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I. V. TARASOV
Project manager, NLMK-SAP Innovation Lab, NLMK Group. Research interests:operational efficiency of business, innovative and strategic development of the companies, innovations and new technologies implementation.

E-mail:
Ivan.Tarasov@outlook.com

N.A. POPOV
Research associate, Center for industry research and consulting of the Financial University under the Government of Russian Federation. Research interests: IT-technologies in the operational efficiency of business, digitalization of production, crisis and arbitration management

E-mail:
Mr.Nikita.Popov97@gmail.com

INDUSTRY 4.0: PRODUCTION FACTORIES TRANSFORMATION[1]

ABSTRACT

The key stage of the company's transition to Industry 4.0. It is the Digital factory development stage. The first part of the article discusses in detail the components of digital factories, the expected effects of digitalization of production and related functions, as well as the transition from strategic initiatives to the operational level — the level of business processes that are transformed under the influence of new technologies. The second part of the article describes the methodology of case studies of Russian and foreign companies that are at the forefront of changes. The third part presents the cases of manufacturing companies that have achieved significant results in the field of digital transformation, in particular, Siemens, SIBUR and Novolipetsk metallurgical combine.

KEYWORDS DIGITAL TRANSFORMATION, DIGITAL FACTORY, INDUSTRY 4.0, OPERATIONAL EFFICIENCY, OPERATING MODEL, BUSINESS PROCESS OPTIMIZATION

INTRODUCTION

A new technological revolution not only increases the level of productive capacity and operational efficiency of the existing factories, but also composes new organizational technical models of the factories [Trachuk A.V., Linder N.V., 2016 a]. Digital factory conception becomes popular – business processes of the appropriate type and/or the way of their combining in order to generate high technological decisions, owing to which fresh competitive items of new generation will be designed within short period of time.

The aim of this article is to examine an approach towards transformation of the production function on the operational level, reveal a digital factory conception in practice and through the example of companies: a public company «NLMK», a public company «SIBUR» and Siemens AG, to analyze the realized transformational projects at production site.

In Russia digital factories will appear during realization of the direction «TechNet» of the National Technological Initiative. It is supposed that in such enterprises it will be possible to arrange production cheaper and quicker in comparison with the traditional factories. Realization of the initiative is expected to be performed within three stages. Realization of the first stage is planned for 2017-2019 yrs, financing will be of 15,6 billion rubles.

The first «Factories of the future» within the direction «TechNet» will appear at the Central scientific and research automobile and engine institute «NAMI», LLC «Ulyanovsk Automobile Plant», Machine-building holding group «Volgabas». It is intended to create a digital factory in shipbuilding industry as well, according to the agreement, in realization of the project United Shipbuilding Corporation will take part. A work flow chart «TechNet» is expected to serve for the period by the year 2035, and within this period of time it is planned to create 40 factories of the future, 25 testing areas, 15 experimental digital certification centers. On the world market of the «factories of the future» Russia plans to occupy 1,5% in the segment of engineering and construction.

The crucial component is a conception of the «digital factory» and transformation of the production factories models. According to the «TechNet», it is offered to create digital factories, «smart» factories and virtual factories. Digital factories realize all production processes – from engineering to virtual testing of the item in virtual format. «Smart» factories is the next and more complicated stage of factories of the future development, they will not almost need a direct involvement of the staff into the operating processes. Virtual factories can be located everywhere and line up into production chains by means of the Industrial Internet of Things.

There are three possible models of the digital factories described below:

- Automated factories are meant for the mass manufacturing of products with a low cost price. Operating processes are totally digitalized and automated, a full complex of Industry 4.0 technologies is implemented within the whole production chain.
- Customs-oriented factories are meant for the mass manufacturing of production with affordable prices with rapid reaction on changing of consumers preferences. Forecasting systems for swings in demand are applied with maximum precision on the ground of large amount of data; applications, by means of which the clients can individually design with which of their needs the goods should correspond, and in such a way they can lay down their demands for the factory; applications for 3D modeling and engineering, 3D-scanners and 3D-printers with high productive capacity.
- Mobile factories, meant for work on territorially remote and niche markets. They are aimed at a small amount of production, low-level capital outlays and opportunity of fast relocation depending on market conditions. The factories will need for this the following things: modular production lines and mounting robots, which can be quickly delivered to the new location, mounted and linked up; 3D-printers for production of some separate details; flexible logistical systems [Industry 4.0, [s.a.]].

The aim of the article is an effort to describe a model of the digital factory in the context of specific technologies, fields of their application and potential benefits. The aim is timely in view of the fact that in literature there are yet no descriptions of the drives and obstructions for creation of the digital factories as well as their models where one could apply concrete technologies of Industry 4.0.

TRANSFORMATION OF THE PRODUCTION OPERATING MODEL

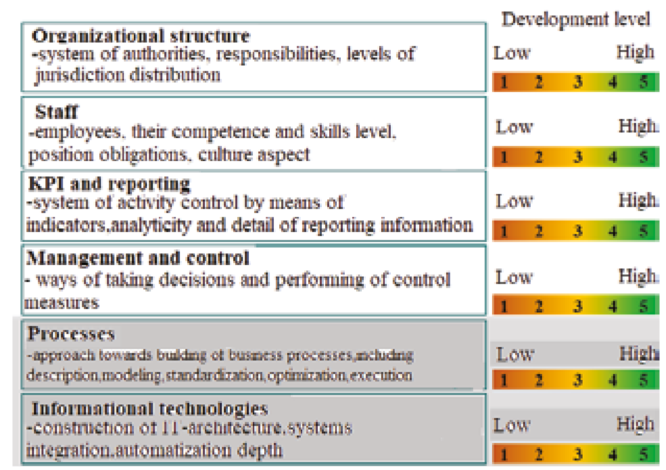
Traditionally, operating model is lined up from six blocks. Level of development (maturity) of every block can be evaluated according to the appropriate features [Operating model, [s.a.]; Our solutions, [s.a.]; Transformation, [s.a.]]. The first level means that the block of the operating model is at the initial stage of development, and the fifth level tells about high progress. In the table 1 detailization of block «Processes» and «Informational technologies» is given (marked on the pic. 1 with a gray area).

Projects on creation of digital factories contemplate, foremost, building of new production processes by means of modern technologies, that's why in the article definitions «processes» and «informational technologies» are of top-priority.

In the table 1 detailization of the five levels of blocks maturity of the company operating model «Processes» and «Informational technologies» is represented. A new digital maturity level is added as well, it completes the model and considers changes which occur at the modern enterprises. In particular, in the block «processes» by way of the last maturity level an optimized level is presented, that doesn't give an opportunity to trace automatization degree of routine processes and transformation degree of the production processes by virtue of technological solutions. Block «Informational technologies» finishes on the maturity level which plans integration of internal systems. From the point of view of Industry 4.0, an important demand is not only internal vertical integration, but

[1] The article is prepared on the ground of "Industry 4.0 research results: research of the impact of the progressive production technologies development on Russian industrial companies productive capacity", performed at the expense of budget financing within a framework of the state task of the Financial University under the Government of Russian Federation, 2018.

Pic. 1. Operating model



Pic.2. Operating model digitalization stages

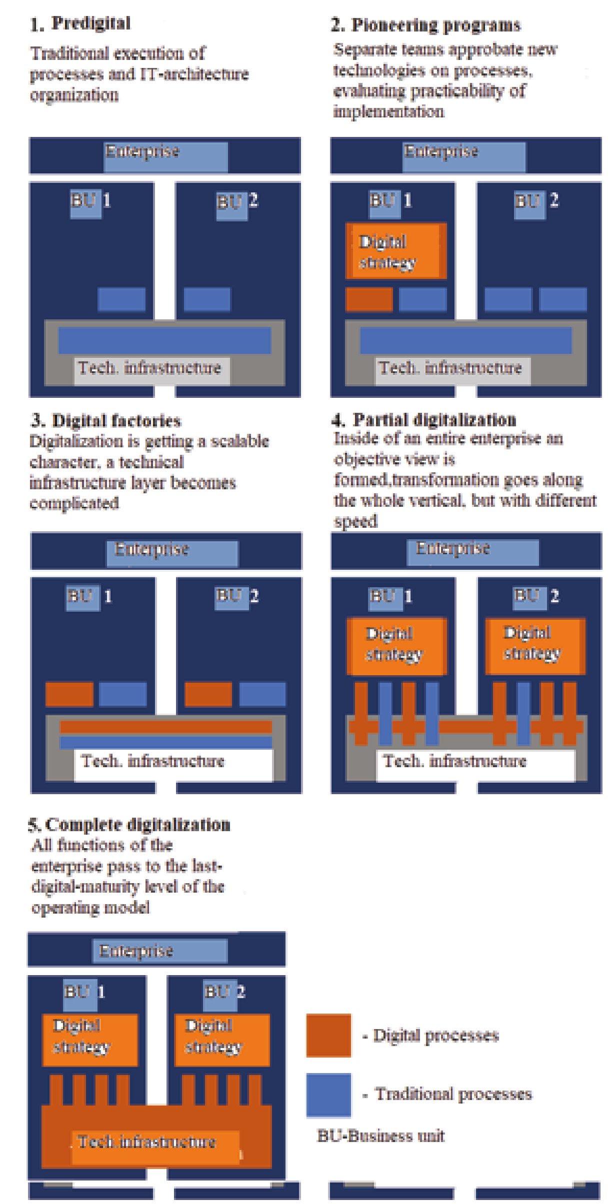


Table 1
Complemented maturity levels of definitions «Processes» and «IT»

