The principle of development should be laid down in the construction of artificial systems like the ability to improve and develop the plan while maintaining the quality, i.e., introducing specific new knowledge during the system's operation.

The above principles make it possible to reflect the characteristics of the construction of the system and take into account all the interrelated relationships between the elements. We will describe the essence of the system by the purpose, which determines the appropriate definition of the system and is specified using the goal tree [14].

According to the generally accepted system analysis methodology, the main goal is to create an information system for quality control of polyethene production. The ability to perform this task appears when all the available sub-goals will be fulfilled. From the top of the goal tree, which represents the primary goal, three branches divide the main goal into three corresponding sub-goals. The first sub-goal is "Checking each stage of production". At this stage, it is necessary to identify the characteristics of the sub-goal and form a structure of knowledge required for the system's effective operation. The selected sub-goal, in turn, is also divided into two lower sub-goals, the tasks of which are to design tools to test the shocks of the production process and create a logical model of the knowledge base with information about the state of the system.

The second sub-goal is "Control and change of parameters by artificial intelligence". The purpose of this branch is the quality analysis and its further control. This sub-goal is also divided into two lower sub-goals, namely: comparison of initial real parameters and nominal (tracks changes in data, analyzes them, and, based on them, conducts self-study to determine deviations from nominal parameters),

control and adjustment of input parameters system (based on the analyzed data decides to change the input parameters to maintain the required parameter of product quality).

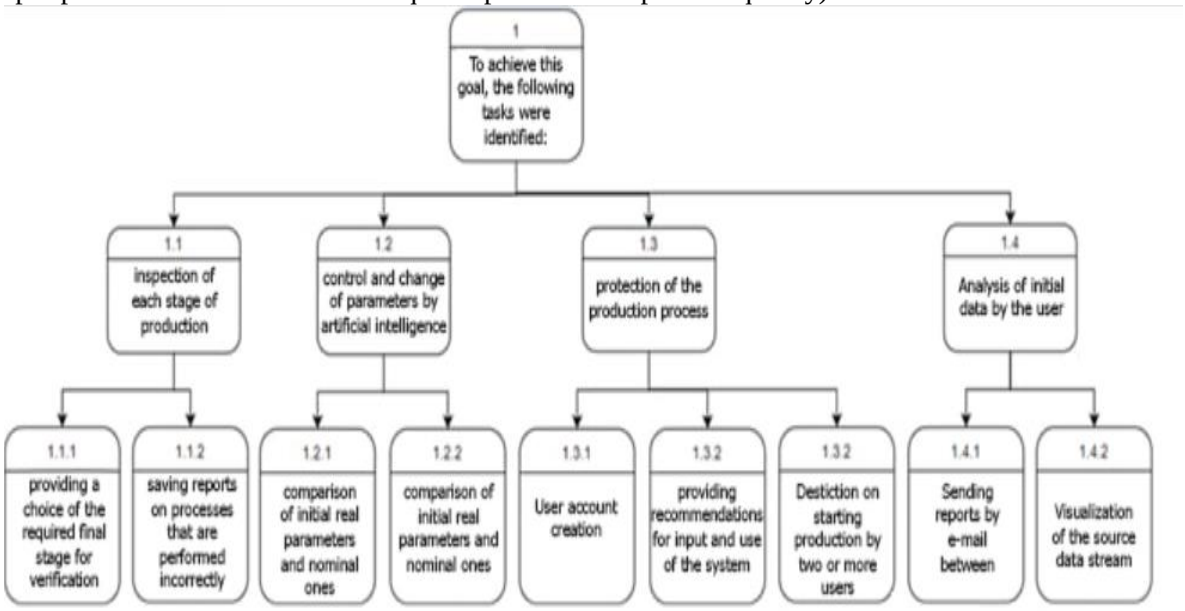

Figure 4: Goal tree

The third sub-goal is "Protection of the production process". This sub-goal aims to ensure the safe operation of the system and reduce the impact of the human factor on the system. This sub-goal is divided into three lower sub-goals: creating a user account (serves to link the user and the production process, analyzing its actions), providing recommendations for input and system use (reduces the intellectual login threshold for using the system), banning production two or more users (necessary to prevent the occurrence of illogical situations in the workplace, which, accordingly, can lead to critical consequences). The fourth sub-goal is "Analysis of initial data by the user". The purpose of this sub-goal is to provide user-friendly tools for data exchange and further analysis. This sub-goal is also divided into two sub-goals: sending reports by e-mail (allows you to report on the system's operation) and visualization of source data flow (provides tools for simplified output of individual information to the system user).

3.2. Concretization of system functioning

To specify the system's functioning, it is necessary to use a structural methodology with implementation in the form of a hierarchy of DFD or equivalent IDEF0. Each process, without exception, requires a unique environment for its construction. Based on the analysis of the necessary charting tools, it was decided to use the AllFusion Process Modeler environment. It has a straightforward user interface, all the functions needed for working with charts and supports three primary modelling methodologies: IDEF0, IDEF3, and DFD. From the list of these methodologies, it was decided to use the IDEF0 methodology to model the specification of the system's functioning because it allows you to explore the functions of the system without linking them to the objects that ensure their implementation. This approach in the performance of diagrams, in our case, most widely allows you to describe the system's operation [15]. First, a context diagram "Information system for quality control of polyethene" was created in the methodology IDEF0 (Fig. 5).

The department included:

- Manufacturing technology-specific is clear instructions to the user of the system, which can be issued both based on the generally accepted standards from technical documentation and based on the personal criteria defined by the head.
- Program algorithm - is a specific sequence of commands to the executor of this algorithm (in our case, the artificial intelligence of the system) aimed at solving a problem.

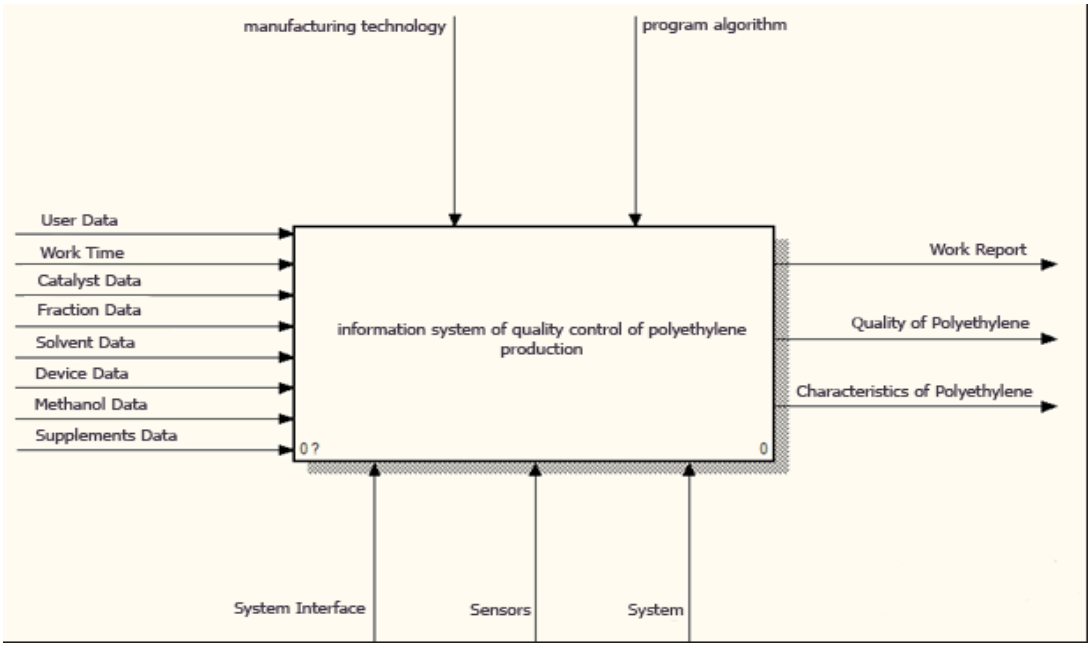

Figure 5: Context diagram IDEF0

The mechanisms for implementing the process are:

- A system interface is a specifically developed set of rules, methods and means of interaction (control, management, etc.) between the designed elements of the system, in compliance with the requirements for the interfaces of quality control systems.
- Sensors are specific measuring devices incorporating mechanical production control devices that produce output signals suitable for remote storage, transmission, and control or monitoring systems.
- The system is logical commands and means of artificial intelligence that can perform essential calculations based on data obtained from analyses or sensors to analyze, control and make appropriate changes in the production process.

Input data:

- User data is e-mail and password required to log in and continue working with it.
- Work time is the amount of time during which the active stage of the production process will be carried out.
- These factions are the basic unit of raw materials used in the manufacture of products.
- Catalyst data is the second most important unit of raw materials, which according to the technology, is used in a ratio of 1: 1 with the fraction.
- Solvent data is data required for chemical reactions.
- Device data value coming from sensors or other devices.
- Methanol data is data required for washing raw materials.
- These supplements - data required to specify the final classification of the finished product following the standards.

The result of the system will be:

- Work report - generated information on the system's operation for the production process, with all the necessary data about the user, the session and the final product.
- Characteristics of polyethene are the central values that are important in evaluating products and their classification.
- Quality of polyethene - is a certain quality of the finished end product, which is based on the calculated and obtained data on the characteristics of the final product, production process and manufacturing technology.

After creating and describing the context diagram, a functional decomposition was performed, i.e. the system was divided into subsystems, and each subsystem was described separately.

The context diagram was divided into four blocks (Fig. 6):

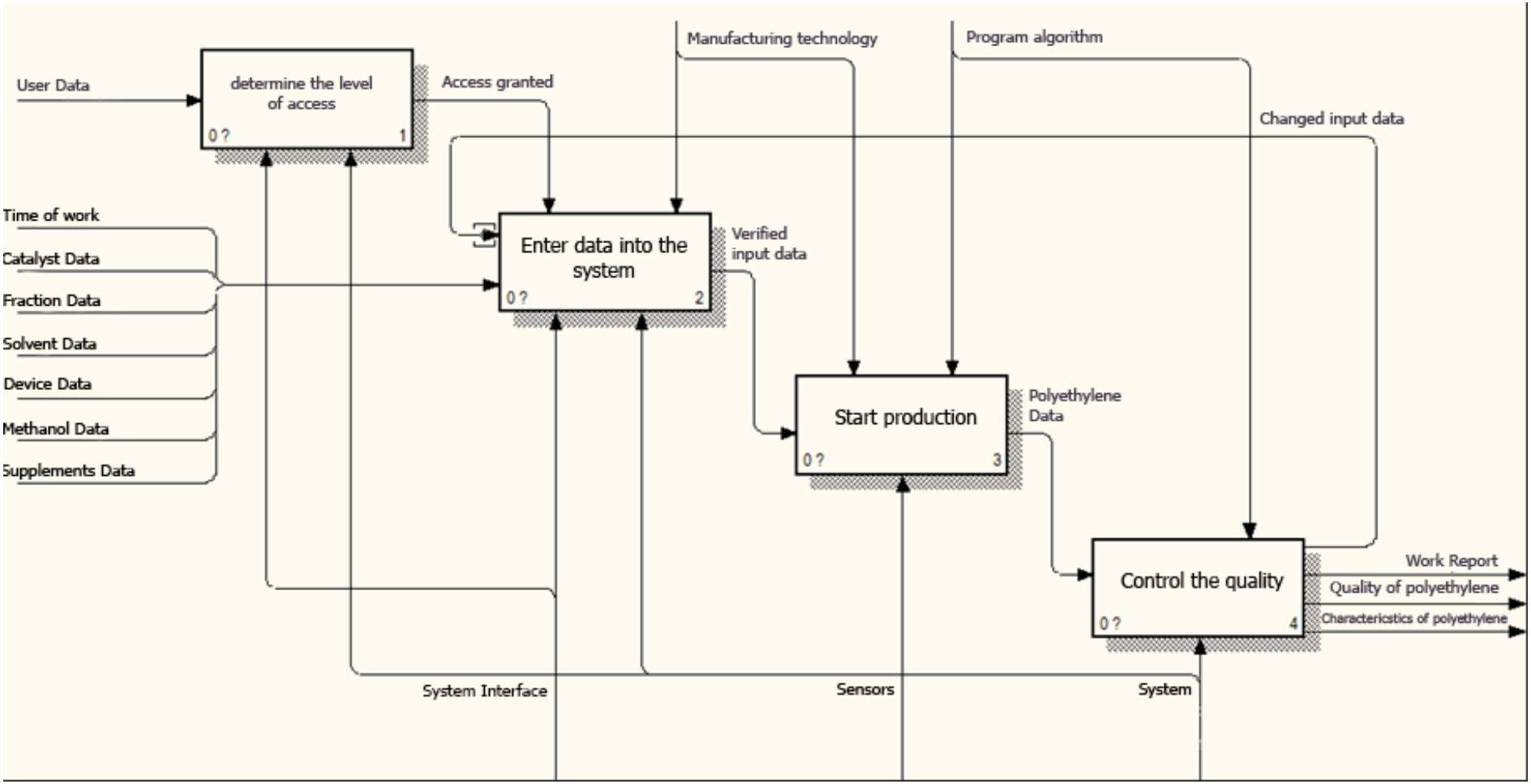

Figure 6: Decomposition of a context diagram

- Determine the access level - a unit responsible for protecting the system, providing access to authorized users and conducting verification by unregistered users.
- Enter data into the system - sets up the production of polyethene following a specific technology specified by the head, and is based on the input of data necessary for testing the system and for a complete start of production, to manufacture finished products.
- Start production- a unit during which the entire production process takes place. In performing this process, all stages occur linearly not to create a situation of uncertainty, which can have critical consequences for both the system and the enterprise's logistics.
- Quality control- unit, all management and analysis of which is based on artificial intelligence, which controls the quality of the final product by collecting and analyzing ready-made data, and based on them by setting new parameters that are within, according to pre-set production technology. In addition, it also decides on the emergency termination of production if the quality is outside the minimum allowable values [16].

