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# From Industry 3.0 to Industry 4.0: production modernization and creation of innovative digital companies

**D A Zakoldaev, A V Shukalov and I O Zharinov**

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: d.zakoldaev@mail.ru

**Abstract.** The task is being studied to create digital productions in smart factories of the Industry 4.0. Some mechanical and assembly productions of existing companies of the Industry 3.0 and mechanical and assembly productions of perspective companies of the Industry 4.0 are described. The basic components of a smart factory and their interconnection to organize a production activity using humanless and paperless technologies are defined. A comparison analysis of parts and blanks movement to complete route sheet of the item manufacturing (radio and electronic item designing) in the companies of the Industry 3.0 and Industry 4.0 is given. The components of a digital item designing company to be created and implemented in the industry at first hand are defined.

## 1. Introduction

Creation of digital production companies of the Industry 4.0 based on humanless and paperless technologies is an interesting direction of the industrial economy sector development [1, 2]. Humanless and paperless production helps to reduce the terms and to increase the quality of the manufactured item designing components.

Basic components for creation of vanguard production companies (smart factories) include virtual and physical components [3, 4]. Physical components are the technological equipment engaged in the production process. Virtual components are a set of cloud services, the access to which is based on the industrial Internet of Things (IoT).

Today, there are two methods to create the productions of a new type:

- modernization of the item designing companies of the Industry 3.0;
- creation of an item designing company of the Industry 4.0 without using the Industry 3.0 companies as a base.

Modernization of production companies of the Industry 3.0 is based on the step-by-step implementation in technological process and organization of existing components [5-7]:

- calculation machines (computerization);
- net machines and software (net creation);
- controlling machines (a digital twin of an item designing company and its technological equipment);
- means of transparency and forecasting of the company activity (technologies of BigData to process vast amounts of industrial data);



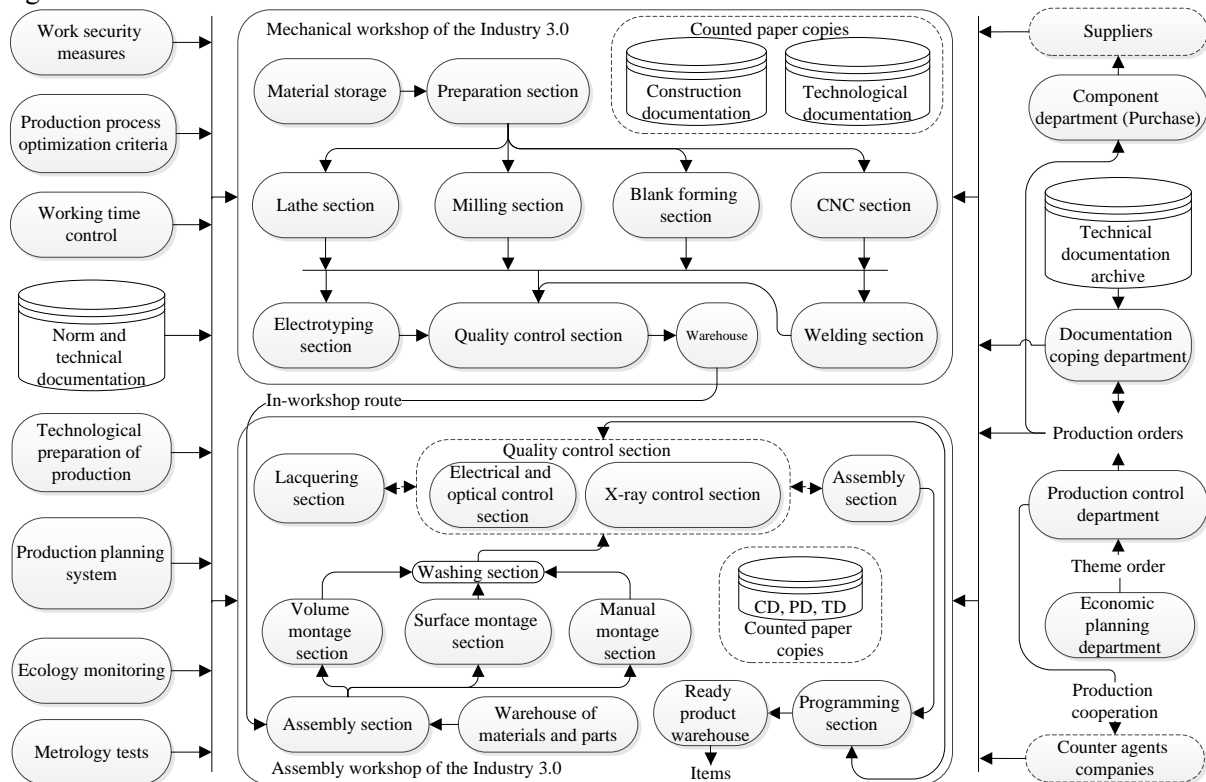
- adaptation means of a company (AI technology in production).