Maturity level	Characteristics
	Block«Processes»
1. Initial	Processes are performed in a chaotic manner, without lined up sequencing. The tasks are successfully done thanks in large part to enthusiasm of the staff and competence of separate employees. Often budget overrun takes place, quality is far from perfect, result doesn't correspond with expectations.
2. Controlled	Processes are planned, traced and controlled. Management of requirements, processes, products and services is performed. Standards, descriptions of processes and procedures can differ from subdivision to subdivision, anyway a process approach towards management is realized in a company.
3. Definite	A single infrastructure of the standard processes is built for the whole organization. The processes are used which are defined, clear and described with the help of tools and methods, officially embodied in documentation. The processes are qualitatively predictable, but there is no obligatory check up of the processes correspondence with regulations and targeted indicators
4. Quantitatively controlled	Quantitative criteria for processes management are in the process of establishment, quantitative information is accumulated and analyzed. The processes are controlled by statistical and other quantitative methods. The results of measurement, conducted for satisfying of an ordering customer demands, end consumers or organizations requirements, are used for making decisions in future
5. Optimized	The processes are improved in whole as well as at the level of a separate performer. The main attention is given to continuous improvement of business processes efficiency by virtue of innovative method improvements. The criteria of improvement are the quantitative characteristics of a process
6. Digital	The processes are maximally automated; optimization in the virtual space (by means of digital twins). Routine, typical, standard processes are performed fully automatically with minimal involvement of a human, the employees work only with non-typical, creative processes. Current processes are simulated in the virtual space in a real-time mode, the future processes are imitated, tested and optimized by the execution. For optimization the data are used collected from IT-systems, supplying the processes. The processes are flexibly adjusted to dynamic environment
	Block «Informational technologies»
1. «Zoo» of systems	Numerous local systems, consolidation and integration performed manually by power of specialists
2. Consolidated	Integrated system of consolidation, numerous local systems, partial integration
3. Half-standardized	Standard and non-standard tools, data stores
4. Standardized	Standard tools/ applications, partially integrated
5. Internal integration	Standard tools and applications, fully integrated
6. Total integration, IT architecture standards	Vertical and horizontal integration of systems; IT architectures of companies are lined up according to united IT standards of Industry 4.0 (for instance, RAMI 4.0)

horizontal integration of a few chains of the cost creation as well and using of unitary standards in IT-architecture.

Consequently, distinguishing of additional levels within examined definitions of the operating model gives an opportunity to evaluate a progress of the company on the way to digital transformation, and show evolutionary, but not revolutionary character of Industry 4.0. Similar conclusion was made by consultants of McKinsey&Company, who composed a work flow chart, where the five steps to transition to the digital maturity level of the operating model are suggested [Khan N., Lunawat G., Rahul A., [s.a.]]. Visually the stages can be represented according to the depth of the digital strategy realization (pic. 2).

Hereafter a conception of a digital factory as an intermediate phase of digitalization of the whole company and the main stage during transformation of the operating model of the production function.

CONCEPTION OF THE DIGITAL FACTORY

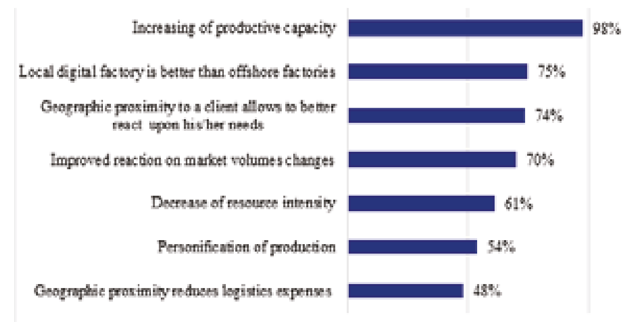
A digital factory is interpreted as a definite type of business processes system and/or the way of business processes combining, which possesses the following features:

- creation of digital platforms, peculiar ecosystems of progressive digital technologies: on the ground of predictive analytics and big volume data the approach gives an opportunity to unite territorially distributed members of engineering and production processes, and to increase the level of flexibility and customization [Trachuk A. V., Linder N. V., Antonov D. A., 2014; Trachuk A. V., 2013];
- development of a system of digital models of the new engineered articles and production processes, so that the models should be notable for a high level of correspondence with the real objects and real processes (convergence of material and digital worlds, causing synergetic effects) [Trachuk A. V., 2014; Trachuk A. V., Linder N. V., Ubeiko N. V., 2017];
- digitalization of the whole life cycle of the articles (from concept-idea, engineering, production, exploitation, service maintenance to utilization): the earlier the changes are brought in, the higher is the cost saving per an article, consequently, the engineering processes become the processes of a top-priority [Trachuk A. V., Linder N. V., 2017 b; Trachuk A., Tarasov I., 2015].

At the stage of digital factories formation the new key competences are generated:

- • fast response to market developments;
- using of system approaches (system engineering), when every moment of the time one should keep in sight a system in whole and all its interactive elements as well;
- formation of a multilevel matrix of target values and restrictions as a basis of the new engineering, essentially reducing risks, volumes of actual tests and works volumes, connected with articles and products finishing on the ground of testing;
- development and validation of mathematical models with a high level of correspondence with the real objects and real processes;

Pic.3. Drives for digital factories creation (respondents were able to choose a few variants)[DigitalFactories,2017]



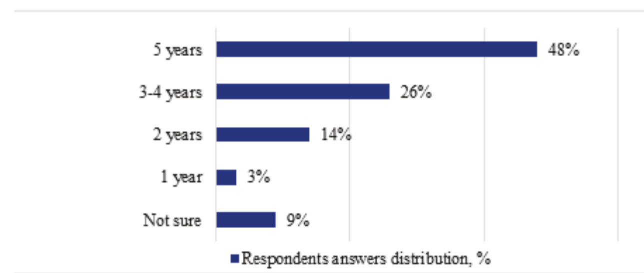
- regulation of changes during the whole life cycle of the product;
- digital certification, based on thousands of virtual tests of separate components as well as the whole system.

A digital factory conception received its rapid development and application in practice very soon [Tarasov, 2018; Trachuk A.V., Linder N.V., 2017 a; Trachuk A. V., 2012]. Progressive manufacturing companies Bosch Rexroth, Philips, Nokia, Fujitsu, Siemens, ABB, Airbus invested into the projects of the digital factories at the very early stages, when the term «Industry 4.0» was for the first time suggested in 2011 at Hannover conference [Ragimova S., [s.a.]]. Today these companies are for sure able to talk about succession of this conception realization, significant results are obtained: direct and indirect costs reduction, product quality improvement, reduction of time-to-market, defect production quantity reduction, transparency promotion and others.

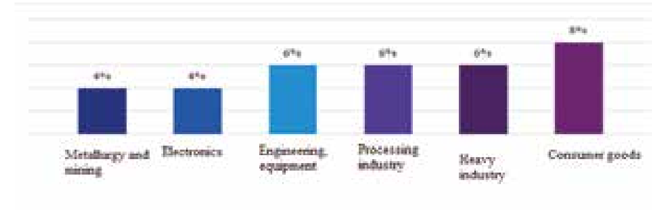
A company PricewaterhouseCoopers questioned 200 representatives of high-technology companies from different spheres in order to find out the main drives for investment into digital factories (pic. 3) and to compare advantages of a digital factory, located in the very country where the company was situated, with creation of the factories in the areas with low-cost labour (China, Korea and others). The representatives of the companies, which plan a digital factory conception realization, realize perfectly well, that vast investments will be needed (pic. 4), and the results will be received only over the long term (pic. 5).

In five years after the project realization start the companies expect to receive significant results: expenses efficiency upgrading and revenue growth (pic. 6). High financial and time spending on realization of the digital factory are conditioned by the need to direct investments into the complex of hardware and software solutions, providing transformation of production processes.

Pic. 5. Period, during which the companies expect to receive return on investments into the digital factory projects [DigitalFactories, 2017]



Pic.4.Revenue share, which the companies plan to direct to the digital factory realization , %[DigitalFactories, 2017]



DIGITAL FACTORY CONCEPTION IN THE CONTEXT OF TECHNOLOGIES

1. **Factories.** A digital twin helps to plan, engineer and build production constructions and infrastructure. It can be used in testing processes, imitation of activity and putting the factory into operation (pic. 7).

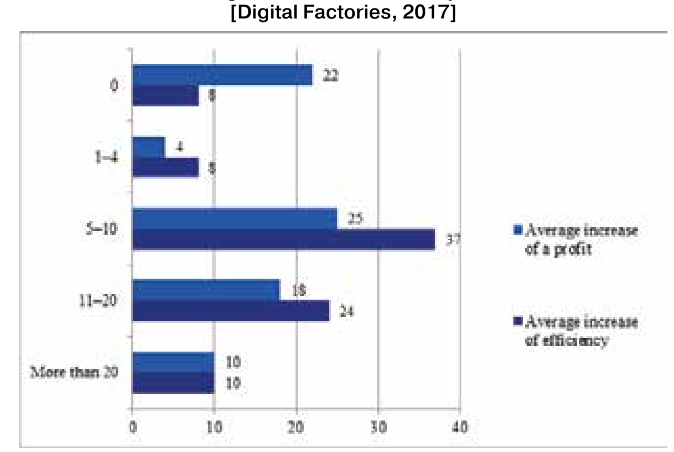
2. **Business assets.** A digital copy of one or a few production equipment for engineering, virtual start and current operations control is used for imitation of production processes of the equipment in order to work bugs out of it and optimize parameters and also in order to receive input data for predictive analytics and augmented reality.