After further partitioning the diagram, we obtain 4 more decomposition diagrams that describe each of the available blocks in the decomposition of the context diagram. The block decomposition "Determine the level of access" (Fig. 7) illustrates in detail the sequence of logging in. When user data is received from the system interface, a request is made to the SD to check the user's presence.

Suppose the user is present in the SD. In that case, the system makes an additional check for authority (it is determined whether another user starts the system) and then granted access to use the system. If the user data is not in the SD, the user is offered registration and further verification.

The steps that follow are similar to the steps for registered users. The decomposition of the block "Enter data into the system" (Fig. 8) details the process of setting the necessary data for the production process to manufacture polyethene or its editing. When granting permission to work with the system, the user can enter the primary data to manufacture polyethene or run a test of the production process.

After entering the primary data, it is possible to make these additives to start full-fledged production. In entering both primary and secondary data of products that will participate in the production process, the user must turn on the device, after which all processed data from each unit is checked. According to the result of the verification analysis, the system starts production with the verified data or provides instructions on adding or editing the input data. All operations performed and described in this decomposition diagram can be achieved by both the user and the system, except for the block "Enable devices", which is implemented only through the user, i.e. the system interface [17].

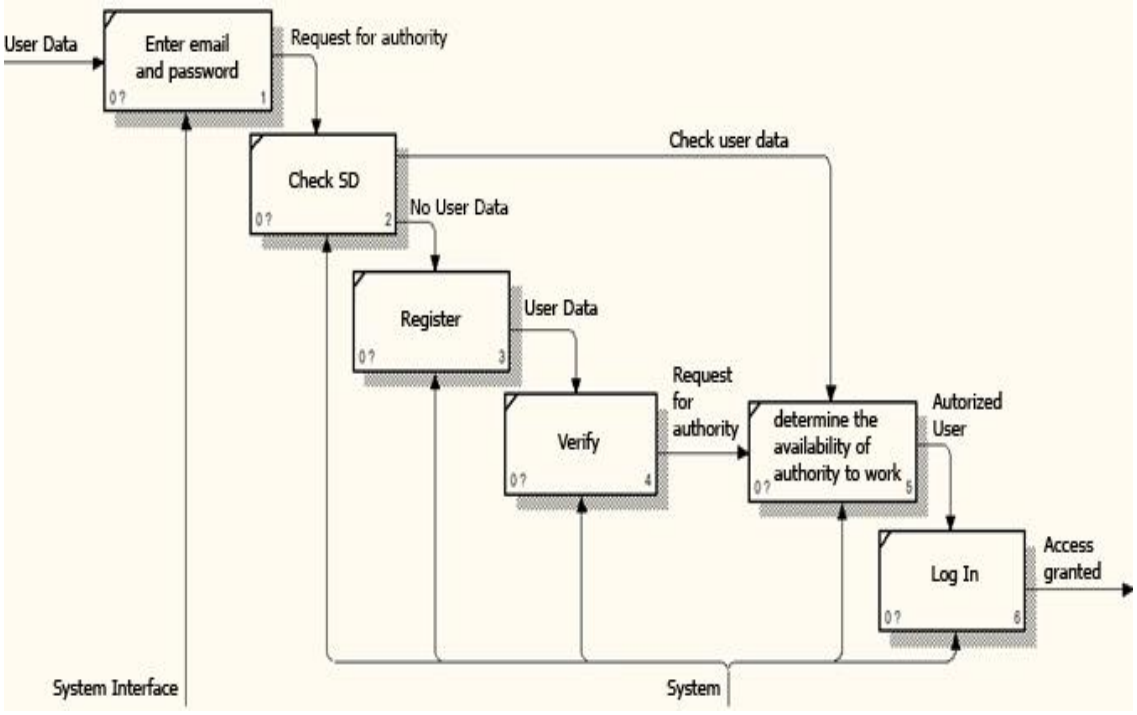

Figure 7: IDEF0 decomposition diagram "Determine access level"

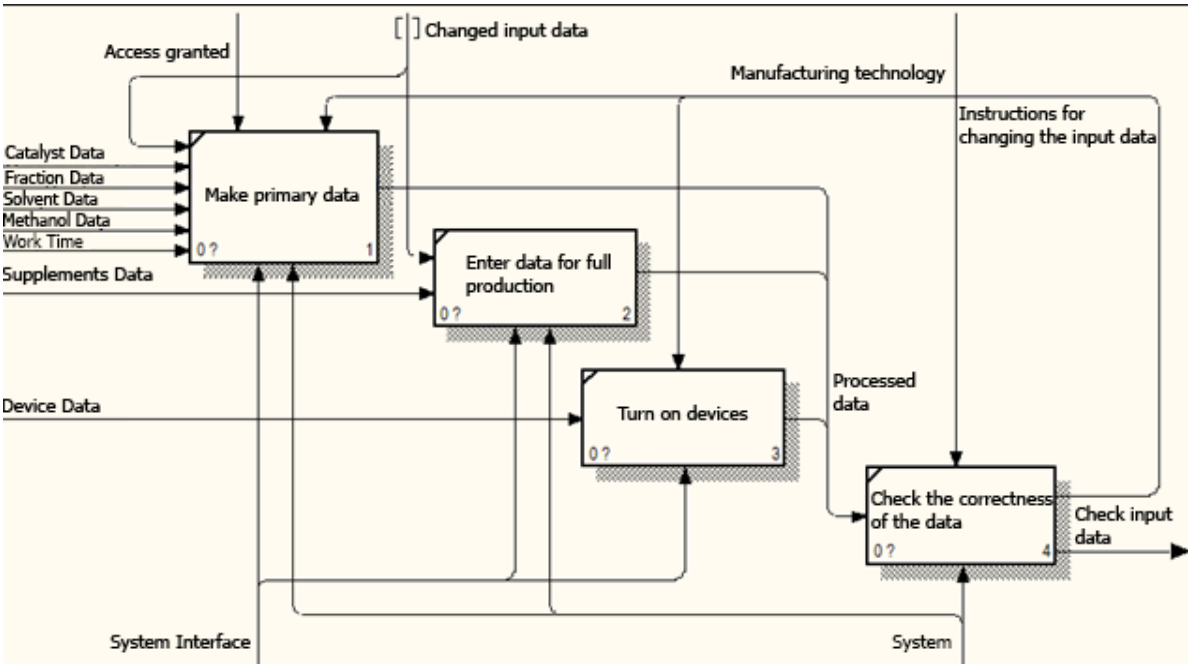

Figure 8: IDEF0 decomposition diagram "Enter data into the system"

The decomposition of the block "Start production" (Fig. 9) illustrates the production process, which is strictly linear and excludes any possibility of branching. After starting production, the verified data enters the polymerization process. In turn, the analyzed polymer data accordingly enters the process of washing from the catalyst. After performing this process, the data on the open-source is sent to the drying unit, which in turn provides the calculated data of polyethene. Only sensors are the mechanism for carrying out the processes in this "Start production" block [18].

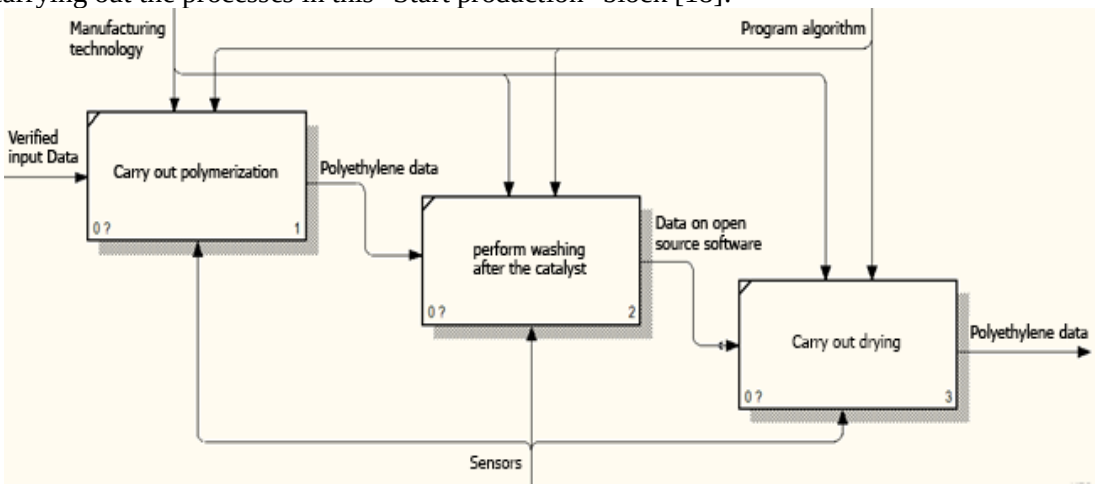

Figure 9: IDEF0 decomposition diagram "Start production"

The decomposition of the "Control Quality" block (Fig. 10) serves both for quality control and control of the general production process. Upon receipt of polyethene data, there is a comparison of genuine and nominal quality parameters. When the data has been verified, information about the polyethene is displayed to the user, namely data such as the quality of the polyethene and the characteristics of the polyethene. In addition, all data on polyethene are recorded in the SD.

In parallel, the same verified data are analyzed by artificial intelligence, and on their basis, the possible critical level of product quality is determined. If the system concludes that the quality level is less than necessary, there is an emergency shutdown and subsequent entry in the SD of the reason for termination. If the system assesses the quality level as permissible, the artificial intelligence determines the data be changed to maintain or improve the quality of the final product. After that, the modified input data is redirected to the block "Enter data into the system".

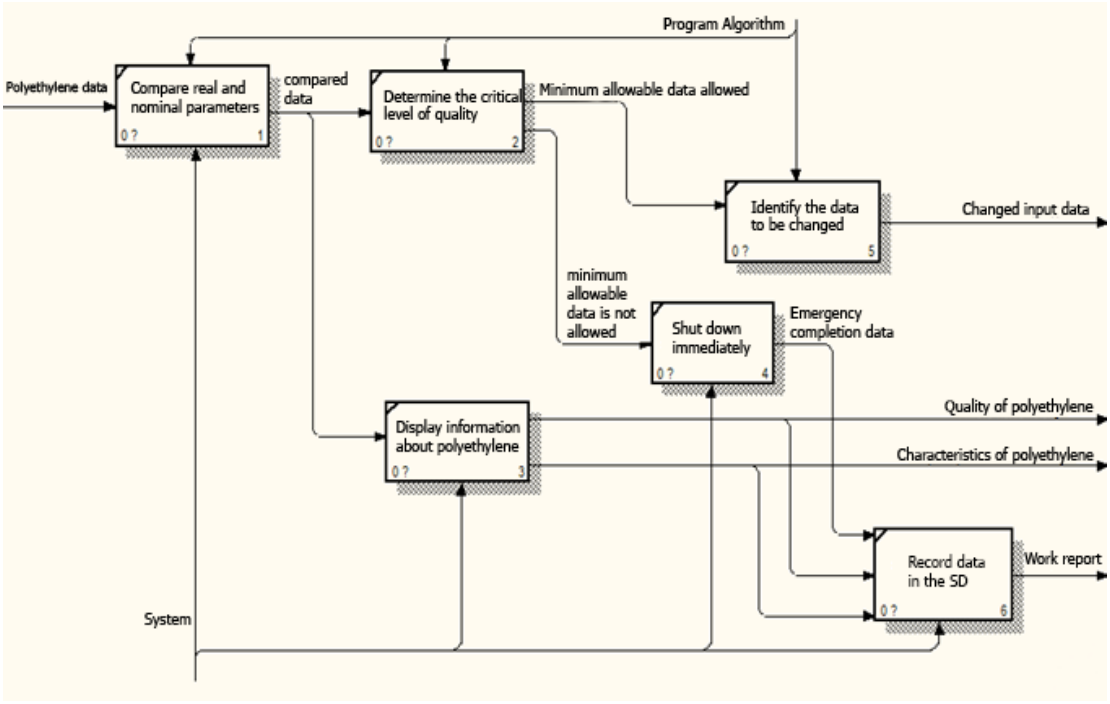

Figure 10: IDEF0 Quality Control Decomposition Diagram

All calculations, analysis and decision-making in the "Monitor Quality" block, and data change in the "Enter Data into the System" coalition, are performed by artificial system intelligence.

3.3. Building a hierarchy of processes

In order not to get confused and get lost in a large amount of information, and such to check the correctness of the decomposition, it is necessary after each change to create a diagram of the tree nodes. Representation of an information system in the form of a functional diagram is a common way to model the system's functionality. The node tree diagram depicts the entire work hierarchy in the model and allows you to view the whole model but cannot show the relationships between existing jobs (arrows). Creating a working model is an iterative process so that the work can repeatedly change its location in the designed node tree.