Modernization of the Industry 3.0 is a long process that requires a lot of resources and materials. The modernization period may require partial or complete cease of any activity in the company. The construction of companies of the Industry 4.0 in new sites can help to acquire and implement the necessary machines and software for production and also such digital technologies as [8-10]:

- the industrial Internet of Things, cloud technologies;
- BigData technologies, sensors technologies;
- cyber and physical systems technologies, additive and other technologies which together help the qualified personnel to organize humanless and paperless production of the item designing components.

## 2. Production sector of the Industry 3.0

A production sector of an item designing company of the Industry 3.0 is made with two structure divisions: the mechanical workshop and the assembly (assembly-mounting) workshop. The scheme of the assembly and mounting workshops of an item designing company of the Industry 3.0 is given in figure 1.



**Figure 1.** The scheme of the assembly and mounting workshops of an item designing company of the Industry 3.0.

The mechanical workshop of the Industry 3.0 is a production division to process the materials made of metal, plastic, organic glass and others first. The mechanical workshop includes:

- preparation sections where materials from warehouse are being cut according to their magnitudes (laser cut, water cut, ribbon saw, and other) into separate blanks which in the future will be a part of a product;
- a lathe section where the blank is being processed with lathe technological equipment;
- a milling section where the blank is being processed with milling technological equipment;
- a blank formation section where the company personnel processes a metal sheet of blanks to

bend the constructions without welding with angles and radiuses defined in technical documentation (it can be done with die technological equipment);

- a CNC (Computer Numerically Controlled) section (command of numerical control) where complicated items are being produced automatically, in accordance with the program from the digital memory of the machine and the 3D item model; with different tool kits installed in the moving base with a program motor step;
- an electrotyping section where metals are covered with special coverings which, according to the respective technical documentation, are robust enough and protected from being worn out, electrical conductivity, surface unevenness, optical reflection coefficient, and other factors;
- a welding section where the parts are jointed by welding of different parts to create a single construction which is robust enough and has sufficient electrical conductivity.

Parts created with different technological equipment, according to the respective construction and technological documentation from the technical documentation archive of the company, are being checked in the quality control section. This kind of check is a visual one, and control and measurement equipment is applied by the specialists of the technological control department. Parts which are made according to the respective technical documentation which was the base of the beginning of its production, are transferred to the warehouse of the mechanical workshop.

The assembly (assembly and mounting) workshop of the Industry 3.0 is a production division that complies with the works of montage of radio and electronic equipment on a printed circuit board (created components with optical and electronic components) and the finishing assembly of item manufacturing (mounting). The assembly workshop of the Industry 3.0 includes:

- a component section where the necessary elements are being searched for from the materials and components available at the warehouse (standard nomenclature) according to the requirements of the construction documentation and production order;
- a surface montage section where the components are being placed and wave-soldered automatically on a printed circuit board to fix them mechanically on its surface and to provide an electric contact of pins with the conductors of a printed circuit board (contact pads);
- a manual montage section where the radio components of a pin packages type are being placed and soldered on a printed circuit board which cannot be placed in the automatic montage;
- a volume montage section where cables that are the parts of the component packages and also cables for inter-system interaction inside the object (car, train, aircraft, and other) are being manufactured;
- a PCB (Printed Circuit Board) washing section where printed circuit boards are being washed automatically with installed (soldered) electronic components from residues of flux, solder, mastics, and other materials;
- a lacquering section where anti-moisture covering is being applied (for example, lacquer) on a printed circuit board with installed components to make sure that the item will function properly under any conditions;
- a programming section where the software components are being inserted into the item (inserted control tests, initializing tests, functional software, and other);
- a quality control section where the manufactured items are being verified according to the requirements of the technical documentation. This verification can be visual one or can be done with the special testing equipment (optical machines, automatic workplaces to verify electrical modes of the item, x-ray machines, and other);
- an item assembly section where the final connection (mechanical, electrical, and other) of all assembly units and parts into a single item of the item designing component is being made to verify its functionality later and transfer it to the warehouse of the ready production.