3. **Product.** A virtual representation of a product provides interconnection between manufacturing operations and product life cycle management. A tool helps to develop and test a virtual copy of the product, rectify defects and increase quality level, not spending physical resources on development and working off the defects.

4. **Connectivity** contemplates availability of a layer in the IT-architecture of the factory, which by means of sensors, Internet of things and other tools integrates the data of the production objects, including resources, transportation means, products etc. The tool provides development of the Manufacturing Execution System, MES and its integration with Enterprise Resource Planning, ERP.

5. **Modular production equipment** is a more efficient alternative to immobile conveyer manufacturing lines. Different units of the hardware can be connected and disconnected depending on the production chain for solving of the current task or an article production. Manufacturing processes become more flexible than they were before.

Pic. 6. Average increase of efficiency and revenue [Digital Factories, 2017]



6. **Flexible ways of production.** Flexibility and adaptivity of production processes are provided on the basis of definite tasks. For instance, an industrial 3D-printing gives an opportunity to quickly produce a wide nomenclature of complex details and accessory equipment, doesn't need starting of large-scale processes or additional involvement of specialist providers. The technology is especially profitable for a single-piece or a low-volume output.

7. **Visualization of the processes for users.** If the staff use in work i-pads or augmented reality technologies, then it is possible to significantly simplify, for instance, complex assembly processes or repair jobs. The i-pads or augmented reality goggles in online mode prompt the employees, which action is the next to be made or which detail should be used.

8. **Integrated production planning.** Integration of production informational systems of the class MES with the systems of resource accounting of the class ERP is planned. Integration provides a fast transmitting of the data about expended raw materials, need of additional constituent parts from production level to the accounting level. A fast upgrading of resources plans gives an opportunity to correct the intensity of their expenditure. As a result efficiency of the inventory control processes and placing orders with suppliers increases.

9. **Autonomous inbound logistics.** Transport and storage equipment should be able to receive and process the information about the current status of the production process and activate specified algorithms, for instance, search and transportation of the constituent parts from the warehouse and giving to the production, or acceptance and transportation of the finished products. In practice autonomous transport robots are widely used, the robots which are able to move vertically and horizontally on the storage rack systems, drones for over size loads.

10. **Predictive analytics.** In online mode sensors and software collect the data of the production equipment, process them on the grounds of specified algorithms and form recommendations/requests for repair and technical service before the actual break-down or crash, and this essentially reduces the risks of stoppage in production.

11. **Big data analysis.** At the new type production numerous detectors and sensors are used, which continuously collect a tremendous packages of information. Companies invest significant means into analysis of these packages by means of statistics methods and computer-aided instruction, analysis of big data is able to provide an essential optimization [Grishyna A., 2017].

12. **Smart systems of resources consumption optimization.** The systems provide optimization of consumption of electricity, water, compressed air at production site. Solutions may be «box» as well as developed individually by the company on the grounds of big data analysis.

13. **Parameters passing.** By virtue of forming-up of production processes mainly in the virtual space the received configurations are replicated, they can be transmitted to other plants within a company in the form of package of parameters and settings.

14. **Track and Trace**. Movement of raw materials and finished products in the space is tracked within the company as well as beyond its borders. The work of these systems is also provided with industrial internet of things technologies, including sensors, RF tags etc. Transmitting of this information into the systems MES and ERP increases efficiency of integrated production planning.

A digital factory conception contemplates transformation of the production business processes system by means of the concrete technologies [Trachuk A. V., Linder N.V., 2016 b]. Destination is a total digitalization of the whole life cycle of the articles and a very high degree of processes independence. Many enterprises abroad as well as in Russia have already started the transformation of their operating models, now they are at the stage of a digital factory creation.

RESEARCH METHODOLOGY

The main method of carrying a research is the remote analysis of cases on the basis of open data, published by the companies, which included the digital transformation and Industry 4.0 into their corporate strategies, and expert evaluation method of the studied economic phenomena. We have set the following tasks:

- In which actions at the level of production function is the strategy of digitalization and Industry 4.0 realized?
- How do the enterprises transform the processes and informational technologies of operating models by means of the modern solutions?
- How is the digital factory conception realized in practice?

As the subjects of research a public company «NLMK», a public company «SIBUR» and Siemens AG were chosen. The criteria for selection were:

- Belonging of the companies to manufacturing industries with a complicated technological chain;
- Active realization of the digital transformation, Industry 4.0, digital factories and experience of a successful implementation;
- Being at different stages of the operating model digitalization.

Pic. 7. Digital factory conception [Digital Factories, 2017]

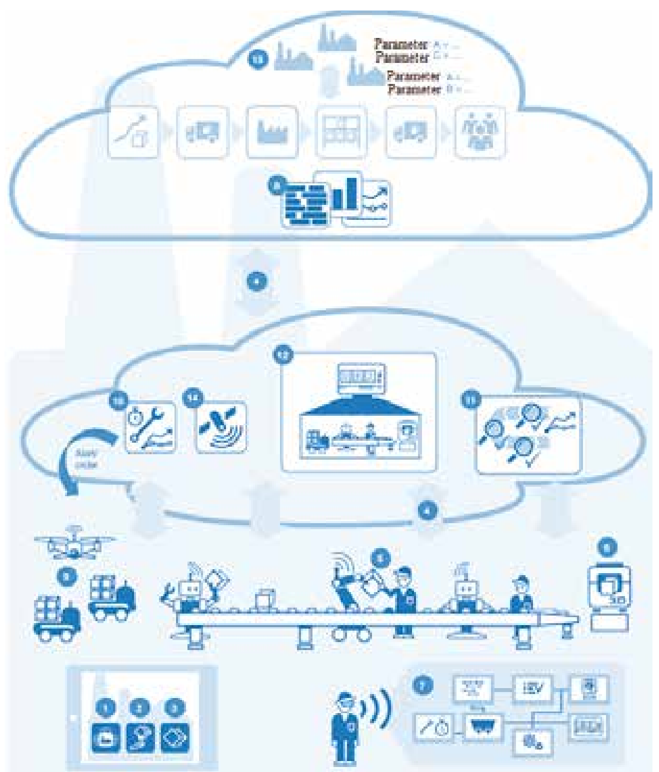


Table 2
Accumulation of the initial information sources

Materials (official informational resources of the companies and public sources)	Analyzed companies		
	A public company «NLMK»	A public company «SIBUR»	Siemens AG
Annual reports of the companies 2015-2017	2 reports	1 report	1 report
Interview with representatives of the company management in mass media, publication about the company	10 publications	11 publications	5 publications
In-house publication	2 magazines	—	—
Documents (provisions, regulations, instructions) of the company	3 documents	3 documents	10 documents
Press-releases, results/technologies presentations, events and the news	7 materials	7 materials	7 materials
Materials of conferences and forums	2 materials	4 materials	2 materials

Information base is open-source materials (table 2).

For a systematic studying of production processes transformation there was formed a set of high level manufacturing processes. Initiatives about realization of the digital factory conception were considered through the prism of production processes (table. 3). The sequence of case study is showed on the pic. 8.

A public company «NLMK»

NLMK Group is one of the largest steel manufacturers in Russia (23% of steel production) and one of the most effective steel producers all over the world. The business is build according to the vertically-integrated model. Industrial sites of the company are located in Russia, Europe and the USA. Their aggregate capacity is approximately 17 million ton per year. The production is used in different industries: starting from shipbuilding to offshore wind turbines. A high demand for the production is accompanied by the appropriate level of financial indicators: in 2017 in comparison with the previous period EBITDA increased 37% up to 2,7 billion dollars, that comes with rise in profitability within EBITDA up to 26% [The key operational… [s.a.]]. It gives an opportunity to the NLMK to rank among the top-grossing steel producers in the world.

Formed in 2017 investment cycle is mainly oriented to increasing of business processes efficiency, development of the raw materials basis, consolidation of positions on the strategic markets and production safety improvement. To achieve the goals it is planned to use the technologies of Industry 4.0 in all the business processes.

At the production engineering stage the main design institute «NLMK-Engineering» got on the path of digitalization. From the beginning the organization dealt only with the objects of the Group, but with the lapse of time the engineering activity sphere was expanded, and now it is a famous engineering company with unique competences and a huge experience of industrial objects designing.

In order to save the leading position within the field it is not only needed to develop and improve, but also to do it faster than others. The main drive of «NLMK-Engineering» development is visualization technology and technology of project documentation creation. (Building Information Modeling, BIM) [Kazantsev A., 2017]. With the help of BIM a complex of tasks can be solved:

- A 3-D model of aggregate is created;
- Digitalization is spreaded not only over engineering calculations, but also over all the technical, value and operational characteristics of the object;
- The formed communication platform allows all the interested parties to effectively interact during a life cycle of the project.

