Transformation of design documentation at the turn of the XXI century

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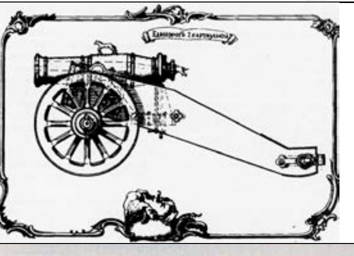
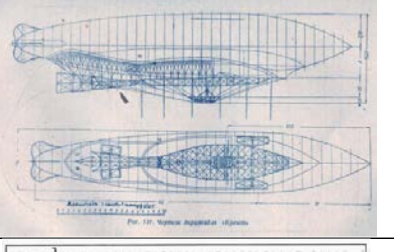
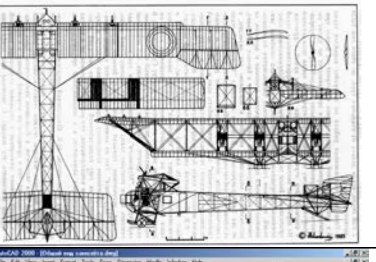
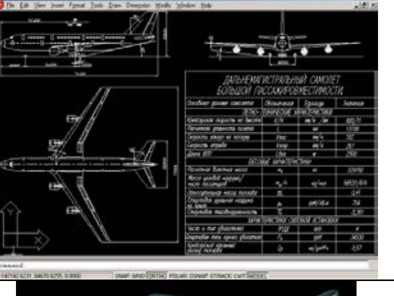
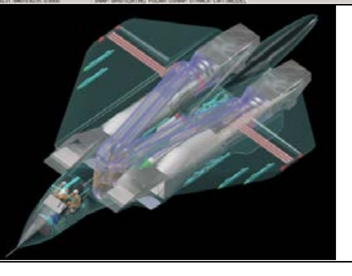
Abstract: *The relevance of the problem stated in the article is due to the fact that in order to use modern methods for creating parts of aerospace technology, it is necessary to recognize their capabilities and strive to improve these methods. The purpose of the article is to analyze the dialectics of design documentation and those contradictions that are caused by digital technologies in the engineer’s language. The paper discusses the main methods and methods for creating prototypes of designed parts for aerospace engineering objects at the design development stages. Possible applications of rapid prototyping technologies in design are shown. A number of reasons have been derived that hold back the widespread use of modern prototyping methods, including the high cost of equipment; lack of proprietary installations and materials for prototyping, lack of trained personnel to carry out work, lack of recommendations on methods for designing parts intended for prototyping. It is shown that the verification of the development trend is through the development of legal documentation and through activities in the relevant technical committees of Rosstandart and specialized dissertation councils of the Higher Attestation Commission of the Russian Federation.*

Key Words: *digital technologies, design automation, additive technologies, technical committee, dissertation council*

1. INTRODUCTION

At the end of the 20th century, technological transformations took place and the language of the engineer “Drawing” underwent changes (Table 1). It became paperless, solid-state, virtual, digital, etc. [1], [2], [3], [4], [5].

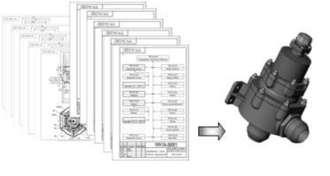
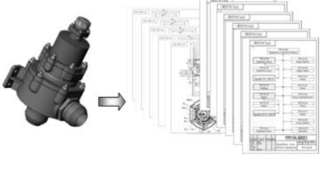
Table 1. – The dialectic of the drawing

No	Time. Era	Characteristic	Graphical representation
1	Technical drawing of the XV century	Leonardo da Vinci on aircraft. Technical drawing. Made in axonometric projection.	
2	Drawing of the end of the XVIII century	Drawing gun unicorn. Revealed main view.	
3	Drawing of the end of the XIX century	Airship Gyrfalcon. Two projections. The main view and the top view are in the projection connection.	
4	Drawing of the beginning of the XX century	Airplane Ilya Muromets. Project I.I.Sikorsky 1913. Three projections and cross sections.	
5	Drawing of the end of the XX century	The project of a long-range aircraft of large passenger capacity made in AutoCAD.	
6	Drawing of the beginning of the XXI century	Solid-state model of a heavy supersonic deck maneuvering vertical take-off and landing aircraft made in 3-D MAX.	

