The Impact of Digital Twins on the Profitability of Large Companies in the Context of "Industry 4.0"

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Abstract: Nowadays, more and more elements of the physical world are becoming sources of digital data, software can analyze, control and interact with devices, equipment and people. The purpose of this work is to track the impact of the Digital Twin technology in the era of Industry 4.0 on the profitability of large companies. The main goal of any company is to create value, including through the use of technological solutions, in such a way that profit growth is achieved by improving the quality of products and services. The study was conducted on the basis of financial statements of organizations, reports on sustainable development, as well as analysis of information from open sources.

1 INTRODUCTION

Digitalization and intellectualization of the production process is a need of modern industry. Currently, the industry is moving from mass production to individual production. Rapid progress in manufacturing technologies in the industry helps to increase its productivity. The term "Industry 4.0" means the fourth industrial revolution, which is defined as a new level of organization and control over the entire product lifecycle chain; it is focused on increasingly individualized customer requirements. Industry 4.0 is still a visionary as well as a realistic concept and concerns the strict integration of human beings into the production process in order to have continuous improvement and focus on value-adding activities and avoid losses, which is a prerequisite for the implementation of the concept of sustainable development (Piccarozzi et. al., 2023).

2 LITERATURE REVIEW

Modern trends in the development of production are due to profound changes in the factors of the functioning of enterprises, including: the widespread introduction of new technologies and modern software, the rise in the cost of labor and material resources, the need for rapid restructuring of production processes to replace the range of products, as well as the constant tightening of competition.

All these factors lead to the need to change the strategies of an industrial enterprise in order to increase competitiveness, labor productivity, financial stability, maintain customer loyalty and improve the quality of products. This leads to the fact that the business processes of the enterprise, being under the influence of these factors, must respond adequately to them without reducing their effectiveness.

In (Bouwman et. al., 2018), the functioning of mechanisms for attracting investment resources to maintain the investment potential of an enterprise is considered. The study showed that the technology markets of Industry 4.0 are growing and attractive to investors and startups.

The article (Ejsmont et. al., 2020) describes the impact of the characteristics of Industry 4.0 and the technologies forming it on society and the economy, concludes about the basic principles and trends of sustainable development and sustainable business models in Industry 4.0. Within the framework of this study, it was determined that the main resource of the industry is data, the main element of which is artificial intelligence based on the Internet of Things and Services, the main problem is delegating to cyber-physical decision-making systems how "people do it". The problems that appeared in the

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areas of sustainable development with the advent of Industry 4.0 were also identified: the problem of electronic waste and unemployment - a consequence of robotics, bias when using machine learning algorithms when considering social issues, information technology security - protection of confidential data, espionage, fraud, viruses. The article presents the emergence of a new sphere - digital.

The paper also identified the idea and concepts of Industry 4.0, characterized by the introduction of "cyber-physical systems" in production processes. The article substantiates four principles of the concept of the fourth industrial revolution: the functional compatibility of man and machine – the possibility of direct contact via the Internet; transparency of information and the ability of systems to create a virtual copy of the physical world. The work also revealed the global dynamics of sales of industrial robots, the global dynamics of the volume of the industrial automation market, the degree of business interest.

The idea of digital twin technology and the emerging market of services for their development are considered and analyzed in (Madni et. al., 2019). Over time, a digital twin will be associated with any product (article, object) that has information sufficient to reproduce it, as well as information that allows optimal use of it at all stages of its life cycle. With the development of additive technologies, many products (in order not to take up extra space and reduce transportation costs) will be created on demand (based on an appropriate digital model), just as it is possible to obtain computing power on demand today.

The article (Shayganmehr et. al., 2021) highlights the key provisions of the digital transformation management strategy. This work is a study of how an organization can develop a digital transformation strategy that includes various aspects of the strategy, taking into account the specifics of the manufacturing sector. The article presents developments that make it possible to form several recommendations for strategic management of digital transformation in an organization. Digital transformation is a complex process, and in order to fully realize its potential, it is important to take into account all possible resources to achieve goals. Competence centers on key end-to-end digital technologies are presented: – machine learning and artificial intelligence; – virtual and augmented reality; – video analytics; – blockchain; – robotics and additive technologies; – unmanned technologies; – industrial Internet of Things, wearable technologies.