The technology possesses a lot of advantages. Let's mark the crucial peculiarities in comparison with traditional drafts:

At the engineering stage the 3D-modelling clarity helps to remove all the miscounts and mistakes, which would be able to influence the work progress. It increases the exactness of planning of the needed for building resources.

From the point of view of stakeholders interrelation, the very engineering process changes crucially. The object modeling is performed by means of the 3-D elements set, available in the database or given by the suppliers. During the process of the virtual «building» all the specialists groups are working simultaneously, but not on a stage-by-stage basis, as it was before. BIM-coordinator is responsible for coordination of works and detection of clashes at the engineering stage. He holds weekly meetings of the project team, points at defects within a model. After this a chief engineer defines a concrete direction, where the specialists should rectify the detected defect by way of making the appropriate changes.

«NLMK-Engineering» possesses all the needed resources for integration of the used technologies into a single system, that strengthens a competitive advantage of the company. Combination of all information systems of the company (resources management system of the enterprise, SAP ERP), information system of the projects management, management system of engineering data and a system of performing of the bill of quantities) allows on the basis of information about the elements, used in a 3-D model, to define the volume of the needed

Pic.8. Sequence of work with a case

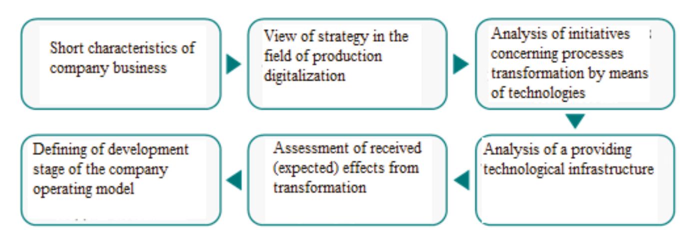


Table 3
Production processes

Process	Initiative of transformation		
	A public company «NLMK»	A public company «SIBUR»	SiemensAG
Service processes			
Engineering and prototyping	✓	×	✓
Production planning	✓	✓	✓
Production analytics	✓	✓	✓
Logistics — internal, inbound, outgoing, warehouse	×	✓	✓
Technical control	×	×	✓
Environment, health and safety	✓	✓	×
Supporting processes			
Technical maintenance and repair jobs		✓	✓
Management of tools and equipment	×	✓	✓
Providing with all kinds of energy (steam, heat, air, electricity etc.)	✓	×	✓
Main technological processes			
Storage, processing, assembling	×	✓	✓

materials and labor costs. This kind of integration significantly simplifies the process of cost estimation development for the building and increases the calculation accuracy of the costs of work.

After a successful approbation of the BIM technology within the turbine generator №5 project the NLMK Group is planning to use 3-D models by fulfillment of the 90% of the orders by the end of 2018 [BIM-engineering, [s.a.]]. It will be accompanied with improving of the software and a further integration with the electronic catalogue of the equipment, which already comprises more than 92 000 objects. Within the strategy of «Industry 4.0» of the NLMK Group it is planned to create virtual twins of the acting production objects – not only of the separate aggregates, but enterprises as well. Such an extensive work will open large opportunities for receiving of the current information about the status of each of the equipment components, changes modeling and formation of the database for performing of the proactive repairs.

Production digitalization is mainly characterized by IT-foundation formation for providing of an opportunity for the further automatization. For this in 2017 an agreement with SAP, a German producer of the software for organizations, was completed. A complex cooperation comprises creation of the innovations laboratory, which presents a unique project for both the parties. Activity is formed up on the foundation of IT-platform SAP S/4HANA [SAP S/4HANA, 2015]. SAP S/4HANA is a new version of the enterprise resource management system— ERP-system, which allows to significantly speed up the business processes and implement in production quantities cloud solutions technologies, technologies of Internet of things, computer-aided learning and artificial intelligence [NLMK Group, 2018]. Undeniable advantage of the platform is an opportunity to develop custom written applications and to rapidly develop in Industry 4.0.

Today there already exist a few realized on the basis of SAP S/4HANA projects. They embrace different sides of business, including a financial one. With the help of the computer-aided learning the computer models managed to be taught how to compare invoices and bank statements. On the grounds of historical data of the contracting agents payments a computer was taught to predict with a probability of 80% the next payments against invoices within horizon of 30 days, that essentially simplifies the planning of financial resources and the volume of the needed reserves.

Geological and Mining Information System is considered to be a unique development, which works with a 3-D model of a career, giving an opportunity to simulate an ideal plan of its development for the future 40 years. The technology allows to mine the ore with minimal costs and maximal efficiency [represented by the NLMK Group, 2018].

Today IT-platform is integrated with more than 20 information and production systems of the NLMK Group, more than 6,5 thousand people use it. It realization didn't take much time owing to united efforts of the NLMK Group, SAP Digital Business Services team, SAP Premium Engagement, global support and SAP development within innovative clients support program.

Great attention is paid by the company to maintenance service and repair works (MS and R) of the equipment for increasing of the production efficiency. Owing to reduction of losses by means of repair works and premature replacement of the facilities with a normal remaining life time, it is possible to save significant means. Today the main trend of this direction is transition from the reactive service to the preventive and proactive service, that is taking measures before the equipment becomes out of service. This is the key characteristics of a new strategy of MS and R management, which is implemented within the NLMK Group [Zasolotskaia E., 2017]. During preventive system implementation it's impossible to go without digital technologies.

In order to decrease the reactive component share a strategy of the proactive service is realized. At its bottom lies implementation of confidence tools. For their efficient functioning collection of big volume of information about the hardware is needed, including that in the context of influence of the quality and service system operativeness on the quantity of running failures of the hardware; as wells as repair works and replacement of the parts of equipment which possess a critical level of run-out. For the purpose of their fulfillment in the NLMK there was created the center of competences in the field of automatics, which is one of the best in the world.

Prospects for the further development of the proactive system are seen by the NLMK Group in implementation of the predictive analytics elements.

Service is conducted only upon availability of changes in the characteristics of the hardware, which is detected on the grounds of mathematical models and big amount of statistical data. Transition to this stage may be promoted by the project «Fast close of repair jobs by home and engaged staff (Fastclose)». The idea of the project is: every 24 hour day all labor and material resources are considered, which are oriented to the repairing and maintenance service of a particular machine. The hardware database was composed by reliability specialists and works planning specialists in SAP, who also formed the appropriate catalogue in SAP ERP. It can be used for building the system of changes tracking.

A project aimed at teaching of forecasting, when furnace tuyeres of «Rossiianka» will be out of service is already realized. Studying of the current practices, collecting of the packages of historical data, received by means of detectors and laboratory investigations, finding out the connection among them, helped to define predictors – key aspects for prediction. On their basis together with application of the computer-aided learning a model of tuyere burnout was composed with using of solutions of SAP Predictive Analytics and SAP Maintenance & Services. The horizon of prediction is 20 days, recommendations allow to replace the tuyeres during the scheduled repair jobs. The effect is evaluated by 20% increase of tuyeres service life with economic assessment of over 60 million rubles [Artificial brain, 2018].

It's noted at the NLMK that the proactive system is not able to fully replace the preventive and reactive methods. Their balanced combination with the technologies of automation will allow to develop a complex approach, which will increase the reliability of equipment and reduce its cost at the same time.

Individual attention is paid by the NLMK Group to following of the safety instructions for the working area. As early as in 2013 there was settled a task to develop and implement modern preventive measures for increasing of labor safety: a united methodology of detecting potential hazards, systems of assessment of the risks range and the best practices for their management. To fulfill the task traditional methods of increasing of the industrial safety are used as well as the new solutions with application of Industry 4.0 technologies. In 2014 and 2016 yrs Lipetsk industrial site was recognized to be the safest one in Russia.

Innovations laboratory of the NLMK-SAP is one of the key structural subdivisions of the company, the activity of which is devoted to the digital initiatives realization. The NLMK Group specialists together with developers and researches of SAP, with other partners create new developments in the field of processes analysis, user interface, internet of things, computer-aided learning, predictive analytics and production planning.

One of the most significant technologies is 3-D locating of the staff (Real-time Locating System, RTLS), which was developed by NLMK SAP innovations laboratory and National center of internet of things. The system is based on a cloud platform SAP CloudPlatform, locating system RTLS-UWB, technology of 3-D visualization and new typical wireless network LoRaWan [implemented by NLMK, [s.a.]]. The system is realized on a scale of an aggregate of continual HD galvanizing №1 on the Lipetsk industrial site. In real time mode the information about movements of the staff and changes in operating regimes of the aggregate is displayed and collected. In order to receive the data about the staff, in the beginning of the working day every worker is given a tag-sensor, which traces his/her behavior in the system of production space. All the information is aggregated and transmitted to the analytical panel – dashboards and to the managers, that allows to swiftly react on probable incidents and alert the workers about possible danger and oddities. Besides, the accumulated volume of information gives a chance to analyze the actions of the staff, in future it can be successfully applied for making decisions in the field of production safety, human resources management and health protection.

NLMK Group notices a prospective viability of other technologies as well, which change our view of a safe production. Just before the beginning of a shift every worker of a hazardous production should have a medical examination. Now this procedure is already fulfilled by means of the automated terminals. Electronic system takes all metrics, characterizing a human's state of health: pupillary reaction, alcohol test, temperature, pulse and blood pressure. The innovation unloads a medical staff and reduces probability of mistakes to a minimum.

