Factories of the future in the automotive industry of Russia: the balance between energy efficiency and digital development

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Abstract. The paper studies the prospects for the introduction of advanced production technologies (APT) and new business models at the enterprises of the automotive industry of the Russian Federation in order to find the balance between the investments into the more efficient energy management of the industrial buildings and the financing of digitalization process in the model of “factories of the future”. It includes the study of the opportunities that appear in companies that are "factories of the future", the analysis of the existing experience in the implementation of APT and energy efficiency tools at the enterprises of the automotive industry in Russia and Europe and the identification of the factors limiting widespread "factories of the future" at the moment. The authors present an economic view on the problem of integrating both advanced production technologies and new energy management models into the activities of the Russian automotive industry enterprises. Keywords: advanced production technologies, energy efficiency, energy management, digital factories.

1 Introduction

The automotive industry is a key sector of the Russian economy, in which more than 900 companies operate, being participants in the chain of redistribution at various levels. Large domestic manufacturers include: OJSC Gorky Automobile Plant (GAZ), JSC AvtoVAZ, LLC Ulyanovsk Automobile Plant (UAZ), PJSC KAMAZ.

The first half of 2022 has become a period of great testing for the Russian automotive industry. Due to sanctions imposed by the West, the import of certain automotive components was directly banned, while the supply of others became impossible due to disruption of supply chains [1-5].

Many foreign car companies, including European and Japanese ones, have been directly banned from investing in the Russian economy. As a result, automobile assembly plants,

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which have appeared in Russia in recent decades, still worked last spring on the remnants of already imported vehicle kits, but by the middle of the year almost all of them had stopped.

The traditional Russian auto industry was not in a much better situation. So, due to the cessation of supplies of key components from Europe, the assembly lines of AvtoVAZ were stopped. A few months later, production was restored, but so far this only applies to the most localized models. Not all Lada models that could be bought a year ago will return to showrooms, and others will return only after alternative suppliers of the missing components are found.

In the second half of the year, part of the factories left by foreigners ended up in the hands of Russian owners. Those, in turn, quickly announced the restart of production. True, in a somewhat unexpected way - with the participation of often unnamed foreign partners.

Thus, the situation in the Russian automotive market that has developed in 2022 actualizes the study of issues of reducing the cost of cars produced by Russian enterprises, reducing the time for their development and applying technologies that make it possible to implement this [6-10].

The global market where Russian automakers operate is highly competitive. To have new advantages in the face of global competition, it is necessary for Russian automotive industry to create products designed on new principles, using new technologies [11-18].

These technologies include advanced production technologies (digital design and modeling, additive and hybrid technologies, robotic systems, industrial Internet, big data, etc.), which solve complex industrial problems and significantly reduce the development time and cost of created products (Moiceanu and Paraschiv, 2022).

According to the authors of the Technet roadmap, aimed at creating in Russia a set of key competencies that ensure the integration of advanced production technologies (APT) and business models for their distribution as Factories of the future, Russia is among the top -20 countries by the number of technological backlogs in the field of advanced production technologies and by the number of first patent applications in a number of technology areas, including 3D printing, nanotechnology and robotics (National Technology Initiative[online], 2021).Thus, APT is the basis for building factories of the future, which are systems of integrated technological solutions that provide the design and production of globally competitive next-generation products in the shortest possible time, which, as a rule, are generated on the basis of test sites (TestBeds). Factories of the future provide an opportunity to meet a new challenge for Russian car manufacturers - Time to Market - the minimum time to bring competitive new generation products to the market.

The Ministry of Industry and Trade of Russia plans to create several testing grounds for testing and replicating advanced technologies in the automotive industry. The main trends of the "Factories of the Future" include: integration of multidisciplinary and cross-industry advanced technologies, distribution of universal inter-industry platform solutions, widespread use of advanced production technologies, formation of a new non-conventional package in developed countries, radical reduction in the cost and acceleration of development and production cycles, and development of distributed production system (Xiaochen et al., 2021).

