

Prospects and challenges of applying digital twin technology as one of the pillars of global economic development statistical analysis

آفاق وتحديات تطبيق تكنولوجيا التوأم الرقمي كأحد اعمدة تطور الاقتصاد العالمي

تحليل احصائي

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Received: 17/10/2025

Accepted: 11/12/2025

Abstract:

Digital twin technology is among the emerging and most advanced technologies that connect a physical system (products, equipment, ...) With another intangible (virtual), through a set of equipment, tools and programs, and with the availability of certain conditions. This technology has helped develop global production techniques and thus the development of the global economy, so it has become one of the basic pillars of its development due to the continuous increase in demand for it. This study aimed to shed light on both the prospects for implementing digital twin technology and the challenges it faces. The study reached an important conclusion that this technology has become more in demand for its contribution to solving some of the important problems that the global economy was suffering from, despite the challenges it faces. Economic institutions must address most of these challenges through active engagement in the development of the technology by providing funding and establishing specialized bodies for this purpose. This can be achieved by strengthening their digital infrastructure, forming qualified teams, and integrating collected data to enable the gradual implementation of digital twin technology.

Keywords: Modern technologies, global economy, digital twin technology, aggregate demand, aggregate supply.

Jel Classification Codes : O33 ; F02 ; O32; E10; E11.

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ملخص:

تعتبر تكنولوجيا التوأم الرقمي من بين التكنولوجيات الناشئة والاكثر تطورا، التي تقوم بربط نظام المادي (منتجات، معدات، ...) بأخر غير مادي (افتراضي)، عن طريق مجموعة من المعدات والادوات والبرامج، ويتوفر شروط معينة، ولقد ساعدت هذه التكنولوجيا على تطوير تقنيات الانتاج العالمي وبالتالي تطور الاقتصاد العالمي، فأصبحت عمود من بين الاعمدة الاساسية لتطوره نظرا لتزايد الطلب عليها باستمرار. وهدفت هذه الدراسة الى تسليط الضوء على كل من افاق تطبيق تكنولوجيا التوأم الرقمي والتحديات التي تواجهها، وتوصلت الدراسة الى نتيجة مهمة ان هذه التكنولوجيا اصبحت أكثر طلبا لمساهمتها بحل بعض المشاكل المهمة التي كان يعاني منه الاقتصاد العالمي، بالرغم من التحديات التي تواجهها، يتوجب على المؤسسات الاقتصادية مواجهة معظم هذه التحديات من خلال الانخراط الفعال في تطوير التكنولوجيا عبر التمويل وإنشاء هيئات متخصصة لهذا الغرض، وذلك من خلال تعزيز بنيتها الرقمية، وتشكيل فرق عمل مؤهلة، ودمج البيانات المجمعة بما يتيح التطبيق التدريجي لتكنولوجيا التوأم الرقمي.

الكلمات المفتاحية: التكنولوجيات الحديثة، الاقتصاد العالمي، تكنولوجيا التوأم الرقمي، الطلب الكلي، العرض الكلي.

تصنيفات Jel: O33، F02، O32، E10، E11.

Introduction

The global economy grew rapidly, with industry entering its fourth generation and employing both modern and advanced technologies. This was an inevitable result, because the economy accelerated through the acceleration of the world's population growth, so the global demand for products increased, in contrast to the limited public supply of products, because their source is limited, and therefore global demand is open compared to the limited supply and has almost become facing the peak problem, with the use of human labor and its limitations and all its problems.

Economic institutions have begun to search for modern and advanced technology that achieves effectiveness, compensates the workforce, and relies in its application on advanced technologies, from robotics technology to the Internet of Things, artificial intelligence, and real-time that allows for immediate intervention in the event of problems and predicting them even before they occur. From here came the idea of the digital twin, which reflects and simulates all the characteristics, movements, and measurements of the physical twin, to which is connected a complete system for transmitting and translating data in a timely manner. The global economy has benefited from this modern technology to address some of the problems it was suffering from. Demand for this technology has increased from some important sectors, despite some fundamental challenges facing it,

in order to develop the global economy and keep pace with the growing demand for products.