A «smart» safety helmet helps a worker to independently and properly evaluate a degree of his/her tiredness. A rim with sensors, fixed on a head, collects data about brain activity and transmits the information through Bluetooth to the computer monitor or a smartphone, it is analyzed by means of a specific software and is displayed in real time mode. In case when a worker ignores the warnings of the program, a supervisor receives a signal of irregularity and makes a decision about the possibility of shift continuing.

A virtual reality technology, which got a wide spreading in the sphere of entertainment and computer games, is also used for production safety providing. The examples of behavior, hazardous for life and health, are recorded by a camera with panorama of 360° and demonstrated with the help of augmented reality glasses. An employee «is placed» into situation, when he/she faces risk, and then answers the test questions and searches for the right way out of the suggested situation.

At the enterprise analysis of big amount of data is widely used, it is to provide a significant potential of business efficiency growth. In order to have an opportunity to process a volume of unstructured information, calculated in petabytes, a tool Big Data is needed, which became a key basis for a new wave of innovations and production capacity growth [Magazine, [s.a.]].

In metallurgy characteristics of a product and production process are defined by means of big amount of parameters. They compose information package which can be analyzed and sent for optimization of production processes.

The NLMK data analysis department deals with implementation of mathematical methods of data analysis and mathematical modeling. By means of application of big data technologies, computer-aided learning and artificial intelligence not only pioneering projects are developed, but a range of initiatives is implemented at the production. A part of them is oriented to saving of highly priced ferro-alloys, search for the reasons of a few kinds of products defects and CHP plant work optimization. Altogether there were chosen ten initiatives from fifty defined ones for realization, an expected economic effect should be approximately 3 billion rubles.

But realization of the initiatives, connected with BigData, demands IT-infrastructure. It serves for collection, analysis and company data storage. Realization of a project concerning creation of a hardware system was trusted by NLMK to the company «Technoserv». In June, 2018 a contractor finished all works - from delivery to starting and setting up of a server hardware Hewlett-PackardEnterprise and means of communications network CiscoSystems[built by NLMK, 2018]. The complex was located in Lipetsk, where the main center of NLMK data processing is situated.

According to the point of view of the company IDC, by 2020 the volume of information about clients, suppliers and production operations, which the company has got, will be twice a large. For taking decisions 60% of data volume will be applicable, but still this index is unapproachable because of a range of restrictions, including those for NLMK.

First, before the appointment the functions in order to solve business-tasks by means of data analysis were not considered. Some separate subdivisions conducted experiments and pioneering projects for the purpose of defining the potential of data analysis and modeling using. Concrete results were not received, but the company members realized that by means of the digital technologies it's possible to essentially increase the operative efficiency. That's why now the task is to arrange a system-based work on implementation of the artificial intelligence, computer-aided learning and the tool BigData.

Second, a full information can be obtained not for all the process stages. On the one hand, it is connected with physical and chemical conditions of production, in which the sensors should be applied. On the other hand, not on every production equipment it's possible to fix the modern devices for data collection. In the first case it is impossible to go throw the limitations within a single enterprise, while in the second case significant time and financial resources will be needed.

A public company «SIBUR»

Enterprises from the petrochemical industry are actively interested in digitalization. For instance, a public company «SIBUR Holding» is not only uses digitalization mechanisms, but also creates them itself.

A public company «SIBUR Holding» is one of the largest national companies with vertically-integrated structure, working in the field of gas and petrochemistry conversion process. It makes a speciality of two business-segments: olefins and polyolefins; plastics, elastomer plastics and intermediate products. For the year 2017 the revenue of the holding was 454 619 million rubles, EBITDA — 160 851 million rubles, and net profit — 120 245 million rubles, that is 6,3% more in comparison with a previous year, [Consolidated, 2017].

One of the strategic aims of SIBUR is a general digital transformation – using of Industry 4.0 technologies in all business processes. It is considered as a means for adding of tools for continual improvements, it is actively used for all production processes optimization. Various mechanisms of «Industry 4.0» are involved almost in all production processes: from engineering of a product to production safety. With their help it's possible to improve the results in the sphere of production capacity, to perform changes faster with a possibility of scaling and to receive more stable result. As a foundation for changes SUBUR uses two traditional competitive factors, defining a general efficiency of business in the petrochemical field: cheap production means and raw materials, and development of chemical substances with new characteristics, which meet the needs of consumers.

Implementation of digitalization began on the 1st of December 2017, and in the beginning of 2018 there was organized a department, which provided creation and implementation of various digital technologies of the digital revolution (augmented and virtual reality, Internet of things, data science, computer-aided learning, mobile applications) into all business processes, starting from delivery of raw materials to the production to sales [«Sibur»: digital-revolution, 2018]. A great advantage is a wide using of the automatic process control system (APCS) [SIBUR Holding, 2018]. Apart from opportunity to control the whole process from the operator's room, APCS accumulates a big amount of data, which can now be used for digitalization. SIBUR implements the systems of advanced process control (SAPC), production systems MES, laboratory systems LIMS and business-applications SAPERP. There already exists a certain IT-foundation for the further digitalization of the company, but still there is no full integration of systems, which is needed for migration to the Industry 4.0 technologies.

SIBUR has been dealing with the digitalization issue not for a long time, but still quite a number of initiatives were realized and even more initiatives are in the process of development or testing.

By means of technology of Near Field Communication (NFC), which is implemented in NFC-tags, the i-pads of the employees receive the information about the tasks, operation status and responsible for a certain equipment item person. The i-pad is integrated with the systems and databases of the enterprise, it contains the whole information about the works which are to be fulfilled. After finishing of work an execution, time, constituent parts are fixed in a system.

DataScience is used for production processes control, analysis of production parameters, which serve as a foundation for prediction of events and drawing up recommendations for machine men.

A virtual reality provides a detailed modeling of operations and events, faced by the employee, the technology is used for teaching new workers and skill improvement of the acting ones.

RFID-tags allow to identify various kinds of equipment, that significantly simplifies processes of logistics and inventory.

Intelligent video monitoring identifies the staff on different production sites, defines their state of health and monitors manufacturing processes. Owing to this technology at Moscow office of the company the office passes were refused.

Common databases are ever-expanding, the information is systematized, analyzed and on this ground the recommendations on production processes optimization are made [Digital, 2018]. SIBUR tries to choose the technologies with regard to all possible results.

Today there are the concrete results. At manufacturing site of polypropylene the quantity of film breaks was managed to be reduced by a factor of 10, the production speed was essentially increased [The Future, 2018]. By means of analysis of a large package of data from the sensors, installed on the processing lines, correlation between the indexes of some semi-finished products production parameters and quantity of film breaks was found out. The changes of these parameters brought the described effect.

The system was implemented, which gives the machine men recommendations so that they should select the best production mode in changing conditions. The system is used during pyrolysis process, which is performed with different sets of initial parameters and raw materials quality and leads to different optimal working modes. On the basis of analysis of the previous production cycles the information about how this or that processing method influences the economic efficiency of the production and what should be changed in it, is sent to the dashboard.

An individual attention is paid by SIBUR to logistics. Production sites of the company are located at a considerable distance, among them a railway communication is organized. A constant transportation of various semi-finished products among the production areas requires railway platforms and railroad cars. The initiative is oriented to systematization and optimization of group consignations, defining of the most effective from the economic point of view term of sending of the railroad car to repair jobs. In order to support business objectives the data of all the transportation management systems and scheduling were consolidated, at the same time analytic tools were created in order to optimize transportation organization. The result of the project, implemented at the railways station Denisovka, was time saving during assortment, controllability and processes clarity upgrading and customer-centricity growth [SIBUR lauched, 2018].

At 22 production sites it is planned to reduce the scope of reactive repair works, to exclude equipment failures, which cause receiving of non desirable brands of products but transitional ones, that considerably decreases the value of the ready products. SIBUR placed a bet on the proactive equipment maintenance. A model developed on the grounds of the current database allows with the accuracy of up to 72% to define, when the failure of the extruding machine, shaft or granulator will occur. It helped to shorten the quantity of the emergency stoppings from 5 to 1.

For simplifying of the equipment maintenance mobile solutions are used. In Voronezh there was started a pioneering project: during repair works on equipment a maintenance team sends photo materials to the specific service and afterwards they obtain consultations. In case of a break at the production site in Tobolsk, a worker can broadcast the picture to the remote expert, who will swiftly issue directions about what should be done in the real time mode. The first consultation was carried with an expert from the German company Linde, technologies of which are used by SIBUR [«Industry 4.0» in operation, 2018]. Consequently one can significantly reduce the terms of repair works fulfillment, especially of the works, which can't be coped with immediately in situ.

Even with the digitalization technologies the quality of the fulfilled works is considerably influenced by the staff qualification, «SIBUR Holding» holds a special training of the staff teaching them how to perform assembly and disassembly, equipment repair and maintenance applying technologies of the virtual and augmented reality, that allows to significantly shorten the repair works time and improve its quality.

Recently in Tomsk there has been installed a special training simulator with using of the virtual reality, by means of which one can master compressor repair. Before now in order to check the compressor from the inside the specialists were waiting for the scheduled stop for repair works, but today the virtual reality allows to fashion any emergency situation, giving the whole description and status of the object.