3 THE PLACE OF DIGITAL TWINS IN THE CONCEPT OF INDUSTRY 4.0

Industry 4.0 (I4.0) is the next step of the industrial revolution, which has the potential to further transform the production flow and change the communication between people and machines, as well as the interaction between suppliers, manufacturers and consumers. It consists of nine promising components and, in addition to the technologies mentioned above, includes autonomous robots, simulation, horizontal and vertical system integration, cybersecurity and augmented reality and can be further improved by solutions in the field of artificial intelligence.

An effective combination of the Internet of Things, cloud computing, artificial intelligence and big data and their integration into business processes and automation will significantly improve the industry not only operationally, but also economically and environmentally to achieve sustainable development goals. In such a structure, machines and equipment are connected to a single cloud, to each other and avoid centralized management systems, but, more importantly, they get full autonomy to make quick decisions in the event of unforeseen events (Piccarozzi et. al., 2023).

Industry 4.0 is considered a technological revolution to achieve higher efficiency and productivity and, as a high-tech strategy of the government, to increase Germany's competitiveness in the global market.

To highlight a unique set of characteristics that affect the functioning and effectiveness of the business, concepts with five clusters were developed. Each cluster reflects in what sense companies expected that the introduction of Industry 4.0 technologies would have an impact on various aspects. In addition, such clustering can contribute to the unification of the Industry 4.0 anthology, which is necessary for the seamless integration of machines, systems and processes. In other words, the extracted metrics could facilitate the establishment of performance indicators for decision makers that should be monitored when implementing Industry 4.0. After that, these clusters were analyzed for how they are supported by technological means.

The first cluster is customer Orientation (CR1), which includes concepts from C1 to C6. This plays a huge role in promoting the widespread adoption of Industry 4.0, as it is considered one of the main driving factors.

The second cluster group is stability (CR2). With the corresponding changes towards new industrial paradigms, it is extremely important to take into account the growing number of problems of sustainable development.

The third cluster group is Knowledge Management (CR3). Knowledge management plays an important and pivotal role in the development of an organization in a changing external environment and covers such processes as the creation, elaboration and transfer of knowledge. This can be supported by researchers in various fields.

The fourth cluster group is the Global Value Chain (CR4). The emergence of new industrial paradigms and concepts already has a significant impact on the activities and strategic decisions made by companies and organizations that focus on value creation processes. Moreover, the introduction of digital functions such as IoT, big data and analytics, robotics and additive manufacturing into production processes will enhance the complex nature of value creation in the organization and affect its performance in the global market.

The fifth cluster group is Smart Factory (CR5). In a huge volume of literature, Smart Factory is considered as one of the fundamental pillars of industry 4.0. This cluster can be considered as the ultimate goal of digitalization, which is a well-integrated workshop, including equipment, machines and devices that interact and continuously exchange data with each other. Therefore, the included characteristics contain elements from all previous clusters. The first five clustered characteristics are related to internal production processes. Real-time data monitoring is important, which leads to increased transparency of data in the organization and throughout the supply chain.

Digital twin technology is a new concept that has become the focus of attention of industry, and in recent years, scientific circles.

Official ideas about digital twins have been around since the early 2000s. However, it may have been possible to define digital twins earlier due to constantly changing definitions. The first terminology was given by Grieves (2014) in a 2003 presentation, and later documented in a white paper creating the basis for the development of digital twins (Glaessgen et. al., 2012). The National Aeronautics and Space Administration (NASA) released in 2012 a document entitled "The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles", setting a key milestone for the definition of digital twins.

A digital twin is an integrated multiphysical, multiscale probabilistic simulation of a finished vehicle or system that uses the best available physical models, sensor updates, fleet history, etc. to reflect the service life of the corresponding flying twin.

A digital twin is a virtual instance of a physical system that is constantly updated with data on the performance, maintenance and health status of the latter throughout the life cycle of the physical system.

A digital model is described as a digital version of a previously existing or planned physical object. There should be no automatic data exchange between the physical model and the digital model in order to correctly define the digital model.