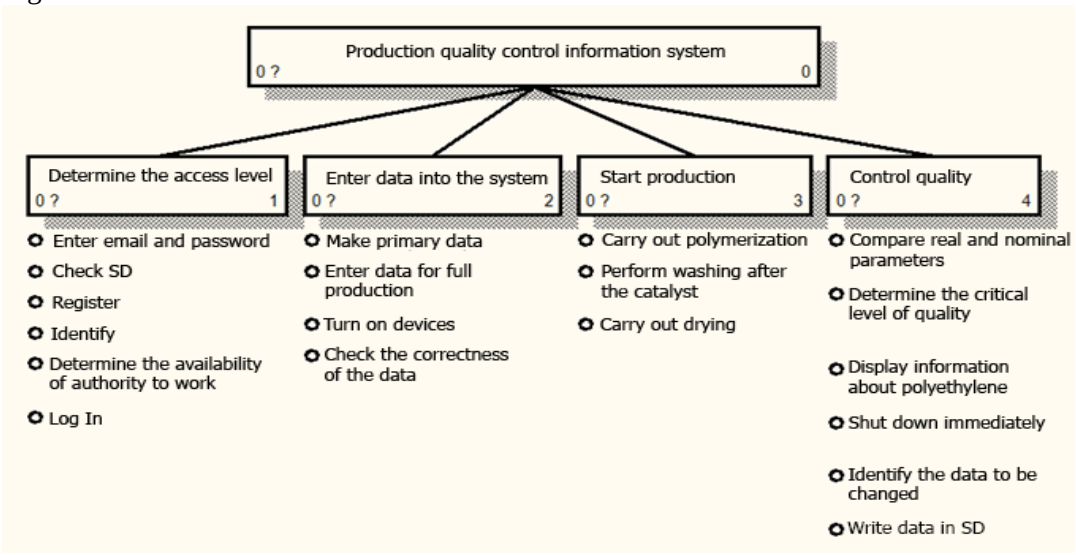

Figure 11: Node tree diagram

In this diagram of the university tree, the depth of the tree is three, and the root of the tree is the "Polyethylene Quality Control Information System", which in turn is the parent work of the diagram. The list shows the lower level of decomposition, but the rest of the results are depicted in rectangles. To fully display the tree using rectangles, you must disable the existing Bullet Last Level option. In this section, the principles of system construction and methodology of system analysis were determined. Based on this analysis, a goal tree was constructed, and each goal was described in detail. To specify the system's functioning, the methodologies for making IDEF0, IDEF3 and DFD are analyzed. After selecting the IDEF0 methodology using AllFusion Process Modeler, the information system analysis was performed by creating a context diagram "Polyethylene Quality Control Information System" in the IDEF0 methodology. All control tools, process implementation mechanisms, input data, and work results are described in the context diagram. Based on the related context diagram of the information system, the functional decomposition is carried out, i.e. the system is divided into subsystems, thus in each subsystem, all blocks and communications are separately described in detail, belonging to means of execution for blocks is specified. Also, for the information system of quality control of polyethene using the same means of modelling AllFusion Process Modeler, the diagram of a tree of knots represents all hierarchy of system processes with a depth of the graph, a root and stylization of diagram display is created. Based on all the system analysis, the collected requirements for the information system and the results obtained, we can move on to the next stage, namely the practical implementation of the system, using both software and hardware.

3.4. 3.1. Selection and substantiation of means of problem-solving

To build an information system for quality control of polyethylene production, it is necessary to use several industries for the most efficient operation of the system. Conventionally, the system can be divided into the part that implements the design, functional, and data warehouse. Several available solutions are provided for this purpose. The first and most primitive solution is implementing a system on HTML + CSS + JS with part of the backend in Python or PHP and a database connection. The principle of creating a page in this way is shown in Fig. 12.

Figure 12: Page structure based on HTML + CSS + JS

However, this solution is highly complex. It requires a lot of time, additional connection to the local hosting library, skills to optimize various system approaches to this code. It is somewhat outdated in terms of system performance, appearance and functionality. The next available solution is to build a CMS-based system. Content Management System, or Content Management System - is software that is used to provide additional functionality and the organization and structuring of websites, both in separate computer networks and in general on the Internet [19].

3.4.1. Analysis of the effectiveness of CMS-systems

There are hundreds and maybe even thousands of available CMS systems. Due to their advanced functionality, these systems can be used in various fields of human activity.

The main functions of modern CMS are:

- Generate the required web page at the request of the user;

- Managing both text and graphic blocks of content on the site, providing the user with a user-friendly interface;
- Providing convenient tools for publishing information on the site, as well as its further storage;
- Automation of all processes for the location of data in existing databases and its subsequent publication in HTML code;
- Preview a webpage for editing by one of the administrators;
- Providing tools for deleting or editing content;
- Consider the most popular of all CMS systems.

WordPress. Probably one of the most popular open-source content management systems, which is widely used to create websites due to its ease of deployment and application. Both blogs and complex websites are used. The existing built-in system with plugins and themes combined with a good architecture allows you to design almost any project. The system uses MySQL databases and is written in the PHP programming language. The source code is distributed under the terms of the GNU General Public License [20]. The advantages of the solution are:

- Convenient presentation of the interface, for its further perception by the person;
- Significant functionality (a large number of created templates and extensions);
- A simple system for deployment and further management;
- The disadvantages of the program are:
- The security system is quite vulnerable to current technologies;
- The possibility of failures and interruptions, with a high level of attendance;
- Low search engine efficiency;
- Limited writing of the system backend;
- Attachment of the system to the principles of construction based on templates.

Joomla! is an open universal system for content management and publication of necessary information on the Internet. This system is quite versatile and can solve problems ranging from creating personal pages to the implementation of Internet portals, online stores or corporate sites. Joomla features media management interface, flexible account management tools, support for multilingual page creation, advertising management system, user address book, voting, link categorization and site click accounting, built-in search, menu support, a system of templates, support for caching pages, as well as a fairly large set of ready-made applications. Joomla! Implemented using the MVC architecture in PHP. Uses a MySQL, PostgreSQL or MS SQL database to store information [21].

The benefits of the Joomla! are:

- Considerable convenience and simplicity when writing a website;
- A specific minimum set of source tools, which expand during further work with software packages;
- Providing support for the system in many languages;
- Created ready-made templates for other use;
- Constant updating of the system and its components accordingly.

Among the disadvantages of the system are:

- Some vulnerabilities in the security system;
- A relatively high load on the server;
- Low opportunities in writing your backend;
- Linking the system to templates and menu components.

Drupal is a flexible CMS based on the LAMP stack, using a modular structure that allows you to add and remove features through the installation and removal of modules and enable you to make changes to the site's appearance through the installation removal of design themes. The Drupal framework, also known as the Drupal kernel, contains PHP scripts required to run several plug-ins, themes, basic CMS functionality, and many CSS, JavaScript, and image files. In addition, this CMS system does not depend on the type of databases used and is suitable for those who, due to certain restrictions, cannot use MySQL, which implements support for most CMS. Drupal also includes tools for developing websites that support multiple languages accordingly. To perform the task of the web site's structure, separating it from the design, Drupal can provide taxonomy. Taxonomy - is the

definition of an arbitrary number of headings. Each document is included in one or more titles, which can be presented in a complex hierarchical structure or list [22].

The advantages of the Drupal system are:

- High functionality and flexibility. The variety of system modules allows you to create custom solutions that will meet all the expectations of visitors;
- Availability of free items for use;
- Availability of a large amount of literature to get acquainted with the system;
- Relatively low server load.

The disadvantages of Drupal operation include:

- Complex application on sites that are supported at cheap rates from hosting providers;
- High complexity at application;
- Relatively inefficient work with functions of objects of language PHP.

UMI.CMS is a commercial site management system (CM) written in PHP. Available in both free and commercial versions. Based on this system, sites of any subject and the sizes are realized. UMI.CMS requires small resources from the system and is operational on virtual hosting and cross-platform (i.e. runs on Microsoft Windows, UNIX, macOS, FreeBSD). It uses MySQL database, but there is the possibility of using other data sources and support for dynamic AJAX change loading technology. To perform communication with the database, a managed object model is used, on top of which a CMS is implemented. Perhaps the main ideological feature of UMI.CMS is a user-friendly interface. For example, the system supports changing the existing structure of the site using drag & drop. New versions use the method of editing the content of pages and page components directly on the site, without going to the dialogue interface or administrative interface. Behavioural technologies are used in UMI.CMS. The system allows you to track how the visitor moved while on the site, individually customize the ads. UMI.CMS uses both the standard XSLT template and the internal system [23]. Advantages of UMI.CMS:

- Ability to edit content online in a user-defined part of the site, without the need to use the admin panel;
- The toolbar in the browser. This feature allows you to receive the required message even when the administrator is not on the system;
- Quick correction if you enter the wrong URL. In the case of an incorrect address, the system will automatically find the most similar design. It will avoid the error message.

Disadvantages of UMI.CMS:

- High purchase and deployment price;
- Somewhat confusing interface;
- There was a small amount of official documentation;
- Limited in writing system backend.

NetCat. Commercial site management system. When creating the NetCat CMS, the main task set is to provide maximum comfort in the use of the engine for both experienced users and those who first encountered them. The site control panel allows access to all major features. Each page is customized using a visual editor, but if the user needs to implement any specific functions, the developers kindly provide detailed documentation. The company actively cooperates with many companies that offer extensions, additional modules and implement the necessary functionality. Even if the user initially has zero knowledge, he can quickly turn to official partners, who will easily launch even the most complex projects. If the user does not need anything supernatural, then you can safely use the built-in designer Landingham. Advantages of the NetCat system:

- *Providing high flexibility*. The CMS is presented in six editions, each of which includes functions of realization of sites of different types.
- *Multisite*. That is, one license in the system allows you to maintain a large number of sites at no extra cost.
- *Mobility*. NetCat allows you to create five different sites: business cards, stores, adaptive and mobile versions (for gadgets).

Disadvantages of CMS NetCat:

- The need for additional purchase of a virtual server from the moment of significant attendance of the resource;

- The high complexity of system settings for virtual companies and directories that use 1C;
- Quite a high purchase price compared to similar systems.

Let's generalise CMS systems according to the main parameters required for effective system creation: writing efficiency in FrontEnd, BackEnd, time-consuming, developer support, the efficiency of connecting additional development tools, availability and optimization.

Table 2
Comparison of the main characteristics of CMS systems

Name	WordPress	Joomla!	Drupal	UMI.CMS	NetCad
FrontEnd	Very low	Low	Low	Low	Low
BackEnd	Very low	Low	Very low	Very low	Low
Labor intensity	Very low	Very low	Low	Average	Average
Additions	Missing	Missing	Missing	Missing	Missing
Support	High	Average	Average	Low	Low
Accessibility	High	Average	Average	Very low	Low
Optimization	Very high	High	Average	Average	Average

After a detailed analysis of the effectiveness of CMS systems, and comparing them with the ability to implement a system in conjunction with HTML + CSS + JS with part of the backend in Python or PHP, it was decided that none of the options is suitable, as CMS save time when building systems, however, do not provide enough leeway to build a design from scratch. In addition, they require additional time for their development, the constant search for templates that will best fit the planned system. It is also worth noting that all CMS systems are built on the PHP language, which is rapidly losing its relevance in information systems development due to its poor optimization, low speed, and low functionality.

3.4.2. Analysis of the effectiveness of frameworks

Although CMS systems are very efficient for users who do not have development skills, they do not have the necessary flexibility to develop, may require additional financial costs, and are not effective in creating combined systems [24]. An alternative to this solution is the ability to use development frameworks. They include several elements that allow you to develop sites much faster and more efficiently and much more flexible to work with the system. Consider the most popular and influential of them.

ExpressJS. A framework that takes off on the wave of popularity of Node.js. It is now one of the most popular web development tools. It is used by large companies Accenture, IBM and Uber, and other frameworks, such as Kraken, Sails and Loopback. Express is positioned as a minimalist, fast and very flexible framework. It provides all the necessary features while actively using all the benefits and power of Node.js. Supports REST API. Perhaps the biggest drawback and at the same time the advantage of Express, especially for beginners - too much flexibility. The same thing can be done in different ways [25, 26]. Benefits of using Express JS:

- Express JS is based on JavaScript - one of the oldest platforms, and a vast community of developers supports it.
- Well documented.
- The framework provides rapid development using Node.js.
- The framework integrates with all the most popular database management systems (DBMS): MongoDB, MySQL and all popular template engines, such as Pug, HAML, EJS, compatible with Express.js.

Disadvantages of using Express JS:

- The framework does not offer security solutions.
- The structure of Express.js is somewhat vague and requires additional time to study.

Ruby. A popular framework with a classic Model-View-Controller structure. Successfully works in Airbnb, GitHub, Hulu and Shopify. The tool is loyal to beginners and has a low initial entry threshold.

However, it is worth taking the first few steps, and you will have to go too deep into this environment to master it. Another disadvantage is the complex process of deployment and launch on the production. To make working with the framework faster and more efficient, you have created many valuable packages and libraries to connect to your application. Rails-community is quite solid and friendly. In addition, the network has a lot of training resources on this tool [27].

Advantages of the Ruby framework:

- Development speed and flexible language makes it easy to use and allows you to solve the same problems in different ways. That is, we can say that it adapts as much as possible to the user.
- The main set of Ruby on Rails includes caching tools. Without any additions, the user is free to cache not only individual data but also entire pages.
- The user has many opportunities to find a huge number of ready-made solutions for any test, regardless of its type. In general, code in a programming language is not generated until tests have been developed for it.

Disadvantages of the Ruby framework:

- The language was initially created for Linux, so writing problems for Windows can cause some issues.
- The language was developed in Japan but later translated into English, which affected the problem with the actual localization.
- Creating projects through Ruby will take a considerable amount of memory. In addition, Ukrainian additions will only worsen the situation, so you should take this fact into account in advance and save extra space.

ReactJS is a library of components for web development. However, its significance is so great that historically no comparison is possible without it. It was React from Facebook that introduced the "fashion" for component architecture and virtual DOM. Development is carried out on a unique dialect of JavaScript - JSX. It is a mixture of the usual JS with the same typical HTML. And in general, it is a very interface-oriented tool that greatly simplifies working with a web page in the browser. React can be used not only on the client but also on the server-side. Supported by Instagram, Facebook, and the community of individual developers [28]. The advantages of ReactJS are:

- It is easy to learn. There is no need to study TypeScript in-depth, as is the case with Angular;
- Quite a high level of flexibility and maximum sensitivity;
- Contains an open-source JavaScript library that receives many updates and enhancements according to the needs of developers;
- Incredibly easy to load, as user-side data can be easily presented on the server-side;
- Migration between versions is usually straightforward.