Pilotless aerial vehicles is an interesting practice of the digitalization technologies implementation. They are used for evaluation of works volumes during building and for status monitoring of pipelines and production facilities. Testing of devices is held at the stock company «SiburTyumenGas» and at Amur Gas processing plant. With the help of the aerial vehicles it's possible to remotely examine communications, hard-to-reach places and also pipelines in order to find out the leakage.

Table 4
The key digital initiatives of SIBUR [Digital transformation in SIBUR, 2018]

Realized:	In process or on testing:
Digital twins DataScience. Training simulator in a virtual reality. Reliability management system. RFID-inventory in the office. Artificial vision. Monitoring of building by drones/ pilotless aerial vehicles. Projects with an artificial intelligence	Mobile maintenance and repair. Digital job orders. Digital logistics. Augmented reality. Proactive operation at production site. Guides at production site. Intelligent video monitoring. Robots at laboratories, maintenance shops, warehouses, loading/unloading. Smart tools and smart clothes (wearable devices and internet of things). Exoskeleton. 3D-printing. Electronic document management and e-trading platform of commerce (eCommerce). Mobile LIMS. Business processes through automation

Digitalization found its application in providing of the staff safety [Burlutskii A. V., Cherepanov V. D., 2017]. A «Smart bracelet» allows to define the state of health of the employee, being in hazardous locations. Inboard gas-analyzers inform about environmental conditions, and alarm button allows to receive the needed aid as fast as possible.

SIBUR thinks it expedient to go on implementation of the digitalization into production processes. The promising directions are:

- Reduction of the information share, which is kept in print format aimed at advancing of the speed of its processing—«data lake» instead of circulation of paper;
- Integration and centralized processing of information packages about railway transportations for optimization of logistics processes at all railway stations;
- Using of 3D-printers for a swift production of details in situ;
- Using of digital tools application practice on the other areas of work.

A further improvement and application of Industry 4.0 technologies allows to significantly increase the volumes of the public company «SIBUR Holding» products.

Siemens AG

A German concern Siemens produces and delivers complex solutions in the fields of electrical technology, electronics, energetic, medicine, transport and communications. The company demonstrates positive financial results: in 2017 sales turnover reached 83 billion euro, profits — 6,2 billion euro. Owing to motorization, automation and digitalization in all the activity directions the Siemens actively implements technologies of Industry 4.0 into its business processes, develops its own systems and tools of digitalization, which are used by other companies.

A distinctive feature of Siemens on the way to Industry 4.0 is a complex approach to the changes (Totally Integrated Automation, TIA). The company is focused on the technologies, which correspond to the five main trends of production:

- The speed of bringing of a pioneer product to the market allows to attract more customers and receive more profits.
- The production flexibility allows to release a wide assortment of products in various modifications at one manufacturing line, to quicker satisfy the needs of a customer and adapt to the market dynamic environment.
- A good quality of products and production promotes minimizing of losses from defects and increasing of customers retention, providing the company with Revealed Comparative Advantage.
- The production efficiency is connected with a speed-up, reliability growth and losses reduction during the production process.
- The efficiency of the «smart» production, implicating a constant data interchange among the production units, depends significantly on cyber security quality. Without a proper defense of the critically essential devices and information it's impossible to guarantee a complete autonomy and production processes independence from the probable outside users intrusion, causing negative consequences [Helmrich K., 2015].

With the context of digitalization cloud technologies, robotics technology, knowledge control automation, Internet of things, production processes modeling, 3-D printing technology etc. are used. The most palatable set is defined according to the production type (discrete or continuous) and the company life cycle chain, which is used by Siemens (pic. 9). For various stages of production life cycle quite a wide range of systems, developed by Siemens PLM Software is suggested.

For continuous production grand-scale systems COMOS, SIMATICPCS 7, PIASelector and SIMOTION are applied.

COMOS is a project management system, which is mainly used for planning, exploitation and maintenance of processing installations and for controlling them [SiemensCOMOS, [s.a.]]. Initially it was an integrated system of programs and program products for solving of engineering tasks in the sphere of equipment design. Today the system is supplied with a centralized data management and an open architecture, where an object oriented programming is supported. Interfaces COMOS allow to integrate a system into already existing IT-infrastructures or apply it together with the other program systems. This helps COMOS not only to support the planning, but also the working processes, that's why the technology can be used by equipment design engineers for the industries with a continuous production (energetic, oil and gas and chemical industries) and by mechanics who implemented the system as well.

SIMATIC PCS 7 is one of the most popular process control technologies at the enterprise. It is characterized by a flexible architecture and possibility of integration into any system of the automated Siemens company management within the conception of a complex approach to the changes [SIMATIC PCS 7, 2015]. In a point of fact, SIMATIC PCS 7 is a part of the complex business digitalization in terms of processes: from logistics to the finish-product output. The system allows to get an access to the concrete processes data at various levels: enterprise resource planning (ERP-systems), manufacturing execution system (MES-systems), industrial process control (Automatic Process Control System, APCS), that is possible owing to using of international industrial standards for the data interchange. A flexible packaging of the system allows to take into account the peculiarities of each separate project: from laboratory digitalization to processes management at the connected installations within an enterprise. It should be noted that the biggest effect can be achieved together with other technologies, developed by Siemens in terms of Industry 4.0 conception, because the manufacturer counts on synergistic effect of all the production processes digitalization.

PIASelector provides selection of the best possible set of sensors and Siemens analytical tools with a function of determination, directions of their application in the processes of automation. In the first place the sphere is chosen where a device, equipment itself and a concrete way of its using can be applied. Siemens wants to simplify in such a way the selection of a perfect product configuration among a big amount of nomenclature items [PIA Life Cycle Portal, [s.a.]].

SIMOTION is a highly-productive scalable motion control system [SIMOTION, [s.a.]]. It allows to create multiuse program modules, improving the efficiency of hardware development. It is counted on modularity, precision and operating speed. SIMOTION was developed considering the possibility of a fast integration with other products and systems of Siemens in terms of TIA. For instance, the system is applied for modernization of veneer peeling line, that provided a continuous work of the installation and parallel energy usage reduction at the production site of the «ILIM» group.

For discrete production similar products are created: (Teamcenter, NX, Technomatrix and SIMATICIT), which are better adapted for the needs of the specific industries: machine building, production of electronics and computers, medical facilities etc.

Teamcenter is a package of software solutions for supporting of the product (PLM) life cycle on the basis of an open platform. The main function is management of the data about a product during the whole life cycle: from engineering to the processes automation of the after-sales maintenance and repair. Data interchange is possible in the real time mode [Data management, [s.a.]]. Teamcenter provides a complex visualization of the product taking into account the whole information about it and markings put onto the 3-D model and into documentation if needed. It allows to arrange interaction among all the participants of the process of engineering and production. As a result a paperless process of documentation negotiation is established. Besides, the system allows to model a finished product as well as changing of its characteristics: it's possible to see the way a detail looks, join a few details into a single one, test at bends, see how the temperature will spread. The solutions package is applied at different enterprises of the national aircraft construction, helicopter building, power-machinery construction and other industries. Teamcenter is used by NPO «Iskra», a stock company «Kaluzhskii zavod "Remputmash"», a stock company «Aviadvigatel», a public company «UAZ» and others.

NX is an integrated solution for design-engineering preparation of production [Survey, 2015]. It is applied as an independent system as well as a guiding product, integrated into already existing software environment. NX allows to define cooperation of a detail with other items, to test a received construction and find out bottlenecks. NX is applicable at all the stages of creating of a product digital mockup and technological preparation of production, that is provided by uniting of the functions for more efficient product development:

- Solutions in the field of sketch design, 3-D modeling and documentation creation;
- Means for calculation of strength, cinematics, thermal transmission, gas and hydrodynamics and interdiscipline analysis of physical phenomena;
- Solutions for work preparation of production of accessory details, engineering of processes of mechanical processing and quality control [Siemens NX, [s.a.]].

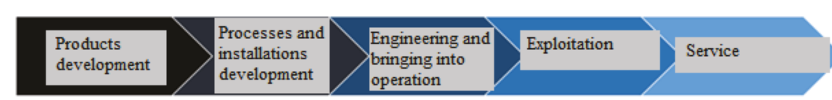
Technomatrix is a complex package of solutions for digitalization, embraces all spheres of production and development of an item: from the production process scheme to the production itself [SiemensTECNOMATIX, [s.a.]]. The solutions allow to perform the 3-D simulation, solve the task of the simulation modeling and programming of industrial robots, to perform a virtual start-up and commissioning of lines, to define mistakes of engineering. Technomatrix comprises a wide range of program products, which are characterized by opportunity to be applied independently as well as to be applied in a compatibility mode with other products, including being managed by Teamcenter. The advantages of Technomatrix are: reduction of time needed for production preparation, a simplified creation of structurally complex items, growth of profitability and production technology optimization by means of investments distribution among a few of products lines at the stage of engineering and modeling. The solution Technomatrix got quite a widespread acceptance in various industries: automobile manufacturing (KAMAZ, Volvo, BMW, Mazda), aero-space industry (Boeing), machine building and electrotechnics (Caterpillar), communication facilities (Motorola) etc.