The manufacturing of the assembly units in the assembly workshop of the Industry 3.0 is being done with counted paper and electronic examples (versions) of construction, program and technological documentation which the manufactures have at their disposal from the company electronic archive.

The transfer of technical documentation counted examples is being made with coping machines (copy) and by the coping department to create the necessary quantity of examples from the archive according to the production order. Production orders are being made according to the item specifications and the theme orders which are being published by the planning and economic department of the Industry 3.0.

For completion of some production orders, other companies (counteragents companies) can be involved. Normally, that happens because the special technological equipment which is used for some technological operations is under repair or unavailable. The department of production control and planning conducts interaction with counteragents companies.

Supplier companies supply the company with materials (lacquer, paint, resin, metals, and other) and components (electric and radio elements, fixture elements, and other). The component department (purchase) conducts the interaction with supplier companies as a part of existing in the company theme and production orders.

Additional departments conduct informative support of the production process of the Industry 3.0. Their functions are:

- events (test in field) to organize the technological preparation of the production before the new item will be manufactured;
- job security and the company compliance with the medicine rules to ensure the safe work of the personnel in the company;
- ecological monitoring to ensure the clean production and environment security;
- metrology verification of the technological equipment engaged in the item manufacturing process (parts);
- events to check the norms of working hours of different qualification specialists in the company and the norms of the technological equipment load-out of each type engaged in the production process;
- events to develop and implement automatic systems of production process planning and automatic systems of technological control in the company;
- events to distribute the norm and technic documentation (NTD) among the personnel (first the supervisor technical specialists). It is the documentation that controls the order of work completion of different technological operations and the technological process in general on the level of government and branch standards;
- events to implement in the company the criteria of the route sheet completion optimization of the item manufacturing (parts) and completion of separate technological processes (operations).

### **3. Production section of a smart factory of the Industry 4.0**

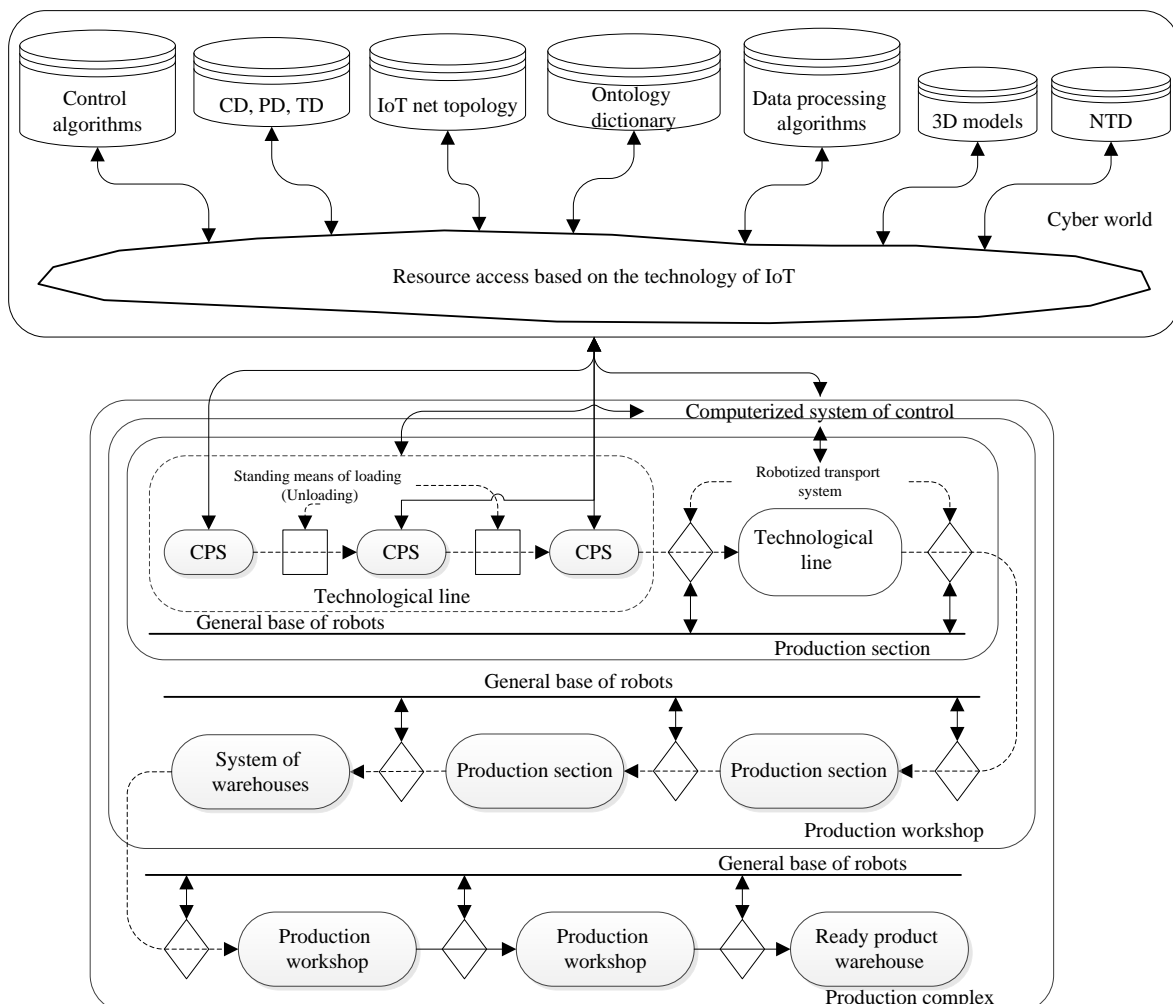
A production section of an item designing company of the Industry 4.0 is a part of the company which unites a set of automatic systems of technological purpose oriented for humanless and paperless process of item manufacturing. The organization of humanless and paperless production includes the implementation of progressive digital technologies (cloud technologies, industrial Internet of Things technologies, and other) in the company. That is made to ensure continuous technological cycle of the item designing components manufacturing of wide nomenclature.