7	Drawing of the beginning of the XXI century	Solid-state parametric model of the main aircraft made in CatiaCAD.	

Recently, with the advent of modern systems of solid-state parametric modeling, the approach to design as such has somewhat changed. If the engineer previously worked in two-dimensional space and was forced to translate his ideas into flat drawings, now he has the opportunity to create in a virtual three-dimensional volume, without thinking about how to draw this or that projection of the part. That is, the design does not go from the drawing to the three-dimensional appearance of the product (Table 2), but in the opposite direction – from the spatial model to the automatically generated drawings, bypassing the time required to create them.

Table 2. – Direct and inverse problems

No	Task type	Definition	Graphic image
1	Straight	When the model is executed according to a set of drawings.	
2	Feedback	When a set of drawings is executed using a model.	

This design approach is also convenient in that the created virtual geometric model can be transferred to the calculation program for the analysis of the gas-dynamic, strength, or other properties of the part or product as a whole.

Solid modeling as a design technology fundamentally changes both the concept of technical documentation and the technology for its manufacture, and, consequently, the technology of maintenance, operation and disposal of equipment throughout the product's life cycle.

To conduct numerical analyzes, specific problem-oriented applications with the appropriate mathematical apparatus are needed.

For production planning, simulators of production processes, packages for simulation of CNC machines, etc. are needed.

For marketing tasks, it is necessary to use systems of photorealistic computer graphics and virtual reality modeling.

The integration of the considered processes within the project as a whole is coordinated by information exchange and transmission systems with the effective presentation of information through networks.

2. FEATURES OF PROTOTYPING USING ADDITIVE TECHNOLOGIES AND LAYER-BY-LAYER SYNTHESIS TECHNOLOGIES

The rapid growth of digital technologies, automation of the product life cycle made changes in the form and role of design documentation Fig. 1.

Digital technologies not only did the culmans electronic, solid-state modeling raised the question of the primary drawing and the product that is shown on it.

The direct and inverse problem in engineering graphics are in dialectic contradiction and deny the primacy of the drawing. Additive technology is another touch of our time [6], [7], [8], [9], [10], [11], [12].

Traditionally, the drawing reflected how the body of a part is formed from a monolithic billet through technological operations, and in additive technologies the part grows out of powder. And the size system is changing radically. Moreover, the assembly units have become non-detachable.

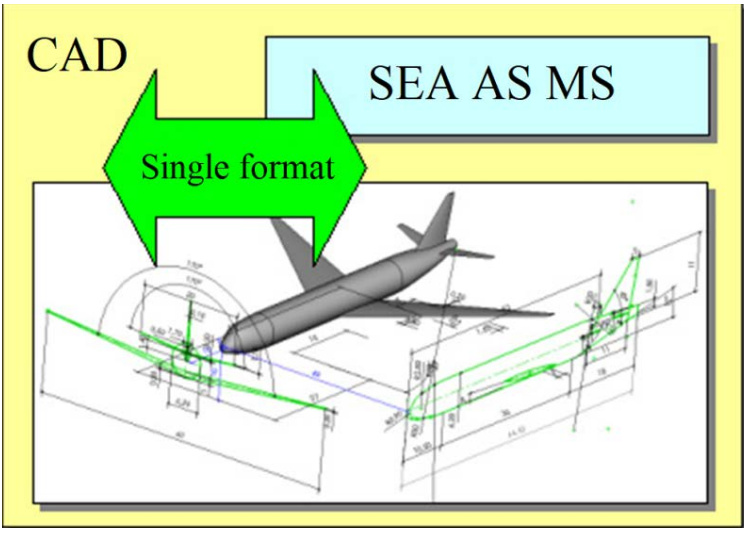


Fig. 1 – 3D-drawing of a general view of the main aircraft

In recent years, requirements for the quality of the specified parameters for the manufacture of aircraft have increased sharply.

If 10 years ago the deviations allowed from the project in the main indicators were 15-20%, and five years ago 10-15%, then now these deviations should not exceed 3-5%.

Rapid prototyping is an indispensable tool for developing new products, allowing check the design before launching into production, identify design errors, make the necessary adjustments not in the part, but in its computer model, and then make a snap using the parallel process. It should be noted that the cost of correcting errors detected at the stage of mass production is 100 times higher than in the manufacture of the prototype.

