Modernization stages of the Industry 3.0 company and projection route for the Industry 4.0 virtual factory

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Abstract. The task is to create the Industry 4.0 company functioning on humanless and paperless principles of production. There are two ways how to complete this task. The option number one is to modernize the existing companies of the Industry 3.0 which means a smooth implementation into informative and production infrastructure of the company the components and technologies which guarantee a slow evolution of research and development institute and item designing companies. The option number two, the example given, is based on solution on some project tasks to choose the components and technologies in their iterative form. There is a scheme how to modernize an Industry 3.0 company and the expected results which allow to project with existing companies new digital factories and smart factories of the Industry 4.0. There is a route how to project systematically a virtual factory of the Industry 4.0 as the main company to support all stages of the item life cycle for different industries. Modernization quality criteria for project and production companies and creation of virtual factories define the economic criterion of company activity.

1. Introduction

The analysis of some economy sectors shows that gradual automatizing of project and production tasks now does not seem to be so potent. Today the task at hand is to create a digital factory of new generation [1, 2]. These companies implement in their project and production activity new informative technologies [3, 4] and they will be the base of the digital economy and the new technological order known as the Industry 4.0.

To project a company of the Industry 4.0 is [5, 6] a multi-parameter task of optimization where the quality criteria of project solution has a value and a functional form. To unite different quality criteria with different values of physical magnitudes is based on implementation of weight coefficient to define the level of importance for each component in integral criteria.

The Industry 4.0 companies are different [7, 8] companies of project, production and exploitation activities. Then it is necessary to define general and specific quality criteria, components and technologies to characterize the efficiency of each company or in a group. A group of companies of the Industry 4.0 shows the virtual factory consistency and is most complicated project task to be solved [9,
10].

To project complicated technical objects which could be a virtual factory of the Industry 4.0 a decomposition of projection goal is required into some sub-tasks to find out the private criteria of optimization and their purpose for integral criterion and make the organization structure synthesis. This sequence of operation is a route of system projection of a virtual factory.

2. Classification of the Industry 4.0 companies

The world economy and automatizing means in projection and production created a company of new type. This new type (Industry 4.0 companies) is a company where project and production stages are being done with progressive informative technologies. Today there are [1, 2] three types of companies which differ in the specialty of their activity.

The first type is the digital factory of the Industry 4.0. The digital factories specialty is research and development and item designing activities which create the item technical documentation. Technical documentation is a collection of construction (CD), program (PD) and technological (TD) documentation. Detailed level in description and functionality of item given in technical documentation may be understood as the item digital twin which is completely similar to the object itself (item designing component).

The second type is the smart factory of the Industry 4.0. Smart factory specialty is the production activity in the item designing. The smart factory result is the product itself (the item) which is done on the technical documentation from the digital factory. Smart factory production division is a collection of technological lines and production sections equipped with cyber and physical systems (CPS) working automatically. Cyber and physical systems are the collection of physical equipment (production machine) and its virtual digital twin being stored in a cloud as a mathematical model.

The third type is the virtual factory of the Industry 4.0. Virtual factory realizes the full life cycle of an item designing component. The full life cycle includes the stages of marketing research, projection, manufacturing, exploitation, repair and maintenance and other. To support the end product user informatively (the item) in a virtual factory there are some technologies and services to unite project and production company, users, logistics service, supply and other. The main advantage of the virtual factory is reduced expenses of the end product (the item) by reducing the costs in each life cycle stage.

3. Modernization of the Industry 3.0 company

Today economy industrial sector is a collection of project and production companies of the Industry 3.0 specialized in development and production of different items. In the companies of the Industry 3.0 there are technologies of paper and electronic documents [9, 10] with some special personnel to watch. The development of the Industry 3.0 companies is based on implementation in project and production company environment the components and technologies which form six stages (steps) of modernization. Industry 3.0 company modernization stages are given in figure 1.

The first stage of the Industry 3.0 company modernization is to supply into the company the digital means of projection and production (company computerizing). In project companies there are some automatic work places with computers for the designers. In production companies there are some machines with computer numerical control (CNC) [7].

The second stage of the Industry 3.0 company modernization is to implement net technologies which unite the digital means of projection and production unifying digital means of this activity into a single system of control functioning in paperless documentation mode. For now it is clear that first two stages are mostly done in the majority of the project and production companies of the Industry 3.0.

The third stage of the Industry 3.0 company modernization is to implement the most part of technologies into virtual space. Virtual space (company virtualization) is done with cloud services with the digital twins of the items being projected (manufactured) and technological (test) equipment (cyber and physical system). In digital factories there are technologies of imitating modelling and physical tests virtualization for the item designing components. In smart factories they implement the hybrid technological lines functioning with humanless and paperless production. All technical documentation
and exploitation documentation are administrated in electronic form.

![Diagram](image-url)

**Figure 1.** The stages of modernization of project and production companies of the Industry 3.0 which must be done to create a digital factory and a smart factory of the Industry 4.0 (CAD - Computer-Aided Design).