The introduction of APT at Russian enterprises in the automotive industry makes it possible to present the result in the form of a digital twin instead of the working documentation used in the traditional production model. At the same time, the digital twin makes it possible to consider an average of 50,000 requirements according to the terms of reference (in comparison, when using the traditional production model, an average of more than 500). The number of full-scale tests, which are a very costly step in product development in the automotive industry, is on average five when using digital twins, while the average value of this indicator in traditional production is about 100. Such a multiple decrease is due

to the possibility of conducting virtual tests as part of the use of a digital twin. Such tests are carried out on average 50 thousand. The developed mathematical models for the automotive industry make it possible to obtain differences from field test data within 5%. The Digital Twin provides an opportunity to reduce the time it takes to create a new product and bring it to market with time shortage from 5 years with a traditional manufacturing model to 1 year with digital manufacturing (Salkutsan, 2021).

2 Problem formulation and methodology

The automotive industry is the most dynamic and innovative industry in which it makes economic sense to implement APT and build the factories of the future. Target indicators for the development of factories of the future in the Russian Federation are shown in Table 1.

Table 1. Target indicators for the development of factories of the future in the Russian Federation.

The name of the indicator	Measurement	2025	2035
Russia's share in the world markets of "Factory of the Future" in the segment of engineering and design	%	0,90%	1,50%
The number of created «Factory of the Future» «Technet»	Unit	17	40
The number of created testing platforms (TestBeds) in «Factory of the Future»	Unit	10	25
Number of experimental digital certification centers (laboratories)	Unit	10	15

Source: CNews Analytics (2017)

The key problem of creating factories of the future in the automotive industry of the Russian Federation, in our opinion, is the high cost of digital solutions being introduced into production. It is known that investments in the project of creating the production of parts of complex configuration for industrial gas turbine engines (GTE) NK-36ST using 3D printing at PJSC "UEC-Kuznetsov", the purpose of which is to create a high-tech production of industrial gas turbine engines with an intelligent system of design and technological preparation to improve functional characteristics, will amount to 497 million rubles, of which the own funds of UEC-Kuznetsov - 252 million rubles, and the remaining 245 million rubles. - this is a subsidy from the federal budget - (Site JSC UEA-Kuznetsov [online], 2021). The above figures clearly demonstrate the high cost of digital transformation projects, in particular, the introduction of digital twins as a key advanced technology used as part of the digital transformation of production (the project of PJSC UEC-Kuznetsov involves the use of digital twins). It should be noted that, according to the data for 2021, the number of manufacturing enterprises using digital twins, according to the statistical collection "Digital Economy Indicators 2022", increased compared to 2020. If in 2020 this value was 3.3, then in 2021 it became equal to 3.8.

It is obvious that the possibility of implementing such projects is within the power of companies that are provided with a large amount of their own funds and are able to attract funds for financing in the form of subsidies or on preferential terms.

32 enterprises from the EU and only one enterprise (PJSC "KAMAZ") from Russia were included in the Industrial R&D Investment Scoreboard, compiled in 2021 based on data from the 2,500 companies that invested the most in R&D worldwide in 2020, in the sector

«Automobiles& Parts» (European Commission [online], 2021). In the first place among EU enterprises is the German automaker VOLKSWAGEN (it should be noted that the first four places in this ranking belong to German companies - DAIMLER, BMW, ROBERT BOSCH), which investments in research and development in 2020 amounted to 13885 million euros. The last (32) place among European companies is the Swedish manufacturer THULE with an investment of 39.7 million euros. At the same time, KAMAZ PJSC invested 41.3 million euros. On the basis of these data, it should be concluded that the automotive industry is a science-intensive industry, the development of which is possible only if there are investments in research and development.

Thus, to the economic prerequisites for the introduction of APT in the automotive industry of the Russian Federation: the cost of developing and / or acquiring and implementing APT, hiring personnel with competencies in the field of advanced production technologies (programmers, new generation engineers, etc.), whose salary higher than that of employees of traditional industries, readjustment of the entire production. The introduction of APT is costly, especially for large enterprises, and as the automotive industry is mainly represented by big companies, huge investments are needed.