The place of additive laser technologies and traditional methods of processing materials is shown in Fig. 2. The role of additive manufacturing is all the more significant, the fewer parts need to be produced and the greater the degree of complexity.

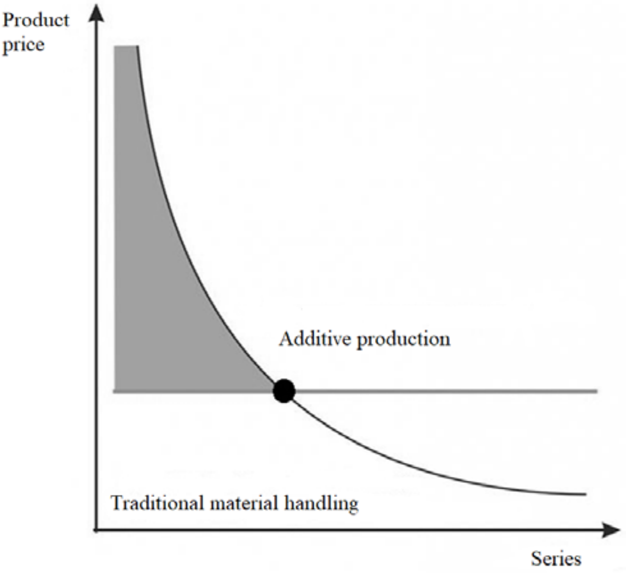


Fig. 2 – The place of additive technologies and traditional methods of processing materials

Layered synthesis technologies are a powerful means of reducing the time of technological preparation of production (CCI), the actual manufacturing and improving the quality of created products during the transition to the production of new products in the aircraft industry, mechanical engineering and other high-tech industries.

The main types of layered synthesis technologies currently used in industry include the following: stereolithography (SLA-Stereo Lithography Apparatus); SLS technology (Selective Laser Sintering – laser sintering of powder materials); EBM technology (Elektron Beam Melting – electron beam melting); FDM technology (Fused Deposition Modeling – layer-by-layer application of molten polymer filament); Ink Jet Modeling Technology; – BPA Powder Bonding Technology (Binding Powderby Adhesives); LOM technology (Laminated Object Manufacturing – lamination of sheet materials); SGC technology (Solid Ground Curing) – UV lamp irradiation through photomask.

The schematic diagram of all prototyping installations is the same: on the desktop, the elevator of the installation, a thin layer of material is applied that reproduces the first section of the product, then the elevator is moved down one step and the next layer is applied. So layer by layer, a complete set of sections of the model is reproduced repeating the shape of the desired product.

Moreover, on a certain layer it may turn out that individual elements "hang" in the air, since they must be attached to the upper layers.

To avoid such a problem, a 3D model is pre-prepared, a support system for each such element is built in it.

Or, the position of the part on the desktop is determined to exclude the presence of supports.

The main difference between prototyping technologies is the working material, as well as the method of its application.

Design products and prototypes for checking the geometry of parts and assembly of components are used in the production of metals, filled polyamides, paper, ABS plastic, thermoplastics, model materials.

3. ANALYSIS OF THE POSSIBILITIES OF MODERN TECHNOLOGIES FOR PROTOTYPING

There are several companies in the world that manufacture prototyping plants; they constantly improve technology and develop new materials. In laser sintering, models or finished parts are created from powder materials due to the sintering effect using the energy of the laser beam. In this case, unlike the SLA process, the laser beam is not a light source, but a heat source. Getting on a thin layer of powder, the laser beam sinteres its particles and forms a solid mass, in accordance with the geometry of the part.

The materials used are polyamide, polystyrene, sand and some metals. Rapid prototyping methods, in addition to creating a physical model from an electronic model, may require new approaches to the design process of parts.

An example of the application of modern technologies for creating prototypes and parts themselves by powder sintering methods is the manufacture of integral assemblies (Fig. 3) at the Department of Engineering Graphics of the Moscow Aviation Institute, at the prototyping plant.