The fourth stage of the Industry 3.0 company modernization is to implement BigData technology to collect and process the vast amount of engineering data in the company. Collection and processing of data (company transparency) means to organize information exchange of digital production, work places and computerized system of control with the industrial Internet of Things (IoT) and remote cloud services. Data collection and processing helps the company personnel to control (to monitor) the completion of project and production operations using the augmented reality technology on the remote base.

The fifth stage of the Industry 3.0 company modernization is to implement some components and technologies to prognosticate the activity. In digital factories the main prognostication components are standards of new generation for virtual tests which are equivalents of the real ones. Smart factories implement for prognostication purposes route sheets of item designing components manufacturing made with modelling of technological lines equipped with cyber and physical systems.

The sixth (final) stage of the Industry 3.0 company modernization is to implement the technology of
artificial intelligence and cyber and physical technological equipment self-organization (company adaptability). In digital factories there are algorithms and optimal criteria to search for the best project solution to synthesize item designing component with given value of robustness and resistance to external influencing factors. In smart factories there are some algorithms of MTBF (mean time between failures) for production infrastructure based on cyber and physical systems self-organization in technological lines.

4. The route of system projection of the Industry 4.0 virtual factory
To create a virtual factory of the Industry 4.0 or to modernize an existing company of the Industry 3.0 into a virtual factory is the most complicated projection task [5, 6]. A scheme of route of virtual factories system projection is given in figure 2.

Figure 2. System projection route of the Industry 4.0 virtual factory.

The first task is the industry of the company and its specialty. The most popular today are maritime, aviation, rockets and space, railroad and automobile industries where the machine building and item
designing are important sub-tasks. To choose the virtual factory specialty one needs first to analyze the current state of economy and must be according to the technical task for the virtual factory creation.

The second stage to create (to modernize a company) a virtual factory is the projection task to choose the nomenclature of technologies applying in this company functioning. Progressive technologies recommended to be implemented [3, 10] in a virtual factory are CALS (Continuous Acquisition and Lifecycle Support), BigData, M2M (Machine-to-Machine), S2S (Systems-to-Systems), cloud technologies and other.

The third stage to create (to modernize a company) a virtual factory is the projection task to choose the company consistency. Each company of a virtual factory must comply one or several stages of the item life cycle according to the company purpose. Such life cycle stages could be: projection, manufacturing, transport logistics, storage, maintenance, exploitation and other.

The fourth stage to create (to modernize a company) a virtual factory is the projection task to choose the means to consist the company which is a part of factory. The main technical components of a virtual factory are cyber and physical systems in production, computers of automatic work places for the designers, smartphone and tablets of augmented reality for the item life cycle and other.

The fifth stage to create (to modernize a company) a virtual factory is the projection task to choose the software to consist the company which is a part of factory. The software means of a virtual factory are systems automatizing of designer work, automatic systems of technological processes control, automatizing systems to control the production preparation, integrated systems to control item life cycle and other.

The sixth stage to create (to modernize a company) a virtual factory is the projection task to synthesize the structure of future company. Synthesis means to find parameters of company activity criteria or to input multi-parameter ones and decisive rules based on the exaggeration of quality of the threshold value. Virtual factory functionality is an economic criterion to evaluate the cost of product usage and the threshold decisive rule to choose the technical appearance is an element to evaluate virtual factory efficiency.

If technical and tactical characteristics of virtual factory have values according to the technical task the designers may begin the stage of projecting new (being modernized) company. Otherwise there are two approaches. The approach number one is to correct the input data of the technical task (an amendment to the technical task). This is a case if it is impossible to realize the technical task requirements according to the previous results of the structure choice task in technology, machines and software of the virtual factory. The second approach is the iterative way shown in figure 2 to choose the technology and components of virtual factory. For this in each stage of virtual factory projection they must input private criteria of choice with necessary rules when if something is wrong it is possible to go back to the previous stage of projection.

5. Conclusion
To project new and modernize the existing companies is the task number one for economy today. The existing companies of the Industry 3.0 implement automatizing means for paperless documentation and computerized control system to support informatively the whole item life cycle. The gradual automatizing may obstruct the company development. But to make this step and develop the Industry 3.0 the item designers and system users should not be diehard in their minds to make a replacement in project task solutions when in the company instead of a new solution they implement a new software component.

The main qualities of the Industry 4.0 company are virtualization, transparency, prognostication and adaptability of the company based on implementation of new technologies of project and production tasks in the item life cycle.

To project digital factories and smart factories of the Industry 4.0 the items and solutions must be close to project a virtual factory. Because digital and smart factories are the main parts of a virtual factory. In this case technical and economic activity points (research completion profitability, item designing works and manufacturing activity) of a digital factory and a smart factory must be put as a
private quality criteria of efficiency integral criteria of virtual factory activity.

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