The functional scheme of digital production components of the Industry 4.0 smart factory is given in figure 2.

The production section of the Industry 4.0 is where the flexible automatic (automatized) production is conducted. The section includes the following components [3, 7]:

- the cyber and physical system (CPS) which is a production machine functioning with physical resources and cloud (virtual) resources to complete a set of technological operations;
- a technological line which is a set of cyber and physical systems to complete a set of technological operations with standing means of loading (unloading) of blanks or parts (a robotized transport system is not engaged);

- a robotized transport system to transfer the parts among technological lines (a system of warehouses) to complete a particular technological process and technological route of item manufacturing;
- a production section which is a set of technological lines and a robotized transport system which are to complete close technological operations to ensure continuous (all the day) technological cycle of item manufacturing;
- a system of warehouses to unite automatic machines to count up and control the transfer of materials, parts, ready items, tools, and other within the production workshop;
- a production workshop which is a set of cyber and physical systems of production sections, a robotized transport system and a system of warehouses for ready items which is controlled by a computerized system during a particular period of time (manufacturing of a set of items);
- a set of cloud services with the components of the technical documentation and 3D-models of manufacturing items, an ontology dictionary of digital production, algorithms of BigData to process the vast amount of industrial data, tables of topology of the IoT net for informative support of the cyber and physical system self-organization, and other.



**Figure 2.** Interaction scheme of digital production components of the Industry 4.0 item designing company.

Figure 2 shows that for the organization of the digital production complex of the Industry 4.0 functioning with humanless and paperless technologies of the item designing components

manufacturing, the primary objects of production infrastructure should be:

- an automatic section of surface montage (a line to apply soldering paste, a line of placing the radio and electronic components on a PCB, a line of PCB soldering, a line of PCB washing);
- a lacquering section, 3D printing section (an additive technology of parts manufacturing), and electrotyping section;
- an item functioning verification section and a section of final assembly, distributed between different production workshops, each one of which provides the necessary level of cleaning the production room and quality of production processes completion.

#### 4. Conclusion

Creation of the innovative production companies to realize a joint operation of physical components (technological equipment) and components of virtual world (cloud services) requires a high level of preparation (qualification) of the personnel engaged in the production process.

Although the production process itself can function with humanless and paperless technologies in an automatic mode with the digital system of control, the personnel involvement is expected in the production process of the Industry 4.0. The personnel must complete the preliminary test in the field with technological equipment for later monitoring of the digital company activity.

The preparation of the qualified personnel who can ensure the functionality and maintenance of cyber and physical systems in the level of physical components and cyber world is a separate task. It should be solved as soon as possible, using resources of the corresponding organizations of higher education.

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