The disadvantages of ReactJS are:

- There is a lack of official documentation.
- React does not have a characteristic clear purpose. It means that there is sometimes too much choice for developers, which brings some chaos and confusion;
- React requires an in-depth understanding of how to integrate the user interface into the MVC structure.

Angular. A framework that characterizes itself as a structural framework for creating dynamic web applications allows you to use HTML as a template language and then extend the HTML syntax for further expression of program components. By binding data and making dependencies, you can eliminate most of the code that would have to be generated. In addition, it is worth noting that Angular offers server-side rendering, which speeds up the loading of the home page and, therefore, improves SEO by simplifying the scanning of dynamic pages. The reasonably fast loading of pages significantly enhances the perception for the next generation of applications written within Angular [29]. Advantages of Angular:

- Includes new functionality such as improved RXJS, accelerated compilation and a new HttpClient launcher;
- Detailed documentation is available that allows each developer to obtain the necessary information without asking for help;
- Implemented two-way data binding, which ensures reliable behaviour of the application and minimizes the risk of possible errors;

- MVVM allows developers to work in one section of the program separately, using the same data set.

Disadvantages of Angular:

- It contains the complex syntax available from the first version of Angular.
- Significant version migration issues may occur when upgrading from the old version to the new version and adversely affect the system.

Let's make a general comparison of frameworks on the basic parameters necessary for effective creation of the system, namely: efficiency of writing to FrontEnd, BackEnd, complexity, support of developers, the efficiency of connection of additional means of development, availability, optimization, interaction with Node.

Table 3
Comparison of the main characteristics of frameworks

Name	ExpressJS	ReactJS	Ruby	Angular
FrontEnd	Low	Very high	Average	Average
BackEnd	Very high	Average	Average	Average
Labour intensity	Average	Low	Average	High
Interaction with Node	High	High	Low	Low
Additions	Present	Present	Missing	Missing
Support	Very high	Very high	High	Average
Accessibility	High	High	Average	High
Optimization	High	High	Very low	Low

After a detailed analysis of the frameworks and comparing them with previous CMS tools for building information systems, it was found that they are highly efficient and relatively easy to use. For further work with the system's front-end, the ReactJS framework was chosen, and for the main work related to the backend - ExpressJS with a connected Material UI data package and additional ExpressRouting tools. These other tools will help implement a modern interface in accordance with modern design requirements and build efficient routing for more straightforward navigation through the system.

3.5. Technical characteristics of selected software development tools

The main connecting software tools for information system development are ReactJS and ExpressJS. Since the main essence of the system is quality control based on artificial intelligence, the main focus should be on ExpressJS as a means of working with the backend. ExpressJS is the most popular web framework for Node. It is the base library for several other popular Node web frameworks and is used as the primary tool for working with the system backend. The main programming languages used in this framework are JavaSript and TypeScript [30]. While Express itself is pretty minimalist, the developers have created compatible middleware packages to solve almost any problem with web development. There are libraries for cookies, sessions, user logins, URL settings, POST data, security headers, and more. In addition, Express is not a restrictive framework, which provides ample opportunities to install in the chain of processing (middleware) requests almost any compatible intermediate components. You can also structure an application in a single file or multiple files using any directory structure. An image of the design of the ExpressJS framework based on NodeJS using the Visual Studio environment is shown in Fig. 13. To examine in more detail all the technical characteristics of the framework, we will conduct a detailed analysis.

3.5.1. The general principle of operation of Express

The web application expects an HTTP request from a web browser (or another client) in traditional dynamic websites. When a request is received, the application determines what action to take based on

the URL of the template and possibly related information contained in the data.POST or GET. Depending on what is required, Express can then read or write data from the database and perform other tasks according to the received request. The application then returns the response to a web browser, often dynamically creating an HTML page for the browser to display by inserting the extracted data into the HTML template filler. Express provides methods to specify which function is called for a specific HTTP request (GET, POST, SET, etc..), and the URL template ("Route"), as well as methods to specify which mechanism of the template ("view") is used where the file templates are and which template to use to display the response. You can use Express middleware to add support for cookies, sessions, and users receiving POST / GETparameters, etc. In addition, you can use any database mechanism supported by Node (Express does not specify database-related behaviour). The following subsections explain some general points that describe working with code in Express and Node in more detail.

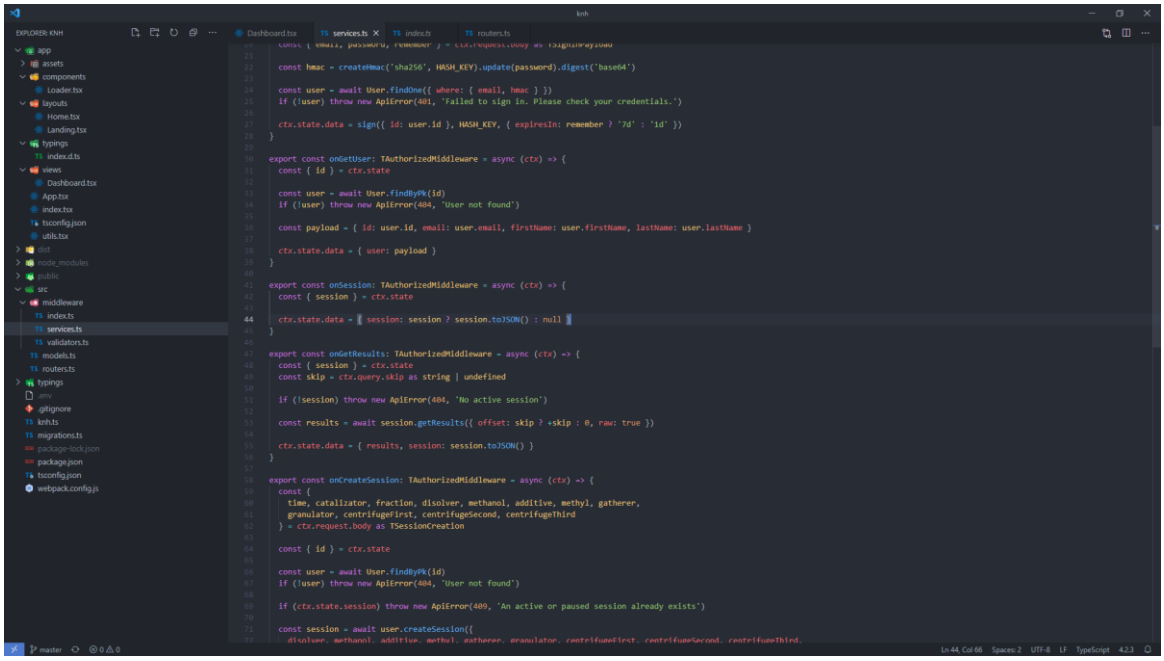

Figure 13: The structure of the Express framework

3.5.2. Import and create modules

A module is a library or JavaScript file that can be imported into another code using a function require ()Node. Express itself is a module, as are the middleware and database libraries used in Express applications. The following code shows how the primary import of a module by name is performed, using the Express platform as an example. The function is called firstrequire (), defining the module name as a string («Express») the returned object is called to create the Express application. After that, you can access the properties and functions of the application object.

```
var express = require ('express');
var app = express ();
```

In addition, it is also possible to create your modules that can be imported in the same way. To make objects available outside the module, you just need to assign them to the export object.

3.5.3. Using asynchronous APIs

In the Express JS framework, JavaScript code often uses asynchronous rather than synchronous APIs for operations that can take a long time to complete. A synchronous API is one in which each operation must complete before the next. For example, such functions of the log are synchronous and display the text on the console in order (first, second).

```
console.log ('First');
console.log ('Second');
```

In contrast, an asynchronous API is when the API starts an operation and returns immediately (before the operation completes). Once the process is complete, the API will use some mechanism to perform additional functions. The use of non-blocking asynchronous APIs is even more critical in Node than in the browser because Node is a single-threaded event-driven event. "Single-threaded" means that all requests to the server are executed in a single thread (rather than generated in separate processes). This model is highly efficient in terms of server speed and resources. Still, if any of the functions call synchronous methods, which take a long time to perform, they will block not only the current request but also any other request processed by a web application.

There are several ways in which the asynchronous API notifies your application that it has completed. The most common way is to register a callback function when calling an asynchronous API, which will be named after the operation is completed.

The Express object also provides methods for determining route handlers for all other HTTP verbs that are generally used in the same way: post (), put (), delete (), options (), trace (), copy (), lock (), mkcol (), move (), purge (), propfind (), proppatch (), unlock (), report (), mkactivity (), checkout (), merge (), m-search (), notify (), subscribe (), unsubscribe (), patch (), search () and connect (). Routes allow you to map certain character patterns to a URL, extract some values from the URL, and pass them as parameters to the route handler (as attributes of the request object passed as a parameter).

For example, using the routing function:

```
var wiki = require ('./ wiki.js');app.use ('/ wiki', wiki);
```

The route module (wiki.js) is provided to use the router, with a call to use () in the Express application to add the router to the middleware processing path.

3.5.4. Use of middleware

Intermediate software is widely used in Express applications for tasks ranging from static file maintenance to error handling and HTTP response compression. Given that routing functions complete the HTTP request-response cycle by returning some response to the HTTP client, middleware functions typically perform some operation on the request or response and then call the following position in the stack, which may be signs of middleware. or route handler. The procedure for calling middleware depends on the program developer. Most applications use third-party middleware to simplify everyday web development tasks, such as working with cookies, sessions, user authentication, accessing POST and JSON request data, logging, and more.

To use third-party middleware, you must first install it in your application using NPM. You can then call use () for the Express application object to add middleware to the stack:

```
var express = require ('express');
var logger = require ('morgan');
var app = express ();
app.use (logger ('dev'));
```

In addition to the above, you can write and add your middleware features to the processing chain using app.use () or app.add (), depending on whether you need to apply the middleware to all responses or responses from a specific verb HTTP (GET, POST, etc.).). Routes are set the same in both cases, although the route is optional when calling app.use ().

3.5.5. Maintenance of static files

Express allows the user to use the express.static middleware to maintain static files, including images, CSS, and JavaScript (static is the only feature of the middleware that is part of Express). For example, you need to use the line below to service images, CSS files, and JavaScript files from a directory named public at the same level where the node is called:

```
app.use (express.static ('public'));
```

You can call static () multiple times to serve multiple directories. If the file cannot be found by one function of the middleware, it will simply be transferred to the next middleware:

```
app.use (express.static ('public'));app.use (express.static ('media'));
```

You can also create a virtual prefix for static URLs instead of adding files to the base URL. For example, specify the mount path so that files are loaded with the prefix "/ media":

```
app.use ('/ media', express.static ('public'));
```

It is then possible to download files in the public directory from the / media path prefix.

3.5.6. Error handling

Errors are handled by one or more special features of the middleware, which have four arguments instead of the usual three: (err, req, res, next). example:

```
app.use (function (err, req, res, next) { console.error (err.stack);
 res.status (500) .send ('Something broke!');});
```

They can return any required content but must be called after all other app.use () and route calls so that they are the last intermediate software in processing requests.

Express comes with a built-in handler. This intermediate default error handling feature is added to the end of the middleware feature stack. If the user passes the error to next () and does not process it in the error handler, it will be processed by the built-in error handler, and then the error will be written to the client with a stack trace.

3.5.7. Use of databases

The Express framework can use any database mechanism supported by Node. There are many options, including PostgreSQL, MySQL, Redis, SQLite, MongoDB, etc. To use them, the user must first install the database driver using NPM. For example, to install the driver for the popular NoSQL MongoDB, it must use the command:

```
$ npm install mongodb
```

The database itself can be installed locally or on a cloud server. Another popular approach is indirect access to the database using the Object Relational Mapper ("ORM"). This approach defines its data as "objects" or "models", and the ORM maps them to the base database format. This approach has the advantage that, as a developer, the user can continue to think in terms of JavaScript objects rather than database semantics. There is a prominent place to perform input validation.

The PostgreSQL database was chosen for this system due to the functions that allow some code to be executed directly by the database server. These functions can be written in SQL, which has some primitive software statements such as branches and loops. But the process documented in one of the programming languages that PostgreSQL can work with will be more flexible [31].

PostgreSQL environment image shows in Fig. 14.

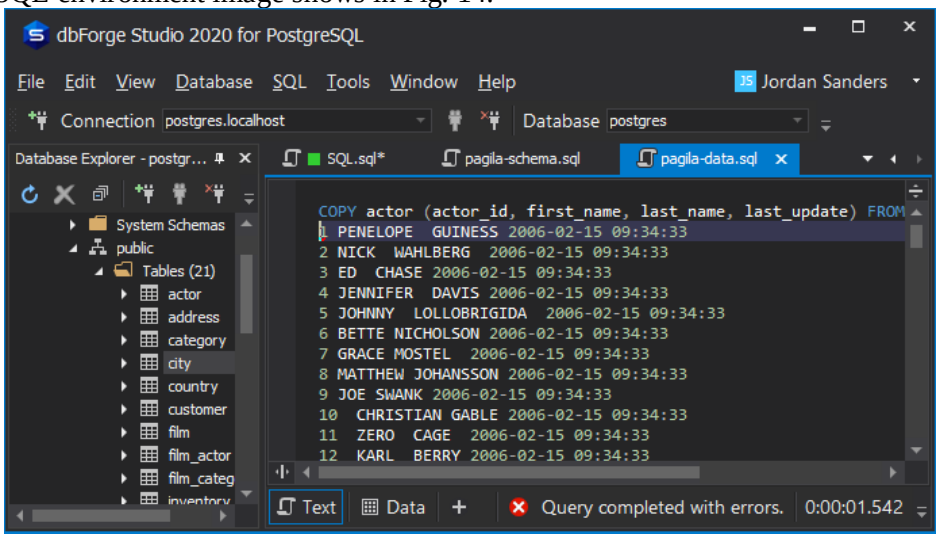

Figure 14: PostgreSQL environment

PostgreSQL programming languages include:

- Built-in language is similar to Oracle's PL / SQL procedural language.
- Scripting languages: PL / Perl, PL / Python, PL / Tcl, PL / Ruby, PL / sh.
- Classic programming languages C, C ++, Java (using PL / Java).