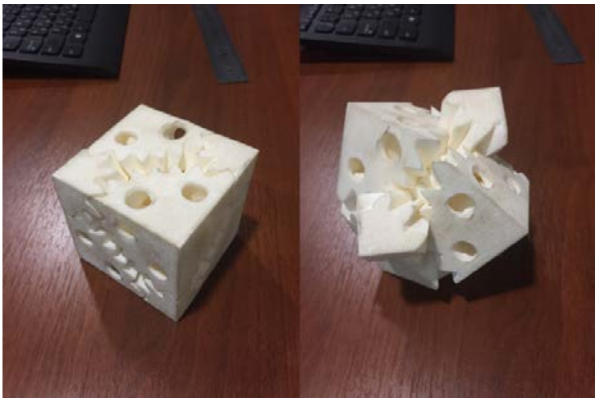


Fig. 3 – 3D model of one-piece assembly

As a result of applying the method to create a part from a metal powder, it was possible to halve the weight in comparison with the assembly of Fig. 4 of several dozen parts made by traditional methods.

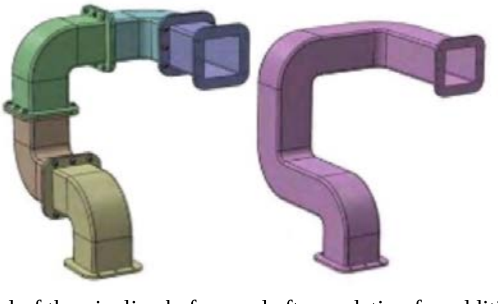


Fig. 4 – 3D model of the pipeline before and after updating for additive technologies

The software used in the design, developed at the department, allowed us to determine the position and distribution of the material during prototyping.

This saves energy, metal and money. The complex curved shapes obtained as a result would be quite difficult to cast or cut from the workpiece, even on the most advanced CNC equipment.

To create prototypes, there are a large number of methods and types of equipment. Depending on the tasks and these methods are selected. They can work simultaneously or sequentially to perform the main task. So, when creating the appearance of a part from resin, it becomes possible to check its manufacture from metal and, in the case of a positive response, launch it into production.

Equipment capabilities ("strict" restrictions on the dimensions of the working area) allow you to create aircraft with a wingspan of 1.2 meters, which is especially effective when creating biplane-tandem aerodynamic balancing devices with 2 or more bearing surfaces. This is achieved by rational dividing the design of the aircraft into units and assemblies and a detailed study of the butt units.

In Fig. 5 presents an innovative example of the implementation of the project of an unmanned aerial vehicle (UAV). The whole structure is made in one chamber by sintering a polyamide powder. The aircraft manufacturing cycle is a day, of which sintering is about 8 hours. Assembly of the aircraft is manual without tools. After installing the engine, the aircraft is ready for operation.

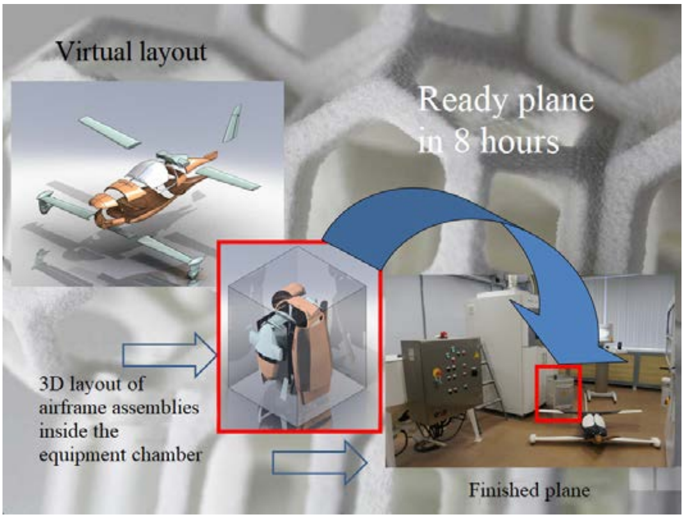


Fig. 5 – Possibilities of additive technologies of the MAI Resource Center Department of Engineering Graphics. Specialty Computer Design

4. PROBLEMS OF USING MODERN PROTOTYPING METHODS AND THEIR POSSIBLE SOLUTIONS

At the same time, the widespread use of modern prototyping methods in aviation is constrained by a number of reasons: the high cost of equipment; lack of proprietary installations and materials for prototyping (primarily metal powders of the required quality), lack of trained personnel to carry out work, lack of recommendations on methods for designing parts designed for prototyping, etc.

