Components and technologies of system projection of digital and smart factories of the Industry 4.0

D A Zakoldaev, A V Shukalov, I O Zharinov and D E Baronov
Faculty of Information Security and Computer Technologies, Saint Petersburg National Research University of Information Technologies, Mechanics and Optics, 49, Kronverksky Av., Saint Petersburg, 197101, Russia

E-mail: mpbva@mail.ru

Abstract. The task is to project systematically a digital factory and a smart factory of the Industry 4.0. Digital factory and smart factory are for project and production activity to create items with the components and technologies of digital economy. There is a scheme how to distribute digital technologies in the companies of the Industry 4.0 and stages of the item life cycle. There are routes of system projection of digital and smart factories. The base of project procedures is to choose project solutions for the organization activity. This particular system projection route is for companies of item designing and machine designing of railroad, automobile, maritime, aviation and rocket and space industries. These technologies are for development of electronic models (digital twins) of items and cyber and physical systems. Cyber production (smart factory) will complete the items automatically. The projection of the Industry 4.0 companies must be completed by research and science institute of necessary expertise.

1. Introduction
The Industry development today means to implement new technologies [1, 2] of project and production activity in real economy. Another component of the Industry 4.0 [3, 4] step by step modernizes the company technological equipment. This is an expensive way and takes a lot of time to see the first results. Here the result means a humanless act of production [5].

To create the Industry 4.0 companies it is necessary to choose and implement the new and existing digital technologies which are capable with technical means and software to make the organization function [6]. Development, research and components and technologies choice planned to be used in the Industry 4.0 are life cycle stages [7] as a complicated technical system (organization).

Project company specialty (digital factory) and production company (smart factory) require some components and technologies which are chosen in the projection. The system projection routes of the Industry 4.0 companies are mostly general and differ in some private tasks [8]. To research the project solutions they need some projection procedure descriptions and quality criteria. All values must be contained in the technical task and the company projection itself is a direct process of synthesis.

2. The Industry 4.0 company technologies
The Industry 4.0 company activity base is the digital technologies of informative and resource support of an item designing component life cycle. Each company of the Industry 4.0 (digital factory, smart factory, virtual factory) they develop and implement some digital technologies [1, 2] to make project
and production or exploitation (user) activity.

A scheme how to distribute digital technologies in item life cycle stages and types of the Industry 4.0 companies is given in figure 1. The scheme general components are three companies which together make the full life cycle of an item.

![Diagram of digital technologies distribution](image)

**Figure 1.** Distribution of digital technologies in life cycle stages and Industry 4.0 companies’ specialty (SaaS – Software as a Service, CaaS – Communications as a Service, PaaS – Platform as a Service, IaaS – Infrastructure as a Service).

According to figure 1 a digital factory is for project works to create the construct and program documentation for an item designing component. Base technologies of company project activity are company automatizing technologies, digital modelling, virtualization, cloud services and industrial Internet of Things (IoT) [9, 10]. Digital company cloud has a deployment model as private cloud. A private cloud is a remote server with the components of virtual machine ready for designer to be used, projection platforms and virtual tests of digital twins available for the personnel of digital company.

Smart factory is an Industry 4.0 company to manufacture an item designing component and prepare the technological documentation. The main technologies to be implemented into a smart factory are cyber and physical systems (CPS), sensors, 3D-printing, augmented reality, Machine-to-Machine (M2M), Systems-to-Systems (S2S), industrial automatizing and digital twins of technological equipment. Information exchange with digital factory to transfer electronic technical documentation for an item designing component smart factory does with society cloud interfaces access to which grants the Industrial Internet of Things. Society cloud means that some persons of a company may exchange the technical documentation to realize some stages of the item life cycle. Smart factory has its own informative resource which is a private cloud. Private cloud of a smart factory has the virtual infrastructure of the company production which support the route sheets item manufacturing technological operations. The main component of the smart factory virtual part is the cyber and physical system digital twin, item digital models and manufacturing technological processes algorithms. Cloud components are resources from science and research, item designing and educative organizations, industrial, professional and educative standards and other.

General technologies for digital and smart factories of the Industry 4.0 are Humane-to-Machine (H2M), BigData technology and IoT. Some smart factories for a complicated item manufacturing could be united in a virtual factory of the full production cycle of item manufacturing based on cooperation. Each smart factory has some clouds (resources) of the type of private cloud.

Having analyzed some economies and state science and technical programs of development it says
that the digitalizing of project and production activity cannot cover the full life cycle of the item. Some companies must be made like virtual factories of the Industry 4.0. Virtual factories are responsible for the full item life cycle including its exploitation. The main technologies for the virtual factories activity are [11] the technologies of BigData, H2M, IoT, cloud technologies. Virtual factory cloud is a hybrid one access to which has the personnel of transport, exploitation organizations; storage organizations and maintenance (service) companies, repair and some others. Item user has an exploitation documentation access to the hybrid cloud. For the cloud hybrid resources user from different companies of the virtual factory have the service of infrastructure type inside the cloud.

3. System projection route of the Industry 4.0 digital factory

Projection route of the Industry 4.0 digital factory is an iterative process with some project procedures. A route projection scheme of a digital factory is given in figure 2.