SIMATICIT is an analogue of SIMATICPCS 7 for the discrete production. The product allows to construct MES-system, manage specifications of the products and deliveries chains, model organization production processes in an integrated fashion, define their opportunities and receive information from the ERP levels and production levels and manage it. It's a modular system, which consists of the software elements interacting together and allowing to solve all the needed MES-tasks, described in an appropriate standard ISA-95. The main advantage is modeling of complicated business processes and structures of production, which remain absolutely transparent, clear, independent from functioning of actual management systems [SIMATICIT, 2004]. Modeling can be held in every place of the enterprise, it provides standardization of processes, and the most successful management methods can be developed onto other business units or an entire enterprise. It is particularly useful for international holdings, having production sites in different countries all over the world. Built-in quality management processes – visual monitoring support, automated collecting of information about operations, defects management – support various management methodologies, including six sigmas.

A common technology for both the production types is an open cloud information system MindSphere, which is the key component of a powerful operating system, based on a technology of Internet of things [MindSphere allows, [s.a.]]. It allows to bind the company equipment and physical infrastructure with a digital cloud, that will provide receiving of information, needed for transformation of business and preventive service of the equipment. MindSphere possesses functions of data analyzing, means for development engineers, applications and services. The main merits of the system are:

- An open standard «OPC with uniform architecture» (OPCUA), which provides a proper level of network for connection of various products;
- A cloud infrastructure allows to use cloud technologies in the form of a closed system;
- New equipment is directly connected to MindSphere in any extents;
- Open interfaces are meant for individual clients applications.

Pic. 9. A product life cycle chain
[The Digital Enterprise 2D/3D Simulation Software from Siemens, 2015]



Thus, implementation of the technology by the company Siemens itself allowed to reduce the downtime by 10%, at the production site Coca-Cola the technology provided reduction of the downtime by 15%, a simultaneous slowdown in spending on maintenance by 5% [MindSphere — Open, [s.a.]].

Applying of a complex of the described technologies and technologies of the kind is needed for creation of a virtual production system («digital shadow»), which is always up-to-date and is expanded during the whole life cycle [TIA Portal V14, [s.a.]]. A complex of physical manufacturing equipment and «digital shadow» comprises the whole information about mechanics, electrics, automation, human-computer interface, security status, software version and other parameters. In point of fact, a complete integration of physical and virtual constituents is the production digitalization itself, which is a final aim of changes. At the beginning expressing of physical production in digital form and then integration of the two obtained parts are impossible without production improvement by means of building of the automated system with the help of Industry 4.0 technologies. A complete integration will be reached only when all the production processes will be automated.

All above mentioned technologies are really applied tools, increasing efficiency of production processes. Practicability of their implementation is demonstrated by the concern Siemens itself — one of the digitalization leaders. The company implements its own developments into all its enterprises, anyway the biggest success was reached at the factory Siemens Electronics Works Amberg (Amberg, Germany), where 75% of all the production processes were automated. Among other things checkers SIMATIC are produced there, which are the hardware component of the same-name system. 50 million of data points generate a constant flow of data, which is collected and analyzed by specific program systems. One of such systems is technology of Teamcenter, which got the widest spreading. Digitalization allowed to cut down the time for changing of product construction and production processes up to a few minutes. Owing to this in an automatic mode it is possible to produce more than 1200 serviced in Teamcenter products articles, which are shipped to more than 60000 customers. Herewith the quality level reaches 99,9% [As a smart factory, [s.a.]].

Siemens technologies are used by special vehicles producers as well, for instance, Maserati. Implementation of the technology led to cutting down of the time needed for assembling and increasing of production output. The time needed for development of the new model was reduced by 30% through digitalization of production processes: testing, assembling and simulation. Besides, models assortment thrice expanded.

National producers try to stay on a tail of their west colleagues. The largest Russian automobile maker a public company «KAMAZ» twice reduced the project deadline, using technologies of Industry 4.0, including those supplied by the company Siemens [«KAMAZ» and company, 2017]. At the production site the software products NX, Teamcenter and Technomatrix are implemented, they are already used for digital modeling of the production process and trucks assembling. In 2017 between a public company «KAMAZ» and company Siemens there was concluded an agreement, where it went about implementation of the conception of «Industry 4.0» in the context of creation of the digital twins of the article and production and development of a proprietary standard «KAMAZ» in the digitalization sphere. A complex approach to the technologies application will allow the company to save the leading position on the world market of trucks and engines producers.

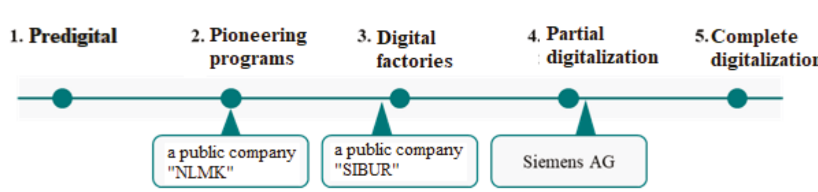
On the basis of the cases analysis one can make a conclusion that the examined companies are at different stages of the operating model transformation (pic. 10). This distribution is based on the studied materials according to which:

- a public company «NLMK» approbates the pioneering projects and prototypes on separate parts of the manufacturing and supporting processes, and possesses an event program for the short-term. One of the most complicated for NLMK tasks during realization of the digital factory conception is technologies adapting to hard temperature and physical conditions of the production, which are specific for metallurgical industry.
- a public company «SIBUR» managed to go a bit further – now 15 projects concerning innovative processes are being implemented at 8 from 22 existing holding production sites. A completely digital factory hasn't yet been created but Tomsk factory is reaching this mark, as a significant volume of processes were transformed there.
- Siemens AG is one of the world transformation leaders. The final stage hasn't yet been reached because various production sites are changed with different speed. Herewith initiatives concerning integration of horizontal value creation chains already extensively develop.

CONCLUSIONS

Passing from the high level strategic initiatives on business transformation by means of the modern technologies to the efficiency growth of the everyday activity is possible due to operating model development. The article deals with such key determinations as processes and information technologies, which immediately provide the digital transformation. Development of the mentioned determinations passes a few sequential maturity levels, missing of which for making a «vault» is fraught with organizational and financial difficulties. The traditional five maturity levels of the processes and information technologies were complemented with a digital level, because a digitalization strategy puts forward new demands to the operation efficiency of the enterprise. It should also be noted that choosing of and a speeded up transformation of a separate production process by means of the innovation technology don't have anything to do with the whole enterprise digitalization. Within this context there are five stages of the operating model transformation presented: predigital stage, «pioneering projects» stage, «digital factories» stage, «partial digitalization» stage and «complete digitalization» stage. A conception of the digital factory is examined in detail through the prism of the concrete technologies.

Pic. 10. Cases distribution according to the stages of the operating model digitalization



The cases of the companies: a public company «NLMK», a public company «SIBUR», Siemens AG are helpful because they show progress through the stages of the operating model digitalization. A structured approach to the cases studying is provided by means of a step-by step investigation of a wide range of manufacturing processes and initiatives concerning their development. Analysis of the operating model gives a work pattern for the realization of the initiatives, allows to make a list of the processes and technologies, which can be implemented at production site.

In future it seems advisable to study a possibility in principle of building of the digital factory from the ground up, without a compulsory passing through all maturity levels, as well as possible barriers on this way, for instance, not enough mature management practice, feeble integration of information systems, qualification deficit of the available personnel etc.