Functions can be performed with the privileges of the user who called it or with the privileges of the user who wrote it.

3.5.8. Data visualization

Template mechanisms in Express allow you to specify the structure of the source document in the template, using placeholders for the data populated when the page is created. Templates are often used to create HTML but can also create other types of documents. Express has support for several template engines, and here is a useful comparison of more popular engines: Jade, Mustache, Dust and More. The program settings code provides the ability to specify template mechanisms to use and where Express should search for templates using the "views" and "engine" settings, as shown below:

```
var express = require ('express');
var app = express ();
app.set ('views', path.join (__ dirname, 'views'));
app.set ('view engine', 'some_template_engine_name');
```

The appearance of the template will depend on which engine is used. Assuming there is a template file named "index. "Template_extension>", which contains fillers for variable data named "title" and "message", the user must call Response.render () in the route handler function to create and send an HTML response. :

```
app.get ('/', function (req, res) {
 res.render ('index', {title: 'About dogs', message: 'Dogs rock!'});
});
```

3.5.9. File structure

Express makes no assumptions about the structure or components used by the user [32-37[. Routes, views, static data, or other application-specific logic can be in any number of files with any directory structure [38-43]. While it is possible to have all Express programs in one file, it usually makes sense to split the application with files based on a feature (such as account management, blogs, discussion boards) and a problem area of the architecture (such as a model, view, or controller) [44-47]. This aspect of the file structure gives additional flexibility to the developer and increases the efficiency of his work several times. Of course, for beginners, there is the option of using Express Application Generator, which creates a modular application framework that can be easily extended to create web applications.

After a detailed analysis of all available tools for building web systems, such as frameworks, CMS systems and standard links based on HTML + CSS + JS, it was decided to choose the framework's application. This decision is based on several factors. The first factor is the faster build speed of the system than the usual HTML + CSS + JS. In contrast to classical construction methods, Frames are built to speed up the work and reliability of the system, save developer time, and minimize its errors. Although CMS tools allow you to develop strategies faster than using frameworks, they are minimal, which leads to the second factor in the choice of implementation tool. CMS systems do not allow significant changes to the selected template in the frontend and generally minimize differences in the backend system. Based on the fact that the system must operate on a backend that contains artificial intelligence and have an HMI interface, which should be convenient for users coming from any device, it is obvious to use frameworks. Considering all the pros and cons that were analyzed for each of the frameworks, ExpressJS was chosen for the backend and ReactJS for building the system's font. ExpressJS is the optimal and most effective way to develop strategies that contain complex backend tools. ReactJS is the most popular tool for building applications and visualizing systems so that developers can create creative, non-template interfaces. ExpressJS also can connect additional tools that facilitate the development of the system and make it more reliable. It is worth noting that the selected frameworks work well with each other, and based on their interaction, there are no errors. In addition,

the PostgreSQL database was chosen for data collection and storage operations, which, together with the ORM connection, will provide good performance with the system and perform all the necessary functionality.

4. Experiments, results and discussion

4.1. Description of the created software

The developed information system for quality control of polyethene is quite complex in its structure and content. To understand the principle of its operation, it is necessary to conduct a detailed analysis of the logical design, functionality and communication of the elements of the system, which are interconnected. In addition, given that the system can expand and develop, there is a need to describe the created software to further provide information to new developers, technical support, testers or other stakeholders.

4.1.1. Functional purpose

The functional purpose of the system is to control artificial intelligence product quality in real-time by detecting defective products at an early stage and establishing compliance with product requirements and processes to the provisions of regulatory and technical documentation, samples, standards, and thus prevent the production of substandard products.

In addition, it is providing users of the system with complete information about the production process and maintaining its stability. Minimizing the need for user intervention in the production process will reduce the impact of human error and increase the efficiency of the information system. It is providing opportunities for communication within the system about the production process.

The powers of artificial intelligence and the user are essential. Although the user is limited in his actions, and his influence on the system becomes minimal after setting the parameters for the product. Still, it has the opportunity to suspend the production process or complete it early.

4.1.2. Description of the logical structure

The logical structure of each information system can be represented based on four basic models: a linear model, a "lattice" model, a tree-like model and a "web". It is worth noting that there are additional combinations based on the basic models that allow the implementation of any logical structure of the site. Since, as mentioned above, the information system is quite complex, and the development of such a resource is a troublesome job, the availability of an optimal structure will minimize the possibility of technical errors. It applies to both code errors and the presence or absence of individual pages and materials on them. Given these factors, a logical tree structure was chosen. A logical tree structure is the most popular model of system organization. This structure allows system users to control the depth of system visits at will. Users can enter only the pages of the highest levels or "descend" to the lower levels. The available choices depend on the "width of the tree".

If users need to perform too many mouse clicks to achieve the end goal, the structure of the system hierarchy may be too narrow in this case. At the same time, endless "clicking" will irritate users, given that their actions do not bring the expected results. At the same time, an extensive "tree", which is based on a relatively large number of choices, will force system users to spend a significant amount of time studying the options provided. It will also not give positive results. Considering these factors of the logical structure of the system, the creation of the optimal level of depth and width was carried out. The graphic image of the logical tree-like structure of the system is shown in Fig. 15.

It is also worth noting that an important role in the speed and operation of the system is played by the file structure, which is also a tree. The basis of the file structure is the main folder with the name of the system, which contains the following main directories and files:

- ./app is the directory that contains the files that form the basis of the system frontend.
- ./dist - directory with transposed backend source (from TS to JS).

- ./node_modules - contains libraries of the NodeJS platform.
- ./public is a compiled build of the front-end (build), which is available for public access to users and static files of the system.
- ./src is the directory that contains the backend source code.
- ./typings - a directory that contains a description of objects and types of the entire application.
- ./env - a file that contains the key parameters for launching the application.
- ./knh.ts is a file that is the entry point for starting the backend.
- ./package.json - a file containing a description of the libraries required for the application.
- ./tsconfig.json - TypeScript compiler configuration file.
- ./webpack.config.js - Webpack Bundler Configuration Configuration File.

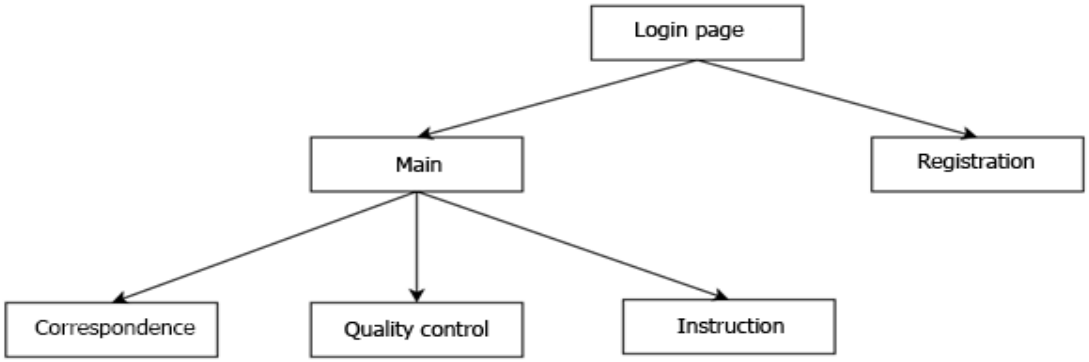

Figure 15: Logical structure of the system

4.1.3. General information about the development tools used

An essential point for understanding the information system is software tools for solving problems described in the third section. Due to the opportunities they provide, several additional tools have been selected that allow implementing specific options in developing the system while increasing its reliability. A list of all connected system development tools can be found in the package.json file, the contents of which are in Appendix A. To get a complete idea of the system's capabilities, we will describe all the features of the system with connected tools:

- FrontEnd and BackEnd are implemented in the TypeScript programming language, a superposition of the JavaScript language.
- BackEnd is based on the ExpressJS framework. A detailed description of this framework is given in the third section.
- The system server runs on the NodeJS platform and has access to all sensors in the enterprise to implement their control to manufacture high-quality products.
- The user interface is based on a web application. It is software that works in a browser and, therefore, system users are not tied to the workplace but can open the system from any portable device (phone, tablet, laptop).
- The web application is a SPA (Single Page Application) application written on the ReactJS framework. SPA is a web application or website that fits on one page to provide the user with an experience close to using a desktop program.
- When implementing the system, a bundle was used, i.e. a program that combines a set of program files and data into one and is contained in the bundle.js file.
- For faster and easier web development, the Material-UI library was used on top of the ReactJS framework, which contains several graphical and dynamic elements that make high-quality visualization of the system and increase its presentability.
- Because different browsers support different sets of JavaScript instructions, it was decided to use the Babel transponder. In general, a transpiler is a program that allows you to change the source code of one program to an equivalent source code in another language. In the case of Babel, it rewrites modern Javascript to the old one to open the system on older versions of browsers.

- The JWT standard programmed authentication. The JSON Web Token is a JSON-based access token standard standardized in RFC 7519. Used to verify, encrypt, and transmit authorized user data between an authentication provider and a service provider.
- The database is a relational database PostgreSQL. The PostgreSQL server is written in C. It is usually distributed as a set of raw text files.
- For easy use of the database, ORM (Object-relational mapping) technology was used. This technology links the database to the concepts of object-oriented programming languages, providing a "virtual object database" and creating queries to the database, object-oriented programming languages.

4.1.4. Call and download

To work on the Internet for users in the usual mode, the system administrator must perform several vital steps with the system boot and deployment. After completing the development of the system and testing its functionality on local hosting, you need to deploy the system for broad access. First of all, you need to compile both FrontEnd and BackEnd. Kteam "npm run build", we translate the backend source code from TypeScript into JavaScript, which NodeJS can already interpret, after which the Webpack bundler will start working, which in addition to transforming TS into JS, will convert ECMAScript 2015+ code into a reverse compatible version of JavaScript for older browsers or environments. The main backend file to which the transpilation is involved is knh.ts:

```
import Express from 'express'
import {api} from './src/routers'
import {requestHandler} from './src/middleware'
const {PORT} = process.env
new Express ()
 .use (requestHandler)
 .use (api.routes ())
 .listen (PORT, () => console.log ('Ξ Launching @KNH'))
```

Further work of the backend is started by the command “node dist / knh.js”. In the case of a "live" server, the PM2 program was used. Process Manager 2, is open-source software developed by Node.js and is a process manager that helps developers manage Node.js. Compared to other process managers such as Supervisord, Forever, Systemd, the critical features of PM2 are automatic program load balancing, declarative program configuration, deployment system and monitoring.

The script for calling knh.js as well as additional information about the system configuration is described in the file ecosystem.config.js:

```
module.exports = {
 apps: [{ name: 'knh', script: './dist/knh.js', instances: 1,
 max_memory_restart: '128M', log_date_format: 'MM / DD HH: mm',
 env: { PORT: 8007,
 HASH_KEY: '7 + frf9pyVhQLOyw5YYdOMAso08c9hdOl',
POSTGRESQL: 'postgres: // username: password @ localhost / knh' } }]}
```

Based on this file, you can see the primary key and information that the backend is served on the internal port 8007, using Nginx as a reverse proxy (to access the system through external ports 443/80).