Examples of a digital model can be, but are not limited to, building plans, projects, and product developments. An important defining feature is that there is no form of automatic data exchange between a physical system and a digital model. This means that after creating a digital model, the changes made to the physical object do not affect the digital model in any way.

A digital shadow is a digital representation of an object that has a one-way flow between a physical and digital object. Changing the state of a physical object leads to a change in the digital object, and not vice versa. If the data flows between an existing physical object and a digital object are fully integrated in both directions, this constituted a reference Digital Twin. A change made to a physical object automatically leads to a change in the digital object and vice versa.

These three definitions help to identify common misconceptions found in the literature. However, there are several misconceptions noted, but they are not limited to these specific examples. Among the misconceptions is the misconception that digital twins should be an accurate 3D model of a physical object.

4 RESULTS

4.1 Content analysis of the impact of Digital Twin technology on the company's profit

Content analysis is a research methodology that allows to understand the (often unstructured) content of messages, be it texts, images, symbols or audio data (Krippendorf, 2018).

Content analysis is a research method for creating reproducible and reasonable conclusions from texts (or other significant material) in the context of their use.

Content analysis in the context of this work is used to answer research questions through a process of conclusions based on text analysis.

Methodologically, the conclusion in content analysis is based on the logic of abduction (as opposed to deduction and induction; that is, from particulars of one kind to particulars of another kind). Thus, the answers received are not final and have a dubious degree of reliability. Within the framework of this theoretical framework, several companies using Industry 4.0 technologies, in particular the Digital Twin technology, were analyzed. Based on the reports on sustainable development, profit and loss, as well as on the cash flow of enterprises, conclusions were drawn about the impact of the Digital Twin technology on the profits received by companies from different fields of activity.

The reports were collected from the websites of individual companies. Then a keyword search was applied to them. Reading documents is based on an informed choice of keywords. To get information on the research topic, a search was conducted in relation to the words "Industry 4.0", "Digital Twin", "Information transformation" and so on. The information obtained with the help of contextual analysis helped to determine the dependence of the profit growth of companies from distinguishable business areas after the introduction of such a technology as a Digital Twin into their business strategy.

However, the results obtained with the help of this type of research are not final and have a dubious degree of reliability. Also, at this stage of work it is impossible to determine the exact degree of influence of the introduction of Digital Twins on the increase in the company's profit. We cannot exclude the fact that this indicator could have been influenced by third-party factors. Therefore, at this stage of the study, it is necessary to continue studying the influence of factors on the company's profit.

4.2 Numerical experiment

The analysis is carried out on the example of 31 companies from various fields of activity. The companies were selected from the rating "The most profitable companies in Russia - 2022. Forbes rating" as of 2021 (Forbes, 2022).

The dependent factor is the profit received by the company for the year (profit).

Selected factors explaining the formation of the company's profit:

1. The company's revenue for the year (revenue)
2. Assets of the corporation (assets)
3. The company's short-term liabilities (debt)
4. Age of the corporation (age)
5. Availability of Digital Twin technology (DT): DT = 1, in the case of Digital Twin technology, = 0 otherwise)

During the construction of the regression, it was found that the coefficient of determination R^2 is approximately 0.81, which is close to unity. According to Fischer's F-criterion, the model is significant in general. According to the Student's t-criterion, the net assets factor was not significant in this regression model, so it was decided to exclude this factor and build a new regression. In it, the coefficient of determination R^2 is approximately 0.78, which is close to unity and, according to Fischer's F-criterion, the model is significant as a whole. According to the Student's t-criterion, factors such as revenue, liabilities, age and the presence of a digital twin are significant at the 1% level.

The analysis of the quality of the constructed models showed that the models are qualitative in general, there is no multicollinearity and autocorrelation in the residuals in the models. At this stage of the study, we need a coefficient that stands in the equation before the factor of the presence of a digital twin.

This coefficient is equal to 0.24.

Thus, we can conclude that the contribution of the Digital Twin technology to the company's profit is approximately 24%.

5 CONCLUSIONS

The work is an attempt to quantify the impact of the use of Industry 4.0 technologies on the profitability of companies. The results obtained show the relevance and prospects of the study and can be improved by modifying the model and introducing new variables into it.

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