REFERENCES

1. Future is here. Nuances of economics digitalization // GaspromNeft. URL: http://www.gazprom-neft.ru/press-center/sibneft-online/archive/2018-may/1589541/.
2. *Burlutskii A.V., Cherepanov V.D.* (2017) A digital factory // SIBUR. URL: https://www.sibur.ru/upload/iblock/0d2/0d2da1eede2be3e8ccee1ad4de33542b.pdf.
3. *Grishyna A.* (2017) 7 cases of application BigData technologies in the production field // habr. URL: https://habr.com/company/newprolab/blog/325550/.
4. Group NLMK was first in CIS who passed to SAP S/4HANA for solutions of Industry 4.0 (2018) // URL: https://nlmk.com/ru/media-center/news-groups/nlmk-group-introduces-sap-s-4hana-for-industry-4-0-solutions-first-in-the-cis/.
5. Group NLMK presented the projects of a digital transformation at SAP Forum (2018) // NLMK. URL: https://lipetsk.nlmk.com/ru/media-center/press-releases/nlmk-group-presents-digital-transformation-projects-at-sap-forum/
6. A magazine «NLMK Company» ([s.a.]) // NLMK. URL: https://nlmk.com/ru/media-center/corporate-media/
7. *Zasolotskaia E.* (2017) Proactive lifestyle: a new strategy of management of the NLMK Group MRO // Production management. URL: http://www.up-pro.ru/library/repair/repair_organisation/proaktivnyj-toir.html.
8. «Industry 4.0» in action: in Tobolsk an experimental industrial pilot development of the augmented reality technologies was started (2018) // SIBUR. URL: https://career.sibur.ru/news/industriya-4-0-v-deystvii-v-tobolske-nachali-opytno-promyshlennuyu-ekspluatatsiyu-tekhnologiy-dopoln/.
9. An artificial intelligence — already at NLMK (2018) // Metal supply and sale. URL: http://www.metalinfo.ru/ru/news/comments101473.html.
10. *Kazantsev A.* (2017) Engineering of the future: BIM-technologies at NLMK-Engineering // Production management. URL: http://www.up-pro.ru/library/information_systems/project/proektirovanie-nlmk.html.
11. The way a smart factory Siemens uses data for increasing of the products quality and improving of the productive capacity ([s.a.]) // Intel. URL: https://www.intel.ru/content/www/ru/ru/internet-of-things/iot-siemens-smart-factory.html.
12. «KAMAZ» and «Siemens AG» signed an agreement about cooperation (2017) //KAMAZ. URL: https://kamaz.ru/press/releases/kamaz_i_kompaniya_simens_ag_podpisali_soglashenie_o_sotrudnichestve/.
13. The key operating and financial performance ([s.a.]) // NLMK. URL: https://nlmk.com/ru/ir/financial-results/.
14. Consolidated financial accounts, prepared according to IFRS, and account of the independent auditor (2017) // a public company «SIBUR Holding». URL: http://investors.sibur.com/~/media/Files/S/Sibur-IR/Financial-results/sibur_ifrs_12m2017_rus.pdf.
15. NLMK implemented a system on the basis of Internet of things for occupational accidents and deaths prevention ([s.a.]) // TADVISER. URL: www.tadviser.ru/index.php/Проект:НЛМК_%28система_3D-позиционирования_сотрудников_на_производстве%29.
16. NLMK built the IT-infrastructure for the work with big *data* (2018) // Digital transformation reporter CIO.RU. URL: https://www.cio.ru/news/130618-NLMK-postroil-IT-infrastrukturu-dlya-raboty-s-bolshimi-dannymi.
17. View of modules CAD/CAM/CAE of the system NX 10 (2015) // IdealPLM. URL: http://www.ideal-plm.ru/uEditor/files/4/397/ObzormoduleyCAD_CAM_CAEsistemiNX10.pdf.
18. *Ragimova S.* ([s.a.]) A digital industry 4.0 // Forbes. URL: http://www.forbes.ru/brandvoice/sap/345779-chetyre-nol-v-nashu-polzu.
19. SIBUR set up a project on logistics digitalization [2018] // SIBUR. URL: https://www.sibur.ru/press-center/news/SIBUR-zapustil-proekt-po-tsifrovizatsii-logistiki/.
20. *SIBUR Holding begins to pass to «Industry 4.0»* (2018) // Chemical equipment. URL: https://chemtech.ru/sibur-holding-nachinaet-perehodit-k-industrii-4-0/.
21. «Sibur»: digital-revolution in petrochemical production (2018) // HH.ru. URL: https://hh.ru/article/312408.
22. *Tarasov I. V.* (2018) Technologies of Industry 4.0: influence on improving of the productive capacity of the industrial companies // Strategic decisions and risk-management. № 2. P. 62–69.
23. Operating model transformation ([s.a.]) // KPMG. URL: https://home.kpmg.com/ru/ru/home/services/advisory/management-consulting/operational-excellence/operating-model-transformation.html.
24. *Trachuk A. V.* (2014). Business models for the hyper related world // Management sciences of a modern Russian. Ch. 1, № 1. P. 20–26.
25. *Trachuk A. V.* (2012). Innovations as a condition for a long time constancy of the Russian industry // An effective anti-crisis management. № 6 (75). P. 66-71
26. *Trachuk A. V.* (2013). Forming of the innovational strategy of a company // Management sciences. № 3. P. 16–25.

27. *Trachuk A. V., Linder N. V.* (2016 a) Adapting of the Russian companies to the changes of the environment: a role of the electronic business tools // Management sciences. №1. P. 61–73.
28. *Trachuk A. V., Linder N. V.* (2016 b) Methodology of a multifaceted estimation of the holdings innovative activity in industry // Scientific papers of the Free Economic Society of Russia. Ch. 198. №2. P. 298 –308.
29. *Trachuk A. V., Linder N. V.* (2017 a) Innovations and productive capacity: empirical investigation of the factors, hindering performance by means of longitudinal method // Management sciences. Ch.7. № 3. P. 43–58.
30. *Trachuk A. V., Linder N. V.* (2017 b) Development of the tools of the electronic business in Russia: empirical investigation results // Russian journal of management. Ch. 15, № 1. P. 27–50.
31. *Trachuk A. V., Linder N. V.* (2017 c). Innovations and productive capacity of the Russian industrial companies // Innovations. № 4 (222). P. 53–65.
32. *Trachuk A. V., Linder N. V., Antonov D. A.* (2014) Influence of the informational and communication technologies on business models of the modern companies// Effective anti-crisis management. №5. P. 60–69.
33. *Trachuk A. V., Linder N. V., Ubeiko N.V.* (2017). Forming of the dynamic business models by the e-commerce companies // Manager. №4 (68). P. 61–74.
34. *Trachuk A., Tarasov I.* (2015). Examination of the efficiency of the organizations innovative activity on the basis of a process approach // Control theory and practice problems. № 9. P. 52–61.
35. Management of the article data on the basis of Teamcenter ([s.a.]) // Ideal PLM. URL: http://www.ideal-plm.ru/uPage/Teamcenter.
36. Digital transformation in SIBUR (2018) // Materials of the conference «Management of the future 2018». URL: https://career.sibur.ru/zsn/SIBUR%20digital%20transformation.pdf.
37. *Shustikov V.* (2017) A digital twin (DigitalTwin) — a component which was so lacking! // Skolkovo. URL: https://sk.ru/news/b/pressreleases/archive/2017/06/23/cifrovoy-dvoynik-_2800_digital-twin_2900_-_1320_-element-kotorogo-tak-ne-hvatalo_2100_.aspx.
38. *BIM-engineering* ([s.a.]) // NLMK Engineering. URL: https://engineering.nlmk.com/ru/responsibility/technology/.
39. Digital Factories 2020: Shaping the future of manufacturing (2017) // PricewaterhouseCoopers. URL: https://www.pwc.de/de/digitale-transformation/digital-factories-2020-shaping-the-future-of-manufacturing.pdf.
40. *Helmrich K.* (2015) Auf dem WegzuIndustrie 4.0 — Das Digital Enterprise //Siemens. URL: https://www.siemens.com/press/pool/de/events/2015/digitalfactory/2015-04-hannovermesse/praesentation-d.pdf.
41. Industry 4.0 How to navigate digitization of the manufacturing sector ([s.a.]) // McKinsey&Company. URL: http://www.forschungsnetzwerk.at/downloadpub/mck_industry_40_report.pdf.
42. *Khan N., Lunawat G., Rahul A.* Toward an integrated technology operating model ([s.a.]) // McKinsey & Company. URL: https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/toward-an-integrated-technology-operating-model.
43. MindSphere — An open cloud platform ([s.a.]) // Digital transformation of industries. URL: http://industry-software.ru/conf2017/slides/08-Mikhaylin-MindSphere-open_platform_for_the_IoT_from_Siemens.pdf.
44. MindSphere allows to conduct a dialogue with Internet of things ([s.a.]) // Siemens.URL: https://www.siemens.com/ru/ru/home/produkty/programmnoe-obespechenie/mindsphere.html.
45. Operating model ([s.a.]) // Ernst & Young. URL: https://www.ey.com/gl/en/industries/oil---gas/ey-operational-excellence-in-oil-and-gas-operating-model.
46. Our solutions — Operating model ([s.a.]) // PricewaterhouseCoopers. URL: https://www.strategyand.pwc.com/cds/operating.
47. PIA Life Cycle Portal. URL: https://www.pia-portal.automation.siemens.com/default.html.
48. SAP S/4HANA — a unified space for all the business directions and innovations (2015) // CNews. URL: http://www.cnews.ru/articles/2015-10-12_sap_s4hana__edinoe_prostranstvo_dlya_vseh_biznesnapravlenij
49. Siemens COMOS ([s.a.]) // Mescada. URL: http://www.mescada.com/portfolio/siemens-comos.
50. PIA Life Cycle Portal ([s.a.]) // Siemens. URL: https://www.pia-portal.automation.siemens.com/default.htmю
51. Siemens NX ([s.a.]) // Tadviser. URL: http://www.tadviser.ru/index.php/%D0%9F%D1%80%D0%BE%D0%B4%D1%83%D0%BA%D1%82:Siemens_NX.
52. Siemens TECNOMATIX ([s.a.]) // TATA technologies. URL: https://www.tatatechnologies.com/us/technology/siemens/siemens-tecnomatix/.
53. SIMATIC IT: MES and beyond (2013) // Siemens. URL: https://www.ien.eu/uploads/tx_etim/Page_16_17_Siemens_47391.pdf.
54. SIMATIC PCS 7 Process Control System (2015) // Siemens. URL: https://w5.siemens.com/italy/web/AD/ProdottieSoluzioni/Sistemiautomazionenew/PCS7/Documents/Catalogo%20SIMATIC%20PCS%207%20(inglese).pdf.
55. *Simon K Reinhard Gr.* (2016) Industry 4.0–Opportunitie sand Challenges of the Industrial Internet assessment.pwc.de/i40/study.pdf.
56. SIMOTION — the high-end motion control system ([s.a.]) // Siemens. URL: https://www.siemens.com/global/en/home/products/automation/systems/motion-control.html.
57. *T*he Digital Enterprise 2D/3D Simulation Software from Siemens (2015) // Siemens. URL: https://dau.dk/Content/file_knowledge_item/DAU_3D_simulering_v1-siemens_226_INT.pdf.
58. TIA Portal V14 ([s.a.]) // Siemens. URL: https://www.pta-expo.ru/moscow/2017/pdf_k_programme2017/02Siemens.pdf.