4.1.5. Incoming data

In its operation, the system uses several input data to perform quality control functions of polyethene. The input data of the system include: Working time of the production process; Catalyst; Faction; Solvent; Methanol; Additives; Methyl alcohol; Technical means. For their proper functioning, it is necessary to implement data validation contained in the file validators.ts:

```
export const validateSessionCreation: IMiddleware = async (ctx, next) => {
```

An important step is to destruct the input data in this file, from the body of the request for local variables:

```
    const {time, catalyst, fraction, disolver, methanol, additive, methyl,
  gatherer, granulator, centrifugeFirst, centrifugeSecond, centrifugeThird} =
  ctx.request.body as TSessionCreation
```

After that, the presence of variables is checked (in case the variables are missing, the system sends an error with code 400 and the corresponding message):

```
    if (time === void 0 || catalyst === void 0 || fraction === void 0 || disolver
  === void 0 || methanol === void 0 || additive === void 0 || methyl === void 0
  || gatherer === void 0 || granulator === void 0 || centrifugeFirst === void 0
  || centrifugeSecond === void 0 || centrifugeThird === void 0) throw new
  ApiError (400, 'Missing required fields')
```

The next step is to check the compliance of the types of variables (if this compliance is not confirmed, the system sends an error code 400 and a characteristic message):

```
    if (typeof time! == 'number' || typeof catalyst! == 'string' || typeof
  fraction! == 'string' || typeof disolver! == 'number' || typeof methanol! ==
  'number' || typeof additive! == 'number' || typeof methyl! == 'boolean' ||
  typeof gatherer! == 'boolean' || typeof granulator! == 'boolean' || typeof
  centrifugeFirst! == 'boolean' || typeof centrifugeSecond! == 'boolean' ||
  typeof centrifugeThird! == 'boolean') throw new ApiError (400, 'Type mismatch')
```

The last element of the file is to check the hardware, as well as the limits of the value of the input data, and the admissibility of their completion:

```
  if (time <1 || time> 240) throw new ApiError (400, 'Bad time value')
  if (+ catalyst <1 || + catalyst> 1000) throw new ApiError (400, 'Bad catalyst
value')
  if (+ fraction <1 || + fraction> 1000) throw new ApiError (400, 'Bad fraction
value')
  if (disolver <1 || disolver> 100) throw new ApiError (400, 'Bad disolver value')
  if (methanol <1 || methanol> 100) throw new ApiError (400, 'Bad methanol value')
  if (additive <1 || additive> 100) throw new ApiError (400, 'Bad additive value')
  if (centrifugeThird && (! centrifugeSecond ||! centrifugeFirst)) ||
(centrifugeSecond &&! centrifugeFirst)) throw new ApiError (400, 'Bad centrifuge
configuration')
  return next ()}
```

After data validation, it becomes advisable to further work with the input data, which is described in the file services.ts:

```
    export const onCreateSession: TAuthorizedMiddleware = async (ctx) => {
```

When performing an export, the input data from the request body for local variables is destructured:

```
     const {
   time, catalyst, fraction, disolver, methanol, additive, methyl, gatherer,
     granulator, centrifugeFirst, centrifugeSecond, centrifugeThird
     } = ctx.request.body as TSessionCreation
  const {id} = ctx.state
```

We receive object of the user or we return an error if such does not exist:

```
   const user = await User.findByPk (id)
    if (! user) throw new ApiError (404, 'User not found')
```

We perform an inspection and determine the state of the production process. If the process is active - we receive a characteristic message, if the session is not active we create a new session:

```
    if (ctx.state.session) throw new ApiError (409, 'An active or paused session
  already exists')
   const session = await user.createSession ({
         disolver, methanol, additive, methyl, gatherer, granulator,
      centrifugeFirst, centrifugeSecond, centrifugeThird,
        time: time * 60, timeLeft: time * 60, catalyst: + catalyst, fraction:
      + fraction, status: 'active'})
```

We start production, with the issuance of results every two seconds. Then return the user to the session:

```
    createSimulation (session, 2000)
    ctx.state.data = {session: session.toJSON ()}}
```

4.1.6. Output data

The basis for any reporting and analysis of the production process is the source data. In this case, they are depicted as a treadmill, during which the user's client asks the server every two seconds for new results. At the end of the session, even if there is an emergency termination, all source data is recorded in the appropriate database of the system, which can then be viewed, analyzed and reported.

Working with the source data is described in the services.ts file and has the following structure:

We export, and state the session. The skip parameter indicates the number of results to skip from the beginning of the tape list:

```
export const onGetResults: TAuthorizedMiddleware = async (ctx) => {
 const {session} = ctx.state
const skip = ctx.query.skip as string | undefined
```

We check the presence of the session, and then perform a query to the database to obtain results (with the possible "skip" of the first results):

```
if (! session) throw new ApiError (404, 'No active session')
const results = await session.getResults ({offset: skip? + skip: 0, raw: true})
```

The last step is to return the results to the system user:

```
ctx.state.data = {results, session: session.toJSON ()}}
```

4.1.7. System database

The database is created to store information about the users of the system and the source data of the production process, which is tied to the user. As mentioned above, the query to the database is performed using ORM technology, and the database itself is created using PostgreSQL.

The database contains three tables, namely:

- Users. This table contains information about the user, such as user id, email address, name, surname, creation date.
- Session. This table contains a session ID, user id, session status, session information, input information, and hardware.
- The result includes result id, session id, and system output.

Users treat Session as one to many. In turn, Session is related to Result also one-to-many. Graphical representation of the ER diagram of the database is shown in Fig. 16.

Figure 16: ER-diagram of the information system database

4.2. User manual

Each information system, regardless of complexity, has a set of rules and requirements for its use. It is logical that the larger the system, the harder it is for the average user to work with it, especially in the initial stages, which are characterized by familiarity with the system.

A user manual is necessary for a polyethene production quality control information system because it helps users effectively start and control production. Because the developed system has full access to the production process, improper use, although it can not cause fatal consequences for the technical means of production (given the control of artificial intelligence), erroneous user actions can lead to a shortage of manufactured products. Given the ease of use of the system, all the necessary instructions for the user are directly in the system itself, on a dedicated page, which can be accessed from the main menu by clicking on the appropriate link (detailed image of the relations between pages is shown in Fig. 17). This solution will allow the user to refer to the instructions regardless of his location in production and make effective decisions quickly. Navigation on the system's main menu is shown in Fig. 17 and is on the left (highlighted in red and numbered one). The beginning of the system is in the middle and is a "START" button (numbered two).

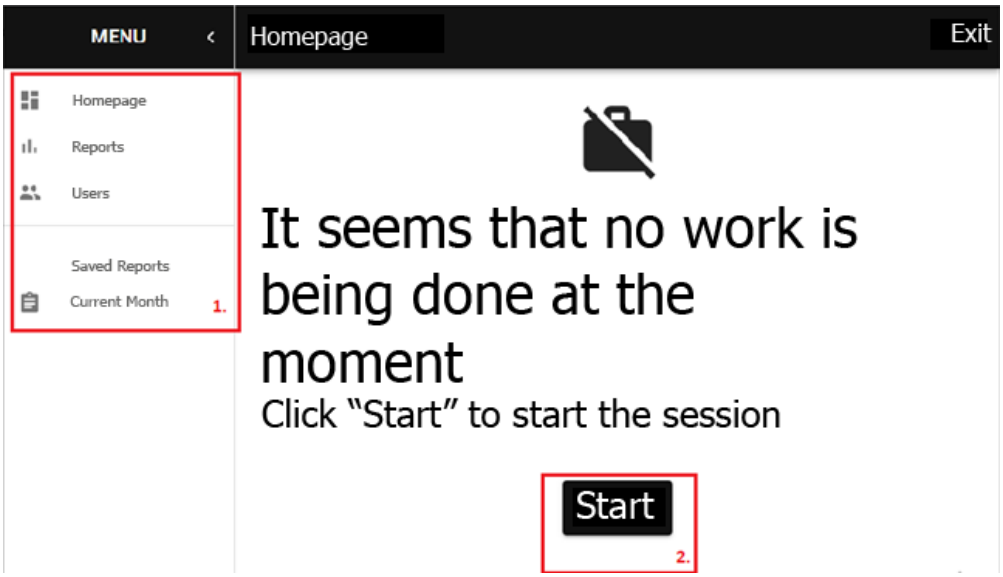

Figure 17: Main menu navigation

4.2.1. Classes of solved tasks

The information system contains three classes of tasks. Following the requirements of the user manual, we will provide a detailed description of each of the functions and precise ways to perform them.

1. *Quality control of polyethene.* This process requires the user to correctly enter the parameters to manufacture products of the required quality following the received documentation with instructions on the products necessary.

The following steps are required to perform this operation:

- Get a document that clearly states the parameters of the product to be manufactured.
- According to the document, fill in each field with the required parameter.
- Include all technical means of production.
- Start production.
- Conduct production analysis. If instructed to do so, suspend or stop production altogether.
- Wait for the production to be completed, and finish the session.

2. *Checking each of the stages of production.* This process is critical, as it allows the initial diagnosis of the entire production process to identify the gap in the manufacture of products on which the system ceases to work correctly.

Thanks to this process, you can easily detect a non-working device, configure a new device, conduct training to work with the system without starting the complete production cycle.

The following steps are required to perform this operation:

- Get a document that allows you to start the production process partially.

- Following the document, fill in the required parameters (in this case, it is not necessary to fill in all the parameters).
- Include only those technical means that are used at the necessary stages of production by the user.
- Start production and monitor the system.
- After receiving the necessary data, end the session.

3. *Analysis and reporting.*The process that is necessary for each production and is used to determine the system's effectiveness, the user, the number of sessions conducted by him. Based on the obtained results, the salaries of system users are formed, new requirements to quality indicators, assessment of production efficiency, calculation of production and sales costs.

The following steps are required to perform this operation:

- After starting the system, monitor its process based on the obtained parameters.
- If necessary, it is possible to carry out an early termination of work. Thus it is essential to carry out all the same further actions.
- After completion of production, go to the database, which records the entire workflow and its quality indicators.
- Sort by the required parameters, and save them as a separate file.
- Send the data to the appropriate e-mail address specified in the startup document.
- Shut down the system.

With strict adherence to each of the three tasks, the system can be used even by a low-skilled worker. Thanks to artificial intelligence, the system will be completely isolated from its improper actions when using similar techniques.

4.2.2. Information about functional limitations on the application

Like any program that contains complex calculations, this information system has certain limitations on application. For the most part, these restrictions were explicitly introduced to protect production from an improper user action. The main rule of the system is the protection of the production process from the parallel start of production. Suppose several new users enter the method in which the user started production. In that case, they will not be able to make any changes in the production process and affect the system's operation until the first user completes its work. This restriction allows you to create conditions that minimize the influence of third-party users.

The second significant limitation is the input of the parameters for the manufacture of products following the percentage proportions. For the manufacture of polyethene, there are no clear indications of the parameters. They may be at appropriate intervals, depending on the type of product, its thickness, strength, elasticity, etc., but there are some limitations on the manufacture.

These restrictions are characterized by the following indicators, following the technology of manufacturing polyethene:

- The values of the catalyst and the fraction must be equal, i.e. be 50% each.
- The percentage of solvent should be more than 30%.
- Methanol should be less than 40%.
- The percentage of the additive should be less than 8%.
- At the start of manufacturing, all technical elements must be included.
- When starting the system diagnostics, all parameters must be filled in, at least the first faucet must be switched on, and methyl alcohol must be supplied.

It should be noted that there are appropriate instructions for users on restrictions (Fig. 18). These can be both prohibitions (indicated in red, number 1) and warnings (shown in yellow, number 2).

It is also essential to provide an understanding of the stage of the production process. This answer can be obtained by looking at the road map of this process (Fig. 19). The stages passed and the stage at which the system is highlighted in black and inactive stages, respectively, in grey.

Based on these requirements, which are based on the user manual and is one of the most important sections of this manual, we can proceed to the direct analysis of the control example of the system.

Figure 18: Instructions for limiting and complying with system requirements

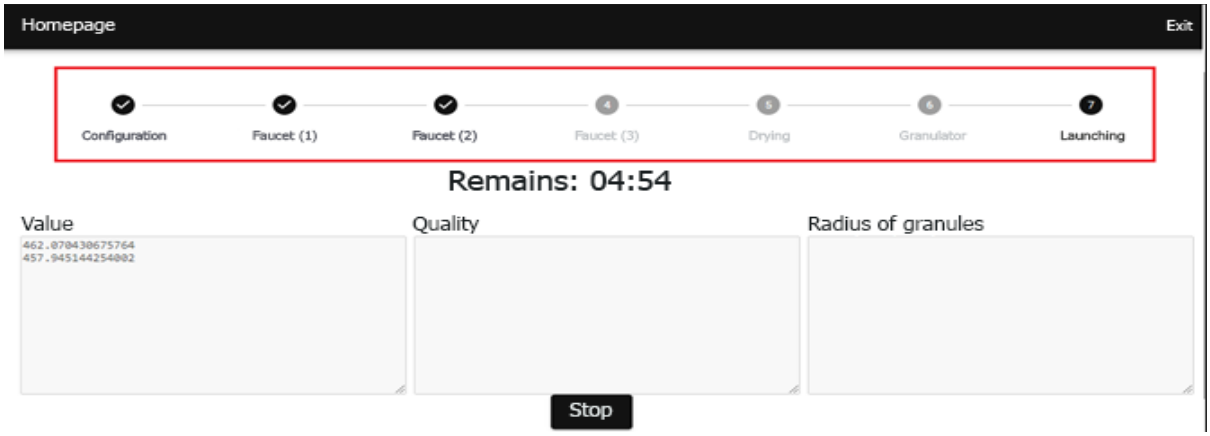

Figure 19: The production road map

4.3. Analysis of the control example

Let's analyze the control example. To do this, we will test the operation in two modes, namely normal mode and system diagnostic mode. After that, based on the results, we group the data based on one of the sessions of the system. As stated in the instructions for the use of the system, for the normal mode of quality control, it is necessary to set all the parameters while maintaining the required proportions and following the instructions of the system. Filling with parameters is shown in Fig. 20:

Figure 20: Filling data for normal mode

After appropriate filling of all parameters, there is direct quality control by artificial intelligence. At this time, the user can monitor the progress of events, perform proper data analysis, and, if necessary, complete production ahead of schedule.

Also, because artificial intelligence takes full control of production, the user of the system can perform a tour of the territory where the production process takes place and evaluate it.