![Figure 2. System projection route of the Industry 4.0 digital factory.](image)

The first task of the digital factory projection is to choose the industry for this factory professional activity. Actual spheres now are automobile and road industries. To choose the industry one needed to
analyze the industry condition of the civilian digital economy.

The second task of the digital factory projection is to choose the specialty of the company activity. Company specialty (item designing, machine designing and other) is closely related to the industry which must be chosen by that time. So these two tasks are subsequent to each other.

Digital factory specialty where some technologies will be implemented is resource and informative activity of the company. In figure 1 and figure 2 we can see that they may apply in a digital factory cloud technologies, IoT technologies, H2M and other. Technical and software ways of digital factory designer activity automatizing must be chosen in two next steps of projection.

There is a lot of software to automatize the project activity (CAD (Computer-Aided Design), CAM (Computer-aided manufacturing), PDM (Product Data Management), CASE (Computer-Aided Software Engineering)-systems of projection; personal computer (PC), routers, communicators for the company netting and other) according to the requirements and criteria taken from the technical task for the digital factory projection and for equipment of automatic work places (AWP).

Digital factory structure synthesis and its economic efficiency evaluation of the company activity is based on multi-parameter criteria are the last steps of the digital factory projection. Multi-parameter criteria are for binary decisive rule where the positive branch supposes the project solution for the Industry 4.0 digital factory. The digital factory projection could be conducted in the Industry 3.0 science and research institute (SRI) or in any other digital factory made before.

4. System projection route of the Industry 4.0 smart factory
The projection of smart factories of paperless item manufacturing is a very important sector of the economy. To project one factory as a complicated system they need to develop and implement new algorithms based on many project solutions. System projection route of the Industry 4.0 smart factory is given in figure 3.

The smart factory specialty is an item nomenclature to be manufactured later. Smart factory initial data is item digital models taken there from digital factories. To develop and research new technologies and materials for a digital production is the projection task number one when you create the new company.

Digital production technologies are used in the companies for software. Those components are related and based on specialists of science and research, item designing and educative companies.

The next step to project the Industry 4.0 smart factory is to create digital twins of cyber and physical systems which are part of the production technological lines. Basically cyber and physical systems of different purpose are finished in functionality and are capable to produce base item nomenclature.

These cyber and physical systems must have digital twins. To put in production new item or after purchasing new technological equipment the task to create cyber and physical systems digital twins could be solved in the stage of production technological preparation.

To synthesize the technological routes of item manufacturing and the description of base technological operation completion is a stage of smart factory projection based on norm and technical documentation and from the government.

Having analyzed the market of existing cyber and physical systems for digital production and the requirements for new cyber and physical systems of industrial purpose are initial data to choose the equipment brand for new smart factory of a particular industry chosen before.

Technologies and software for production cycle is a base for project solution of new digital production (smart factory). To synthesize structure is an optimal procedure. For the Industry 4.0 smart factory such criterion is economic efficiency of future item manufacturing. If economic criterion of the decisive rule is for production efficiency the digital factory starts to project a smart factory of the Industry 4.0 with given route.
5. Conclusion
To project digital companies of the Industry 4.0 is an iterative process to make project solutions based on multi-parameter optimization task. The most part of components and technologies which will be used in digital factories and smart factories today exist as services of being ready (the second usage in new companies).

The more difficult procedure is to synthesize the companies structure of the Industry 4.0. Some private criteria to choose the technologies and components cannot match in first stages of company projection (integral) criterion of structure synthesis. It means that optimal private criterion for the designer when choosing something can hardly reach the optimal integral criterion which is the...
compromise value per se. So the routes of projection for digital and smart factories are subsequent procedures where the optimal criterion is being optimized and private criteria become mathematical equations with restrictions. The good solution for such system of equations is mathematical apparatus of linear programming with real or number variables.

To solve the task of linear programming for an equation system with restrictions is the final plurality of project solutions limited in space of parameter with the restrictions of possible values. A plurality of Pareto is an example of one. In parametric space they need some integral criteria for which the project solution optimization methods are effective.

References
[1] Leitao P, Colombo A W and Karnouskos S 2016 Computers in Industry 81 11-25
[2] Zhong R Y, Xu Ch, Chen Ch and Huang G Q 2017 International journal of production research 55(9) 2610-21
[3] Liao Y, Deschamps S, Loures E F R and Ramos L F P 2017 International journal of production research 55(12) 3609-29
[4] Radziwon A, Bilberg A, Bogers M and Madsen E S 2014 Procedia engineering 69 1184-90
[5] Cai Y, Starly B, Cohen P and Lee Y-Sh 2017 Procedia Manufacturing 10 1031-42
[6] Gurjanov A V, Zakoldaev D A, Shukalov A V and Zharinov I O 2018 IOP Conf. Ser.: Mater. Sci. Eng. 327 022110
[7] Lee E A 2015 Sensors 15(3) 4837-69
[8] Gurjanov A V, Zakoldaev D A, Shukalov A V and Zharinov I O 2018 IOP Conf. Ser.: Mater. Sci. Eng. 327 022111
[9] Hwang G, Lee J, Park J and Chang T-W 2017 International journal of production research 55(9) 2590-02
[10] Jeong H-Y, Jeong Y-S, Park J H 2014 Sustainability 6 8510-21
[11] Ore F, Hansson L, Wiktorsson M 2017 Procedia Manufacturing 11 4-12