In a certain sense, university science could help solve these issues. So, at the Department of Engineering Graphics at the Moscow Aviation Institute (national research university), a 3-D Printing School was created and there are a number of installations designed to create prototypes and parts using RPM technologies.

The Institute's Resource Centers, created to train personnel in the aviation, missile and space industries and other high-tech defense sectors of the Russian Federation's economy by integrating science, education and production to maintain the parity of creating technological superiority in these sectors at the world level, have equipment designed for rapid prototyping. Installation of Viper Si2 ™ SLA® Installation of EOSINTM270 3D Printer Alaris 30.

The availability of equipment at the institute allows both jointly and individually to cover most of the entire complex of rapid prototyping by creating an educational-scientific-production center for prototyping complex technical products and technological processes. For mobile monitoring of such changes in Rosstandart created technical committees. For example, 182 TC – This is the Technical Committee for Standardization "Additive Technologies" (hereinafter – TC 182) is a form of cooperation of interested organizations, authorities and individuals in carrying out work on national, interstate and international standardization in the field of economic activities, products and services according to Section C "Products of manufacturing industries" according to OK 034-2014. Or TC 482 "Supporting the life cycle of exported military products and dual-use products".

The dynamics of the modern world requires not only training of secondary vocational education (SVE) and higher professional education (HPE), but also retraining of personnel at the level of competencies at a predetermined time determined by the technological structure. The three-level model (undergraduate, graduate, postgraduate) education supplemented by the system of additional education APE (additional professional education) was born as a result of a dynamically developing digital world (Fig. 6).

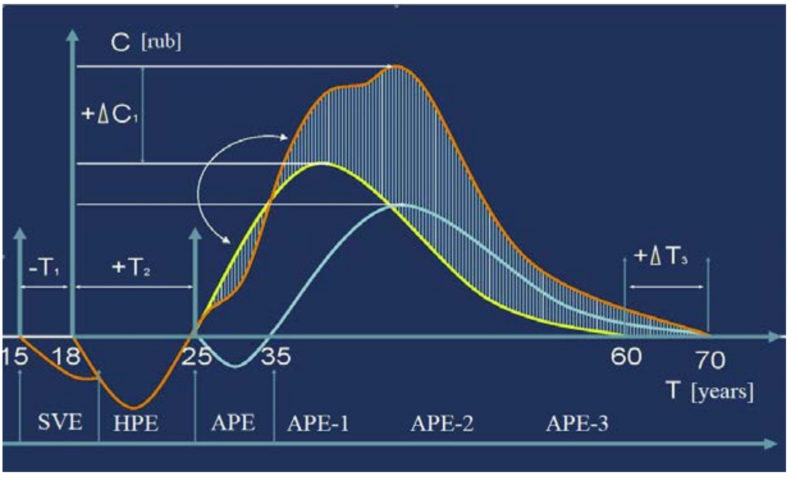


Fig. 6 – A modern model of a specialist's business goal within the framework of SVE-HPE-APE programs

To make a profit on the business goal of the life cycle after graduating in engineering, it is advisable to obtain APE for additive technologies, which will allow for the formation of a higher competency model of a specialist engineer, which allows obtaining a higher income level C1 delta in the market.

In Fig. 7 presents the competencies of digital engineering depending on the time of their development in the framework of educational programs SVE-HPE-APE.

Digital "World without Borders" demanded flagship landmarks, points of competence assembly. One of them is the joint Council for the defense of dissertations for the degree D999.048.02 on the basis of the Nizhny Novgorod State University of Architecture and Civil Engineering and the Nizhny Novgorod State Technical University.

R. E. Alekseeva (approved by order No 1400/nk of 11/17/2015) is the only Council in the country that discusses dissertations in the specialty 05.01.01 Engineering geometry and computer graphics.