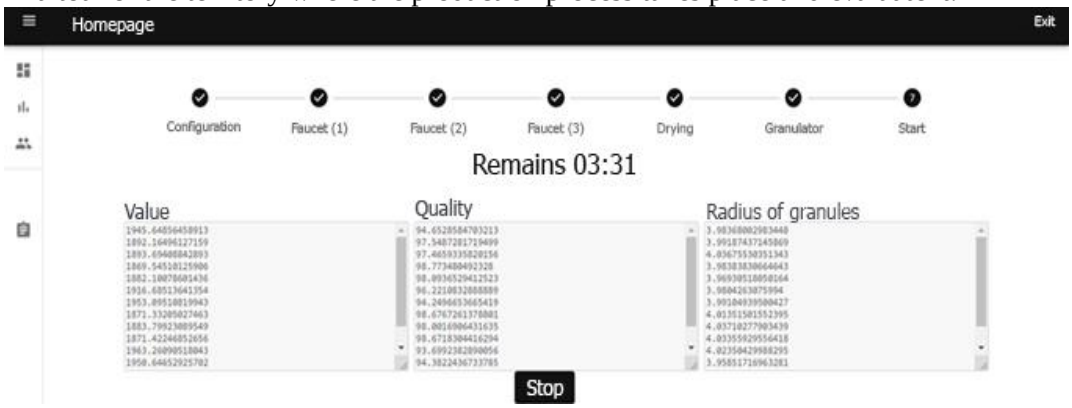

Figure 21: Output of quality indicators

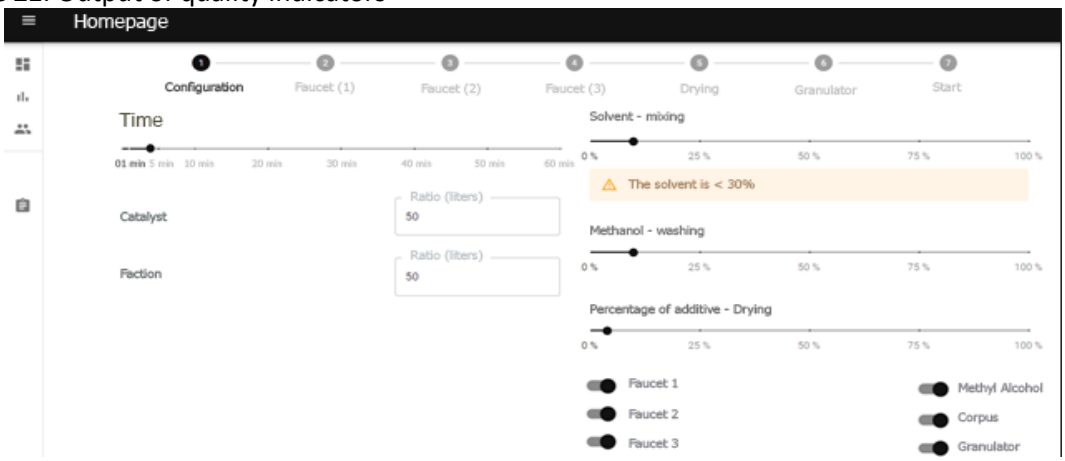

Figure 22: Filling with data for diagnostic mode

We perform similar actions with filling in the parameters for the system diagnostics mode, but we include only those technical means that we need to diagnose. In this mode, it is allowed to enter parameters that do not meet the requirements for polyethene manufacturing. This factor is since the diagnosis is not the final product, and therefore the definition and quality control, in this case, is impractical. Filling in the parameters for diagnostics is shown in Fig. 22.

After all the parameters are filled and the appropriate technical means are included, we press the start button and observe the calculated values of the processed raw materials.

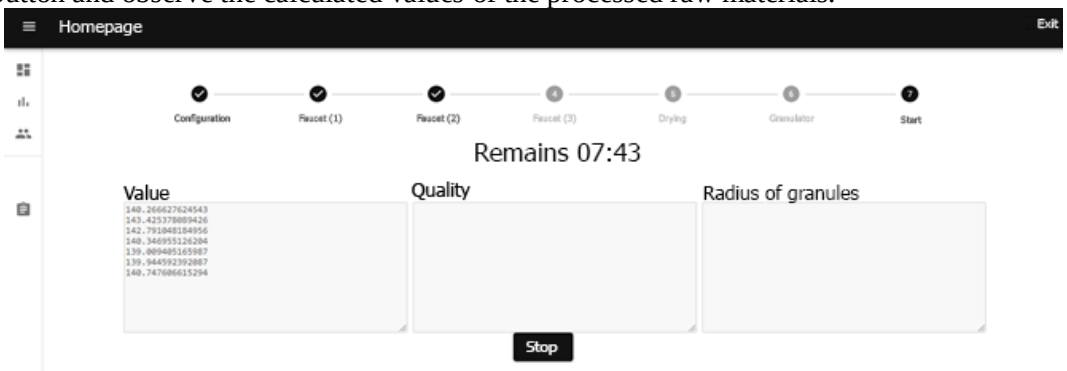

Figure 23: Derivation of processed raw materials

According to the instructions for using the system, the last step is to display detailed information about the completed session. To do this, open the database and search for the session we need, or with a corresponding query output the session we need. We carry out an output of parameters for the third session. For this purpose, we write the following request:

```
select * from results where "sessionId" = 3;
```

Based on this query, we obtain the relevant results:

psql

id	value	quality	radius	temp1	temp2	temp3	createdAt	sessionId
21	39.9550776954334	97.5152257112132	3.98855917648323	51.1463108629378	103.019227524064	73.6476469027823	2021-03-06 12:22:37.945+00	3
22	41.0065213235054	94.8182728052085	3.95434375928644	50.4500052889284	100.430711102371	70.2375690641921	2021-03-06 12:22:39.944+00	3
23	41.6015257614215	93.2920864219538	4.03594070267298	50.37412668849	104.394565231303	74.739047067402	2021-03-06 12:22:41.944+00	3
24	39.9437978090262	97.5441586198478	4.02891020663115	50.223216422223	104.407376082843	71.5841013844989	2021-03-06 12:22:43.944+00	3
25	40.7874181933317	95.3802723341041	4.04479326153905	51.1246191079625	104.184242849001	74.8134557698383	2021-03-06 12:22:45.944+00	3
26	39.735557360269	98.07829537091	3.97020602955835	50.8552791876997	101.815575358276	72.0178396197633	2021-03-06 12:22:47.944+00	3
27	40.3601379052054	96.4762462731482	4.04274852603671	50.6855127392177	104.640361340783	75.3090263318143	2021-03-06 12:22:49.944+00	3
28	40.172862847858	96.9566067952442	3.97345087660016	50.9657075346338	102.147008751541	71.1700948617442	2021-03-06 12:22:51.944+00	3
29	40.5271455060874	96.0478717768858	4.04122997377257	51.4312042984719	101.794328852707	71.2395968565669	2021-03-06 12:22:53.944+00	3
30	40.306132361429	96.6147704929347	3.97461146889697	50.5251890626474	104.566616749937	74.6299867370787	2021-03-06 12:22:55.945+00	3
31	41.0977190266314	94.5843506966904	4.04562665013886	50.8638652500321	100.19356395651	74.7384317214525	2021-03-06 12:22:57.946+00	3
32	40.2876311462256	96.6622261099315	3.99105366073324	50.9416441384734	102.124336747016	70.0689540547853	2021-03-06 12:22:59.946+00	3
33	40.0762375753718	97.2044506191714	4.03462856057163	50.5451448361222	100.046288091557	71.038654906007	2021-03-06 12:23:01.947+00	3
34	39.0679338873304	99.7907495789974	4.00508657721883	50.4490316105095	101.739637015183	73.3038703512827	2021-03-06 12:23:03.947+00	3
35	39.596440507744	98.4351300976366	4.02701599335634	50.1139264586728	102.202103526576	71.7435767379913	2021-03-06 12:23:05.947+00	3
36	39.270207799125	99.2719173010244	3.95632276314834	50.7782605688779	102.483481717883	71.4231071579776	2021-03-06 12:23:07.948+00	3
37	41.0780441864343	94.634816661796	3.957162039325 8	50.4593307245735	102.007893461234	71.7644405633339	2021-03-06 12:23:09.956+00	3
38	41.2465138453157	94.2026919867653	4.01190236549625	50.686986371358	104.29035257763	74.347840104384	2021-03-06 12:23:11.948+00	3
39	40.0937179926089	97.1596133489581	4.01625230437202	50.1370978679864	104.400007947638	75.3387884196779	2021-03-06 12:23:13.949+00	3
40	39.6976435574602	98.1755442751145	3.97866760380224	50.8593054889857	102.285837938077	72.614392656545	2021-03-06 12:23:15.95+00	3
41	41.5232456799578	93.4928748309083	4.01084615947817	50.9575221240574	104.98941289228	72.7459093970018	2021-03-06 12:23:17.949+00	3
42	41.088607756735	94.6077211039747	4.03723511071568	50.947965037789	101.371324790356	70.5812295846617	2021-03-06 12:23:19.949+00	3
43	41.0249761331033	94.77093621859	3.99863573670003	51.0138631044161	102.470968177173	74.9380030034222	2021-03-06 12:23:21.949+00	3
44	39.1502016968149	99.5797326476699	4.0026408180255	51.3683701232656	104.199153617271	70.4621034774534	2021-03-06 12:23:23.95+00	3
45	39.7407333498254	98.0650189576978	4.01454824204589	51.4863677832662	103.116141425216	75.2170643651634	2021-03-06 12:23:25.951+00	3
46	41.5199413114353	93.5013505361685	3.9904305691327	50.3768340571408	100.702866921604	74.7706256941229	2021-03-06 12:23:27.952+00	3

Figure 24: Output of quality indicators for the third session

To provide an understanding of the full functionality of the system, its limitations, input, output data, features and detailed structure, a detailed description of the quality control system of polyethene production and highlighted the main technical characteristics. A hierarchy of the system's file structure was provided during this description, detailing the leading directories and files. Provided all software tools that were used to implement the information system, its testing, deployment and further support. In addition, the logical structure of the system pages, which is a tree-like structure and helps users understand the navigation of the system better, is described and graphically depicted. This structure was chosen to consider the need for initial verification of users and subsequent selection of the necessary functionality. The main files responsible for input and output operations, calling, and booting are also described. A detailed description of the database structure with the corresponding ER diagram is given. An essential point for any system is a set of rules and recommendations for using the system, for which a user manual was created. This manual contains several detailed, step-by-step steps for using the system, outlines the main functions that can perform this control example, and illustrates the main features of the interface. To verify the compliance of the system with the described requirements, as well as the analysis of the efficiency to do, a start-up and subsequent analysis of the control example was performed. During these actions, each of the three main functionalities of the system was implemented, namely: quality control of polyethene, an inspection of each stage of production, analysis and reporting. After a detailed analysis, the compliance of the system with the specified requirements was confirmed. No errors were detected during the operation of the control example.

The purpose of the work is the design and software implementation of an information system for quality control of polyethene production. The main functionality of the system includes such basic features as means of communication between operators and the vertical of the enterprise, reporting on the user's work with the system, which includes all the basic parameters of the production process and the ability to control the production process. Regarding data visualization methods, it should be noted that this information system has added the ability to graphically view temperature data, shown in the form of graphs, and created a road map with the stages of production. The economic feasibility of making this information system is to reduce the number of staff to service the production process and, at the same time, reduce the cost of raw materials in connection with quality control. Due to the artificial intelligence of the system, the need for intervention of the system operator is reduced, and the efficiency of manufacturing the final product is increased. Currently, there are three main methods of quality control of production and their basis several mixed methods. The created algorithm in this software will provide new opportunities for more economical and, most importantly, high-quality production of polyethene and fewer people, which will lead to a significant increase in profits. As the developed system is based on modern methods of quality control, is scalable according to the size of the enterprise and contains all available functionality for practical work, it will have wide demand in the market both among small business people of chemical branches as integral software and among extensive, in. quality of the modular part.

The software market is increasing, and new types of interfaces, data processing tools, and hardware controls are emerging. To remain competitive, you need to have an advantage in something, whether in the greater functionality of the lost product, the speed of calculation, or the quality of analyses. Through the development of information technology, they have penetrated various areas of human life without missing the chemical gazelle. The need for complex calculations and analysis of the technological process is critical. As a result, different software tools for process support have been developed, which use HMI methods. Currently, there are a variety of quality control methods (as mentioned in previous sections). Each of them is used in different enterprises, so creating a universal system is used primarily combinational approaches to quality control. The most commonly used control methods are:

- Measuring is based on technical means of measurement and control. They determine, for example, the weight of the product, speed.
- Registration is based on observation and counting the number of certain events, items or costs.
- Calculated is based on the use of theoretical or empirical dependences of product quality indicators on its parameters (to determine the product's weight, productivity, power, strength).
- Organoleptic is based on the analysis of the perception of the senses (in points, the quality of drinks, perfumes, the use of which is associated with the emotional impact on the consumer).
- Expert is based on the decision of experts.
- Sociological is based on the collection and analysis of opinions of current and potential consumers of products.

Each company spends many human resources, which requires high skills and, accordingly, payment. According to this principle, an algorithm was designed and implemented for this software, which, based on artificial intelligence, will independently control the main aspects of polyethene production while reducing the need for many qualified employees and their participation in the process. This approach proposes to enter the operator's initial data, which theoretically, in ideal conditions, should produce polyethene with the appropriate calculated quality. Artificial intelligence will adjust the parameters to achieve the highest quality. It will minimize the impact of the human factor on the production process, and the correct distribution of raw materials will save it significantly. Based on the above, we can conclude that creating this information system is a good choice and will allow entrepreneurs to save raw materials, respectively, increasing revenue from manufacturing and end-users the opportunity to use better products. These factors will create a significant demand for this software. They will allow it to be used both for the direct manufacture of polyethene and further modernization to manufacture polybutylene and polypropylene. After analyzing the environment and expert assessment of external and internal factors, it was determined that the total impact of elements corresponding to the external environment is positive and is in turn 2.07 out of 5.00 possible, which is quite a good result for the possibility of further software development. Accordingly, after assessing the internal environment factors, the total score of which is 4.03 out of 5.00 possible, we can conclude that internal factors have a relatively high level of influence. The summary data of the elements of both environments indicate that the development of a quality control software application will have a reasonably high potential in the market among its direct counterparts and competitors. After conducting a straightforward analysis of the strategy of alternatives for the first group, the process of creating a new product was chosen, which will provide the market with entirely new methods and means of solving problems, better, faster and cheaper than competitors' software. Regarding the second group of alternatives, developing a new software product for the existing market segment was chosen here, as currently, there are production control tools based on HMI systems. Still, they do not use artificial intelligence to achieve their goals. Taking into account the above calculations and the need for each company to purchase at least two quality control tools, as each company has at least two operators, it can be argued that the developed software will bring significant profits. Therefore, this development can be considered such that it is appropriate for this market segment and in terms of economic costs.