- Study Problem:

From the above, we can identify the main problem of the following study:

What are the prospects and challenges of digital twin technology for developing the global economy?

- Study hypothesis:

One of the key features of digital twin technology lies in its robust integration of physical and virtual systems, enabling the mitigation of several challenges currently faced by the global economy. This technology therefore presents extensive prospects for application; nevertheless, it remains subject to certain limitations that manifest as methodological and practical challenges.

- Study Objectives:

This study aims to identify the prospects for applying digital twin technology and to examine the key challenges that hinder its effective implementation. By systematically highlighting these challenges, the research seeks to propose practical and evidence-based solutions that can enhance the applicability of digital twin systems and contribute to sustainable global economic development.

- Study Methodology:

This research adopts both descriptive and inductive approaches. The descriptive approach is employed to outline and classify the theoretical foundations of digital twin technology, while the inductive approach is used to extrapolate and analyze practical applications supported by statistical evidence. Together, these methods enable a comprehensive examination of the prospects for applying digital twin systems and the challenges associated with their implementation.

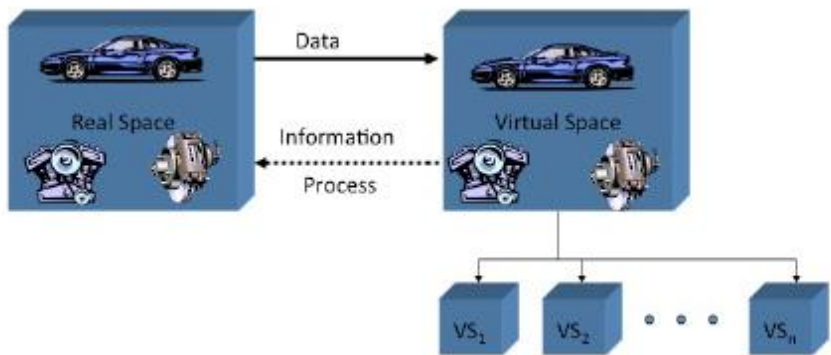
1-The Concept of the Digital Twin:

Digital twin technology originated in the early 1960s with NASA, although it wasn't referred to by that name at the time. The agency utilized it to link two spacecraft: one being an actual spacecraft and the other a virtual

model on Earth, equipped with software, sensors, and real-time data carriers to replicate the spacecraft's conditions. This setup allowed NASA to make timely interventions. The term "digital twin" was later introduced and developed by Dr. Michael Grieves at the University of Michigan in 2002. Since then, the technology has significantly progressed and is now employed across various economic sectors.

The first scientific concept of digital twin technology appeared to the world in a presentation presented by the University of Michigan in 2002 under the supervision of Dr. Michael Graves, in which he explained the use of this technology in the product life cycle (PLM). This presentation showed all the important components that make up this technology, and was based on the assumption that there are always two systems, a physical system that existed before Another virtual one contains all the information related to the previous physical system, which reflects the existence of a twinning between the two systems, Grieves, M., & Vickers, J. (2016) and the doctor summarized digital twin technology in the following figure:

Figure 01: Ideal use of digital twin technology in the product life cycle



Source: (Grieves & Vickers, 2016).

The term digital twin technology was defined and developed by Dr. Michael Grieves, who tried to give it a definition that he could frame it with. Hence, we will rely on the definition of this technology based on the definition given by Dr. Michael Grieves:

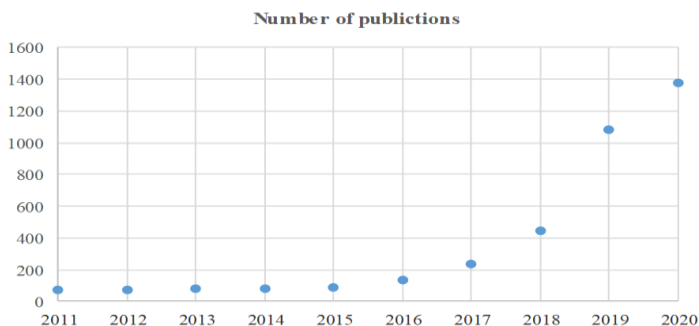
"Digital twin technology is an integrated set of virtual information structures that give a complete description of an existing physical system, from its physical components to its external geometric shape in its normal (ideal) state, which enables appropriate examination and intervention in case of necessity through its digital (virtual) twin".(Grieves & Vickers, 2016)

2-An overview of digital twins through the number of published research:

Digital twin technology is becoming more important to the global economy day after day and year after year, as confirmed by the number of studies published around the world regarding its use in various sectors of the global economy.

According to a study conducted by researchers Sleit and al (2022), that relied on data and statistics from works published in the "Scopus" database in various fields, in which the term "digital twin technology" appeared during the period from 2011 to 2020, the number of studies doubled, as shown in the following figure:

Figure 02: Evolution of the number of published research on applications of digital twin technology

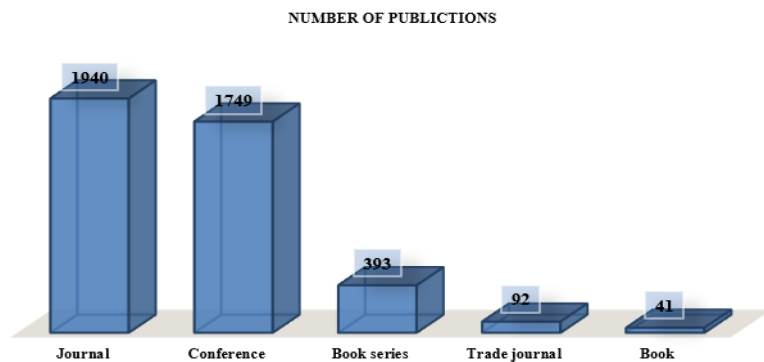


Source: Prepared by the researcher based on: (Sleit and al., 2022, p. 3707).

From the previous figure, published research moved from 72 published studies on the application of digital twin technology in 2011 to 1377 published studies in 2020, meaning that published research has doubled more than 19 times, an increase of 1,812.5 percent, which confirms that this technology is important to the global economy.

Attention has been paid to digital twin technology in various scientific forums. Researchers have addressed it in their research across all scientific platforms. The following figure shows the number of published research papers by source type.

Figure 03: Number of published research by source type

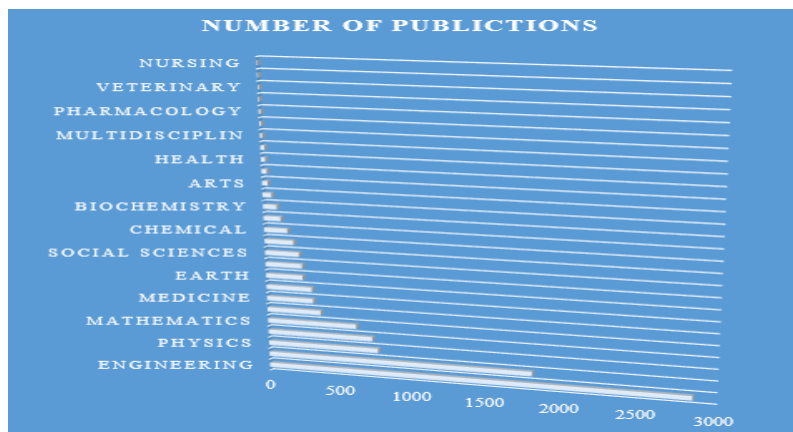


Source: Prepared by the researcher based on: (Sleit and al., 2022, p. 3707).

From the previous figure, we conclude that the number of published research papers according to the source is led by newspapers with 1940 published research papers, followed by conferences with 1749 published research papers, followed by book series with 393 published research papers, and in last place are books with 92 published research papers. This is what leads us to believe that digital twin technology is of great importance to researchers, but it has not yet been framed by books that give it scientific dimensions as a new technological sector.