Digital Factories are the basis for further development of Smart and Virtual Factories from the point of general construction of the Factories of the Future. (Borovkov, 2015; Igiri et al., 2022; Salierno et al.,2021). The economic consequences will vary depending on the technologies introduced. They are shown in table 2.

Table 2. Parts of the factory of the future, the technologies behind them, and the economic consequences of introducing them into the activities of a manufacturing enterprise

Parts	What includes	Key technologies	The economic consequences of introducing them into the activities of a manufacturing enterprise
Digital factory	The process of product design up to the prototype stage, - the final product can be the prototype itsel, the sample or its digital twinк	- technologies for digital design and modeling, additive technologies, technologies for collecting and analyzing big data necessary to create digital twins; - new materials, the properties of which are taken into account in the design as part of a systems approach - their use helps to reduce the number of design errors and speed up the time to market.	- cost reduction by 10–50%, - reduction of production time by 20–70%, - profit growth by 10–50%
«Smart» factory	everything concerning the exact manufacturing capacity – robotics, industrial Internet, various technology of production management and organization: - integrated corporate systems for technological process management (ICS), - the systems of production management at the	- Digital Factory technologies that allow using the received digital models and samples for further mass production - with the help of such technologies it is possible to increase productivity, reduce the number of defects, and speed up the production process.	- reduction of production time by 2-4 times, - growth inputs 50–70%, - up to two times profit growth

	level of production unit (MES), - sensors and indicators		
Virtual factory	expands and extends the physical production site, linking it to other factories, if it is a question of several sites of the same enterprise, as well as to suppliers and contractors. Thus, a single information field is formed, in which each participant in the value chain has access to the most up-to-date information. This helps to make the process more transparent, improve and speed up communication both between business units and between contractors.	Industrial Internet technologies that allow receiving feedback from all components of the production chain	- increase in predictability by 2-4 times, - cost reduction by 40%, - reduction in the number of pieces of equipment by 7-15%.

Source: Compiled by the authors on the materials of the "Action Plan ("road map") "TECHNET" (advanced production technologies) of the National Technology Initiative (National Technology Initiative[online], 2021).

3 Problem Solution

The problem of attracting investments in the automotive industry of the Russian Federation is being solved in several ways.

Russian auto enterprises constantly receive anti-crisis support from the state. In 2020, the government of the Russian Federation actually allocated 56.1 billion rubles, which is 10.6 billion rubles. more than it was planned. The funds were directed to programs: preferential car loans, operating leasing (25% discount on advance payment when buying domestic cars, advanced purchases of equipment for government needs), subsidizing the certification of unmanned vehicles, grants for the development of components, soft loans for organizing the production of components (Vedomosti [online], 2020). For example, under the preferential leasing program in Russia in 2020, 46.4 thousand units of cars were sold. In 2021, the demand for cars exceeded supply, and the demand for car loans and leasing services increased in 2021 up to 17.5 billion rubles (CARRU[online], 2021). In 2022, a decision was made to allocate 20.7 billion rubles. to support demand in the automotive industry of the Russian Federation: for the renewal of car loans - 10.2 billion rubles, for preferential leasing - 4.9 billion rubles, for discounts on electric transport - 2.6 billion rubles, for gas-powered vehicles - 3.3 billion rubles. Until 2023, there are preferential lending programs for the purchase of domestic cars "Russian Tractor", "Own Business", "Preferential Leasing"(GARANT RU [online], 2020).

Measures to stimulate sales of the automotive industry are indirect measures to support automakers. Such products sale does not suppose a large margin. This means that the funds

earned by the enterprises themselves may not be enough to cover the costs associated with the implementation of innovation projects. For these purposes, loans should be used.