5. Conclusions

During the project implementation, the main goal of the information system implementation, the novelty of work and practical value were clearly identified. To achieve this goal, first of all, a detailed analysis of quality control systems was conducted. Particular attention was paid directly to the quality

control systems of the chemical industries. The study revealed a high impact of negative factors. This industry is quite complex, requires accurate calculations, is under the constant influence of the external environment and the human element. When designing a quality control system for polyethene, many factors must be taken into account. Thus, based on the analysis of work in the international and national segment, the need for quality monitoring and control of the production process, minimizing the cost of raw materials, financial fees, and reducing the complexity of training to work with these systems. The need is to develop a plan that is not tied to a specific device or panel and built on the principle of multiplatform, which provides mobility in the work of the system operator. Considering the comparison of similar quality control systems, it is evident that from many modern techniques, it is impossible to single out one that would be universal and the best from all points of view, but their advantages and disadvantages were taken into account when developing polyethene quality control information system. It is worth noting that when designing the system, it was impossible to do without neglecting certain positive factors in exchange for greater physical and software functionality and system security.

Having a holistic view of the system requirements, its functionality and features, carried out a systematic analysis of the object of study in which formed hierarchical levels, specified the system's functioning, and created a hierarchy of tasks using IDEF0 (functional diagram). Given the complexity of the system, a three-level decomposition was performed. This solution allowed us to clearly understand the problems that could arise during development and correct them in advance.

After a detailed analysis and further comparison of software tools for system implementation, the high efficiency of the NodeJS platform was revealed, which includes such tools as ExpressJS and ReactJS. With these tools, the system received modern modules, a reliable database, beautiful visualization, the ability to connect middleware, high-quality administration, and optimisation. This software can run on weak devices and older versions of browsers.

The created system aims to improve quality control, thanks to which significant savings are made on the raw materials needed to manufacture products. In addition to savings, with the help of artificial intelligence, the system has a substantial increase in quality compared to similar quality control methods. Given the need to protect the production process, several tools have been created that provide control against unauthorized login by third-party users or erroneous actions of users. These include a ban on new users entering, during the start of production, verification, warning the system to enter critical parameters, and implementing instructions for users.

The developed quality control system can be used both as an automated workplace of the user and portable, according to the device on which it is open (the personal computer, the laptop, the tablet, phone). For maximum efficiency of the system, it is recommended to use it on a tablet. This device will allow the user to move around the company and perform additional supervision over its operation. Unlike the phone, the tablet has a larger screen diagonal, which will allow you to set the necessary parameters accurately and save time when setting these parameters.

During the software verification of the control example and further analysis of the obtained results, the compliance of the information system with the requirements was confirmed and, accordingly, the necessary goal was achieved. Given the capabilities of the NodeJS platform and the selected software tools, the system has great potential and all the conditions required for further expansion by adding quality control of related end products in this field, such as polybutylene, polypropylene.

6. References

[1] H. A. Antonov, Osnovy standartyzatsiyi ta upravlinnya yakistyu produktsiyi. SPB: SPbUEF, 2003.

[2] V. Lytvyn, V. Vysotska, P. Pukach, M. Vovk, D. Ugryn, Method of functioning of intelligent agents, designed to solve action planning problems based on ontological approach, volume 3/2(87) of Eastern-European Journal of Enterprise Technologies, 2017, pp. 11-17. DOI: 10.15587/1729-4061.2017.103630

[3] Y. Burov, V. Vysotska, P. Kravets, Ontological approach to plot analysis and modeling, volume Vol-2362 of CEUR Workshop Proceedings, 2019, pp. 22-31.

[4] I. Zolotova, L. Landr′ova, Systemy SCADA, volume 33 of HMI ta novi tekhnolohiyi, 2000.

[5] L. Chyrun, The E-Commerce Systems Modelling Based on Petri Networks, volume Vol-2870 of CEUR Workshop Proceedings, 2021, pp 1604-1631.

[6] M. Bublyk, V. Vysotska, Y. Matseliukh, V. Mayik, M. Nashkerska, Assessing losses of human capital due to man-made pollution caused by emergencies, volume Vol-2805 of CEUR Workshop Proceedings, 2020, pp. 74-86.
[7] A. Berko, M. Bublyk, L. Chyrun, Y. Matseliukh, R. Levus, V. Panasyuk, O. Brodyak, L. Dzyubyk, O. Garbich-Moshora, Models and Methods for E-Commerce Systems Designing in the Global Economy Development Conditions Based on Mealy and Moore Machines, volume Vol-2870 of CEUR Workshop Proceedings, 2021, pp. 1574-1593.
[8] V. Vysotska, V. Lytvyn, M. Bublyk, A. Demchuk, L. Demkiv, Y. Shpak, Method of ontology quality assessment for knowledge base in intellectual systems based on ISO\IEC 25012, in: IEEE 15th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT, 2020, pp. 109-113. DOI: 10.1109/CSIT49958.2020.9321871
[9] Y. Matseliukh, V. Vysotska, M. Bublyk, T. Kopach, O. Korolenko, Network Modelling of Resource Consumption Intensities in Human Capital Management in Digital Business Enterprises by the Critical Path Method, volume 2851 of CEUR Workshop Proceedings, 2021, pp. 366-380.
[10] V. Vysotska, Y. Burov, V. Lytvyn, O. Oleshek, Automated Monitoring of Changes in Web Resources, volume 1020 of Advances in Intelligent Systems and Computing, 2020, pp. 348-363. DOI: 10.1007/978-3-030-26474-1_25
[11] M. Bublyk, V. Vysotska, L. Chyrun, V. Panasyuk, O. Brodyak, Assessing Security Risks Method in E-Commerce System for IT Portfolio Management, volume Vol-2853 of CEUR Workshop Proceedings, 2021, pp. 462-479.
[12] Schneider Electric. Harmony STW6 User Manual, 2020.
[13] V. Vysotska, L. Chyrun, Methods of information resources processing in electronic content commerce systems, in: Proceedings of 13th International Conference: The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM, 2015.
[14] K. Alieksieieva, A. Berko, V. Vysotska, Technology of commercial web-resource processing, in: Proceedings of 13th International Conference: The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM, 2015.
[15] I. Rishnyak, O. Veres, V. Lytvyn, M. Bublyk, I. Karpov, V. Vysotska, V. Panasyuk, Implementation models application for IT project risk management, volume Vol-2805 of CEUR Workshop Proceedings, 2020, pp. 102-117.
[16] V.A. Holubyatnykov, V.V. Shuvalov, Avtomatyzatsiya vyrobnychykh protsesiv u khimichniy promyslovosti. M.: Khimiya, 1985.
[17] V.YE. Hul′, V.N. Kuleznyev, Struktura i mekhanichni vlastyvosti polimerov. Moskva: Vyshcha shkola, 1972.
[18] V.M. Kuleznev, V.N. Shershnev, Khimiya i fizyka polimerov. Moskva: Vyshcha shkola, 1988.
[19] V. Vysotska, A. Berko, V. Lytvyn, P. Kravets, L. Dzyubyk, Y. Bardachov, S. Vyshemyrska, Information Resource Management Technology Based on Fuzzy Logic, volume 1246 of Advances in Intelligent Systems and Computing, 2020, pp. 164-182. DOI: 10.1007/978-3-030-54215-3_11
[20] L. Sabin-Vilson. WordPress dlya chaynykov - M.: Vil′yams, 2010.
[21] B. Nort, Joomla! 1.5. M .: Symvol-plyus, 2017.
[22] D. Vandyuk, CMS Drupal. M.: Vil′yams, 2017.
[23] A. Berko, V. Andrunyk, L. Chyrun, M. Sorokovskyy, O. Oborska, O. Oryshchyn, M. Luchkevych, O. Brodovska, The Content Analysis Method for the Information Resources Formation in Electronic Content Commerce Systems, volume Vol-2870 of CEUR Workshop Proceedings, 2021, pp. 1632-1651.
[24] V. Vysotska, A. Berko, M. Bublyk, L. Chyrun, A. Vysotsky, K. Doroshkevych, Methods and tools for web resources processing in e-commercial content systems, in: IEEE 15th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT, 2020, pp. 114-118. DOI: 10.1109/CSIT49958.2020.9321950
[25] NodeJS. URL: https://nodejs.org/docs/latest-v9.x/api/.
[26] I. Braun, Web Development with Node and Express. Sankt-Peterburh: Piter, 2017.
[27] M. Khartl, Ruby on Rails dlya pochatkivtsiv. DMK, 2017.
[28] A. Khorton, R. Vays, Rozrobka veb-dodatkiv v ReactJS. URL: https://e.lanbook.com/book/97339
[29] Hrin Bred, Sheshadri Shyam. AngularJS - O'Reilly Media, 2013.
[30] Mario Kaskiaro. Shablony proektuvannya Node.js. M.: DMK Press, 2016.

[31] Saymon Rihs. Administruvannya PostgreSQL 9. M.: DMK Press, 2018.
[32] V. Kuchkovskiy, V. Andrunyk, M. Krylyshyn, L. Chyrun, A. Vysotskyi, S. Chyrun, N. Sokulska, I. Brodovska, Application of Online Marketing Methods and SEO Technologies for Web Resources Analysis within the Region, volume Vol-2870 of CEUR Workshop Proceedings, 2021, pp. 1652-1693.
[33] O. Kuzmin, M. Bublyk, A. Shakhno, O. Korolenko, H. Lashkun, Innovative development of human capital in the conditions of globalization, volume 166 of E3S Web of Conferences, 2020, pp. 13011.
[34] A. Gozhyj, L. Chyrun, A. Kowalska-Styczen, O. Lozynska, Uniform method of operative content management in web systems, volume 2136 of CEUR Workshop Proceedings, 2018, pp. 62-77.
[35] L. Chyrun, Y. Burov, B. Rusyn, L. Pohreliuk, O. Oleshek, A. Gozhyj, I. Bobyk, Web resource changes monitoring system development, volume 2386 of CEUR Workshop Proceedings, 2019, pp. 255-273.
[36] L. Chyrun, A. Kowalska-Styczen, Y. Burov, A. Berko, A. Vasevych, I. Pelekh, Y. Ryshkovets, Heterogeneous data with agreed content aggregation system development, volume 2386 of CEUR Workshop Proceedings, 2019, pp. 35-54.
[37] L. Chyrun, A. Gozhyj, I. Yevseyeva, D. Dosyn, V. Tyhonov, M. Zakharchuk, Web Content Monitoring System Development, volume Vol-2362 of CEUR Workshop Proceedings, 2019, pp. 126-142.
[38] Y, Kis, L. Chyrun, T. Tsymbaliak, L. Chyrun, Development of System for Managers Relationship Management with Customers, volume 1020 of Advances in Intelligent Systems and Computing, 2020, pp. 405-421. DOI: 10.1007/978-3-030-26474-1_29
[39] A. Bondariev, M. Kiselychnyk, O. Nadobko, L. Nedostup, L. Chyrun, T. Shestakevych, The software complex development for modeling and optimizing of processes of radio-engineering equipment quality providing at the stage of manufacture, in: Modern Problems of Radio Engineering, Telecommunications and Computer Science - Proceedings of the 11th International Conference, TCSET, 2012, pp. 159.
[40] O. Bazylyk, P. Taradaha, O. Nadobko, L. Chyrun, T. Shestakevych, The results of software complex OPTAN use for modeling and optimization of standard engineering processes of printed circuit boards manufacturing, in: 11th International Conference Modern Problems of Radio Engineering, Telecommunications and Computer Science, TCSET, 2012, pp. 107-108.
[41] L. Chyrun, I. Turok, I. Dyyak, Information model of the tendering system for large projects, volume 2604 of CEUR Workshop Proceedings, 2020, pp. 1224-1236.
[42] A. Demchuk, B. Rusyn, L. Pohreliuk, A. Gozhyj, I. Kalinina, L. Chyrun, N. Antonyuk, Commercial content distribution system based on neural network and machine learning, volume 2516 of CEUR Workshop Proceedings, 2019, pp. 40-57.
[43] I. Pelekh, A. Berko, V. Andrunyk, L. Chyrun, I. Dyyak, Design of a system for dynamic integration of weakly structured data based on mash-up technology, in: Proceedings of the 2020 IEEE 3rd International Conference on Data Stream Mining and Processing, DSMP, 2020, pp. 420-425. DOI: 10.1109/DSMP47368.2020.9204160
[44] A. Berko, I. Pelekh, L. Chyrun, M. Bublyk, I. Bobyk, Y. Matseliukh, L. Chyrun, Application of ontologies and meta-models for dynamic integration of weakly structured data, in: Proceedings of the 2020 IEEE 3rd International Conference on Data Stream Mining and Processing, DSMP, 2020, pp. 432-437. DOI: 10.1109/DSMP47368.2020.9204321
[45] A. Berko, I. Pelekh, L. Chyrun, I. Dyyak, Information resources analysis system of dynamic integration semi-structured data in a web environment, in: Proceedings of the 2020 IEEE 3rd International Conference on Data Stream Mining and Processing, DSMP, 2020, pp. 414-419. DOI: 10.1109/DSMP47368.2020.9204101
[46] O. Garasym, L. Chyrun, N. Chernovol, A. Gozhyj, V. Gozhyj, I., Kalinina B., Rusyn, L. Pohreliuk, M. Korobchynskyi, Network security analysis based on consolidated threat resources, volume 2604 of CEUR Workshop Proceedings, 2020, pp. 1004-1018.
[47] L. Chyrun, P. Kravets, O. Garasym, A. Gozhyj, I. Kalinina, Cryptographic information protection algorithm selection optimization for electronic governance IT project management by the analytic hierarchy process based on nonlinear conclusion criteria, volume 2565 of CEUR Workshop Proceedings, 2020, pp. 205-220.