The great interest in digital twin technology is distributed according to the number of published researches according to each scientific discipline.

Figure 04: Number of published research by scientific discipline



Source: Prepared by the researcher based on: (Sleit and al., 2022, p. 3707).

At the top of the specializations that used digital twin technology in their research is engineering, with 2859 published research papers, and nursing is at the bottom of the ranking with 5 published research papers. We conclude from this ranking that digital twin technology is widely used in technical specializations that develop everything technological.

We can arrange the number of published researches by country as follows:

Figure 05: Number of published research by country



Source: Prepared by the researcher based on: (Sleit and al., 2022, p. 3707).

d in digital twin technology. The Most developed countries are interested in digital twin technology. The United States, China, and Germany are accelerating their research and development of this technology. This is confirmed by the number of published research papers. These countries are led by the United States with 684 published research papers, followed by China with 635 published research papers, a difference of 49 papers, and Germany with 621 published research papers, a difference of 14 papers from China. We conclude that developing, and applying ,technology giants are interested in researching digital twin technology.

The study relied on major global statistics from various research works that examined the applications of digital twin technology from different perspectives, in order to provide a comprehensive overview of the importance of this technology for economic institutions in particular and for the global economy in general. These statistics revealed that approximately 70% of the challenges are related to digital infrastructure and cybersecurity. Comparative data between sectors helped to highlight the differences in the implementation of digital twin technology between intensive industries (such as energy) and other sectors-capital.

lped The use of digital twin technology by economic institutions has he them solve and avoid significant problems that hinder their daily activities, leading to an increase in demand for this technology. As a result, it has become one of the emerging and pioneering technologies in developing the pioneering studies that have shed light on the global economy. Among the use of digital twin technology in the economy are the following:

-Moh javaid&Abid haleem&Rajiv suman, "Digital Twin applications toward Industry 4.0: A Review", 2023: The research paper addressed the digitization process in industrial activity. It highlighted the use of digital twin technology in industrial economic sectors and described how institutions can benefit from it. This technology gives a digital image of all activities within factories. The paper also explained how digital twin technology supports the fourth generation of the industrial revolution. The study provided industrial economic institutions with digital diagrams showing all stages of manufacturing processes. As a result, these institutions are able to intervene in real time and predict solutions to the problems they encounter ;

-Deloitte insights, "Tech Trends 2020", 2020: The annual report of "Deloitte Insights" highlights the importance of digital twin technology in developing various sectors of the global economy. This technology is among the latest and most advanced. Integrating it into economic sectors will have a very positive impact and help achieve its full potential;

-Naser Bakhshi&Marc den Boogert&Dario Raffaele, "Digital Twins and their impact on the Supply Chain", 2025: The research paper highlights innovative leadership practices in supply chains, using digital twin technology to improve and increase their effectiveness in order to accelerate strategic decision-making in real-time. The study concluded that the growth of the global economy is increasing very quickly, which requires all economies of the world to rely on more effective supply chains and a chain to keep pace with this development and adapt to all global changes. The availability of large and updated data and information around the clock is the only way this economy can meet this requirement. Digital twin technology is an innovative tool for developing and leading global supply chains ;

-Frances Yu&Brian Campbell&Timothy Murphy, "From manufacturing to medicine: How digital twins can unlock new industry advantages", 2025 : This research paper studies digital twin technology, which has proven its presence and effectiveness in various manufacturing sectors. It examines the transition of this technology to a very sensitive sector: the medical sector. The paper examines how this technology can facilitate the development of medical activities. Digital twin technology provides those in charge of the sector and institutions with a wealth of important data. This data helps them design simulations that predict highly accurate results. As a result, it enables them to make proactive decisions and respond in a timely manner.