Russian automakers have the opportunity to attract investments for the digitalization of production in the form of loans from the Industry Development Fund, which provides preferential loan co-financing at 1% with high-quality collateral and 3% per annum with other types of collateral for projects implemented in priority areas of Russian industry and aimed at import substitution, introduction of the best available technologies, as well as the localization and creation of mass production of competitive high-tech critical industrial products. The amount of such loans varies in the range from 500 to 2000 million ₽. At the same time, the total budget of the project should be from 625 million ₽, and the loan term should be less than or equal to 7 years. Co-financing from the applicant, private investors or banks must be more than or equal to 20% of the project budget, including from own funds or shareholder funds ≥ 0% of the loan amount.

The products of a project applying for this type of financing must either be included in the list of modern technologies for concluding special investment contracts, and also have a conclusion on the confirmation of production in Russia, or be included in the sectoral plans for import substitution of the Ministry of Industry and Trade of Russia, and also have a conclusion on the confirmation of production on the territory of Russia, - in the Russian Federation there is an action plan for import substitution in the automotive industry of the Russian Federation, approved by order of the Ministry of Industry and Trade of Russia dated July 6, 2021 No. 2648 (The Ministry of industry and trade [online], 2021)

From the Industrial Development Fund, funds are allocated at 1% per annum for projects under the “Autocomponents” program. The loan amount is from 50 to 1000 million rubles, while the total budget of the project should be from 125 million rubles, and the loan term should be less than or equal to five years. Financing condition: the project products may be Russian components for the automotive industry and special machine building, and these products must be included in the sectoral import substitution plans of the Russian Ministry of Industry and Trade. Co-financing from the applicant, private investors or banks must be greater than or equal to 60% of the project budget.

In 2021, REMDIZEL JSC (Republic of Tatarstan), specializing in the development, design and manufacture of automotive and armored vehicles, received a loan in the amount of 57.5 million rubles as part of the "Digitalization of Industry" program in 2021. (project budget 74.4 million rubles) for the implementation of the project "Implementation of a production process management system based on the 1C: ERP information platform."

The data provided in (Industrial Development Fund [online], 2021) indicates that in 2021 the IDF was financed under the Components program for enterprises that create components for car manufacturers for projects in the amount of 2,713.8 million rubles, in 2020 - 4927.1 million rubles, in 2019 - 200.7 million rubles, in 2018 - 1439.2 million rubles, in 2017 - 1431.8 million rubles. Thus, in the period from 2017 to 2021 inclusive, 10,712.6 million rubles were allocated.

4 Conclusion

There is experience in creating a car using digital twin technology in Russia, for example, an electric car Kama-1. The development was carried out within the framework of the project "Creation of a "Smart" Digital Twin and an experimental sample of a small-sized urban electric vehicle with a level 3-4 ADAS system" (Peter the Great St. Petersburg Polytechnic University Site [online], 2020). The industrial partner of the project was PJSC "KAMAZ", and the developer was the Engineering Center of St. Petersburg Polytechnic University. According to the creators of the electric vehicle, the smart crossover is competitive with both

in terms of technical and consumer characteristics, as well as in terms of design, safety and comfort, it meets the requirements of international certification. Thus, it was possible to develop such a project thanks to state support.

Initiatives to create the Factories of the Future in the automotive industry are supported, in particular, in the countries of the European Union. As part of the technological development program Horizon 2020 The pilot project of the Digital Factory was created on the basis of Volkswagen (Germany), which, according to the data given above, is the leader among European companies engaged in the production of cars and auto components in terms of investment in research and development. And despite this, the digital factory was created at the expense of the Horizon 2020 program (European Commission [online], 2020).

As the data presented in this paper show, the creation of factories of the future in the automotive industry of the Russian Federation has prospects and limitations, the key of which can be considered the high cost of such projects. For this reason, the task of creating the factories of the future is not only a task for engineers, programmers, mathematicians, but also for economists and financiers who are able to evaluate the cost-effectiveness of introducing AMT into the activities of existing enterprises or as part of the creation of new ones. In our opinion, the new generation of economists and financiers should be competent in the field of AMT and the factories of the future, since project evaluation is based on an understanding of the business processes inherent in enterprises using AMT, and the business models corresponding to such enterprises.

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