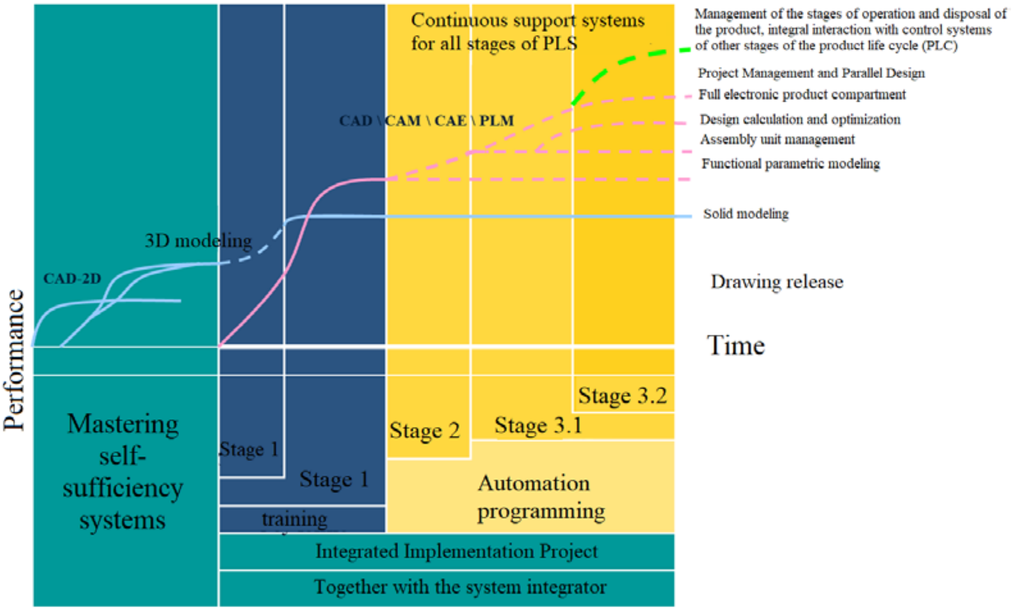


Fig. 7 – Efficiency of training in the field of design and modeling depending on time

Specialty formula: Engineering geometry and computer graphics is a field of science and technology engaged in the development of theoretical foundations and practical methods of geometric modeling of phenomena, objects and processes of wildlife, engineering, technology, economics, construction and architecture. The solution of scientific and applied problems of this specialty is aimed at achieving optimal parameters of geometric models of phenomena, objects and processes, providing the most complete account of functional, structural, technological, economic, aesthetic and other requirements. Research areas:

1. Image theory and practical methods for its implementation in the construction of geometric models.
2. Theory and practice of continuous and discrete geometric modeling. Design of curved lines, surfaces and bodies according to predetermined requirements.
3. Theory of geometric transformations and their use in modeling.
4. Geometric optimization methods in various fields of science and technology.
5. The theory of multidimensional geometry and nomography and their use in geometric modeling.
6. Geometric fundamentals of computer-aided research of processes: design, construction and production technology.
7. Development of visualization methods and algorithms. Methods and algorithms for image processing in vision systems.
8. Geometric fundamentals of information technology and systems.

5. CONCLUSIONS

The digital world has led to the transformation of the blueprint, as a communication language for engineers. The virtual solid state image became primary in relation to a flat drawing. With the advent of modern solid-state parametric modeling systems, the approach to design as such has changed. If the engineer previously worked in two-dimensional space and was forced to translate his ideas into flat drawings, now he has the opportunity to create in a virtual three-dimensional volume, without thinking about how to draw this or that projection of the part. That is, the design does not go from the drawing to the three-dimensional appearance of the product, but in the opposite direction – from the spatial model to the automatically generated drawings, bypassing the time required to create them. Direct and inverse tasks in the development and reading of drawings is a new challenge to engineering education, which is solved through the digital transformation of design documentation.

Additive technologies make it possible to realize the design complexity of monolithic parts and integral assemblies, which in principle do not allow them to be displayed on a flat drawing and to ensure their production on metal-cutting machines corresponding to the modern technological level of development. To make a profit on the business goal of the life cycle after obtaining a higher education in an engineering specialty, it is advisable to obtain additional professional education on additive technologies, which will allow creating a high-level competency model for a modern specialist engineer. The digital "World without Borders" required benchmarks, points of assembly of competencies. One of them is the joint Council D999.048.02 for the defense of dissertations for the degree of candidate and doctor of technical sciences. For mobile monitoring of such changes in Rosstandart created technical committees. For example, Technical Committee No 182 is the Additive Technologies Standardization Committee. It is a form of cooperation of interested organizations, authorities and individuals in carrying out work on national, interstate and international standardization in the field of economic activities, products and services in accordance with Section C "Products of manufacturing industries".

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