3- Benefits of different uses of digital twin technology:

Digital twin technology has several different uses. We can summarize these uses in the following figure:

Figure 06: Different uses of digital twin technology



Source: (Attaran & Celik, 2023, p. 3).

The benefits of applying digital twin technology in some key sectors of the global economy are as follows. (Attaran & Celik, 2023, p.4)

-Production and manufacturing:

- design customization;
- simulate and validate each step of development;
- Enhancing operations process;

- Reducing overall cost of engineering;
- Predictive maintenance;
- Virtually monitor and manage performance.

-Aerospace/Automotive:

- Design customization;
- Defect detection;
- Aircraft tracking;
- Stipulation of weather conditions;
- Optimizing the transport load;
- Vehicle defect detection;
- Real-time monitoring and predictive analytics.

-Construction/Real estate:

- Automated project control ;
- Safety monitoring ;
- Project planning and logistics ;
- Building performance assessment ;
- Evaluate space capacity and smartly design it ;
- Quality assessment.

-Utilities :

- Power grid planning ;
- Enhanced visibility across physical grid ;
- Efficiency improvement of the grid ;
- Power grid self evaluation ;
- Ecological reconstruction of the grid .

-Agriculture/Farming :

- Advance smart farming ;
- Plan, monitor, control, analyze and optimize farm processes ;
- Weather prediction ;
- Stress identification ;
- Livestock monitoring and management.

-Healthcare :

- Diagnosis and therapy ;
- Preventive treatment ;
- Drug development ;
- Medical device utilization ;
- Facility and operations design ;
- Education and training.

-Retail :

- Supply chain optimization ;
- Product inception, development and distribution ;
- Fleet management and route efficiency ;
- facility and operations design.

-Mining :

- Improve machinery productivity ;
- Allow for realistic simulation training ;
- Drug development ;
- Medical device utilization ;
- Facility and operations design ;
- Education and training.

4-Prospects and challenges of applying digital twin technology:

Digital twin technology has begun to be applied in various sectors of the global economy, with the development of big data analysis, artificial intelligence, cloud computing, and the Internet of Things. This technology has been able to solve some of the problems that some vital sectors of the

global economy were suffering from, the most important of which are industry, smart cities, smart supply networks, and the smart energy industry. This is what opens up the horizons of using this technology wide. (Zhang & Lv, 2022, p. 14178)

With the development of economic institutions, they have become forced to deal with their branches in a decentralized system as an inevitability for the tremendous development of their production operations in huge quantities, and with a large number of employees. Consequently, the quantities of materials used in their production have increased, their assets have expanded, and their position has been strengthened by the rapid digital transformation, reducing the expenses of digitizing the institution, and the risks it is exposed to, by using and benefiting from the features of the Internet of Things and building digital twins. It controls everything related to the economic institution, from its material assets to the management of its employees and resources, as digital twin technology plays an important role in the various activities of the economic institution. (Zhang, 2023, p. 225)

In the field of logistics and supply chain, the use of machine learning technology and digital twin technology supported by the fifth generation network provides the possibility of monitoring and tracking product demand channels, and introducing improvements to the process of goods flow in real time globally, so that the location and environmental conditions of the products become visible in real time automatically. This gives the monitoring center precedence in intervening in everything related to the transportation of products and the required modifications. (He & Bai, 2020, pp. 14-15)

Despite the prospects that the use of digital twin technology opens for enterprises looking for effectiveness and accuracy in strengthening their presence in the market, and despite the benefits that this technology provides them, it has not witnessed a significant expansion as a modern and advanced technology that keeps pace with the digital transformation of the global economy. This is due to some problems that are considered challenges to the expansion of its use in various economic fields, the most important of which we summarize as follows. (Zhang & Lv, 2022, pp. 14179-14180)

-The high cost and modernity of sensor equipment: Digital twin technology relies on high-resolution data very quickly, which requires the use of sensor equipment with modern and advanced technology in large

numbers. We cannot implement this requirement due to the high cost of these sensors ;

-Diversity and complexity of equipments: Due to the protectionist trade policies of institutions, which require them to follow confidentiality in all the operations they carry out from the production process to the distribution process, institutions are forced to use various equipment with very complex protocols to store data coming from the physical aspect at the Internet level, on the one hand, and on the other hand due to the diversity of institutions that produce this equipment at the various stages or activities of the institution, It has to deal with it, which makes using and building digital twins very difficult;

-Storage power and computer processing power of equipment: Digital twin technology relies heavily on the computer programs used and their storage power to keep up with the huge amount of data coming from the physical system. The storage power and processing power of the large amount of data flow are considered a major challenge in using digital twin technology ;

-Powerful algorithms for predictive maintenance: Digital twin technology must rely on powerful algorithms that allow the organization to intervene in forecasting before the danger occurs, which is called predictive maintenance, which makes the organization reduce the costs of losses, equipment maintenance, and optimal energy management, which makes it the basis of this technology;

-Digital Modeling with Unified Standards: The Digital Twin Technology Center is a high-resolution digital multi-modeling center that connects all entities representing digital twins, from equipment and installations to power supply, and various digital media, with different operating standards, which makes digital modeling very difficult. Digital modeling with unified standards is among the challenges facing the organization in using digital twin technology;

-Cyber protection for digital twin technology: The transition of digital twin technology from a closed system or network to a system or network open to the world that uses the Internet for work, this exposes the organization to the dangers of a Siberian hack, which requires the organization to provide protection for its digital twin technology from

Siberian risks, which is considered another challenge to implement this technology.

5-Discuss and analyze the results :

Various previous studies have focused on the benefits of using digital twin technology in specific sectors and the problems that hinder its adoption in these sectors. However, the study examines the prospects for using this technology and the challenges it faces, and proposes some solutions to address these challenges by economic institutions and thus their impact on the global economy, given that the economic institution is the primary actor in developing the economy.

To implement digital twin technology, the institution is forced to try as much as possible to remove some of the basic challenges, which are considered an obstacle or problem to its use of this technology, as follows:

-The challenge of protecting the privacy of enterprise data: Since digital twin technology uses modern technologies, the most important of which is the high flow of the Internet in its modern generations, which helps it collect and analyze data very quickly to make decisions in a timely manner (in real time), it is vulnerable to the risks of hacking. If it does not protect its data from these risks by using the latest protection programs and protocols, which are very expensive and require periodic updating to download everything new about data protection methods;

-The challenge of the specificity of each model of the digital twin: Every economic institution has its own specificities. We do not find institutions that are identical in structure and method of activity. Rather, we can find institutions that are similar in the type of activity they carry out or the sector in which they operate. From here, we can say that every economic institution has its own specificities. To be able to build a model of digital twin technology, it must take into account its specificities, even in the smallest details of all its activity processes, so that the application of digital twin technology can play an effective role in making effective decisions to solve some of the problems that the economic institution suffers from at the time;

-The challenge of the requirements for creating a successful model of digital twin technology: to build a successful model of digital twin

technology that is advanced and in line with all the variables in which the economic institution works to achieve its goal. This requires both time, money, and adequate effort to install and purchase the necessary equipment, tools, and programs that will help ensure the success of this model.

-Challenging the inconsistency or inconsistency of all programs operating the equipment used by the digital twin technology model: All equipment used by the digital twin technology model in all stages of its application depends on a different set of programs that translate the signals coming from the physical version into machine language for the virtual version of the digital twin technology model to recognize, to collect and analyze them to make decisions in time. In most cases, it varies depending on the institution producing this equipment, or varies depending on its operating systems. The economic institution must make all the changes in order to coordinate between the various programs to make its digital technology model a success, or to seek the help of experts in the field to do so.

The direct and indirect economic effects on economic institutions, and the global economy will result from addressing the challenges that have faced the application of digital twin technology.

The direct economic effects of implementing digital twin technology lie in the following main points:

-Reducing total costs: The adoption of digital twin technology by economic institutions contributes to reducing costs at various stages of their activity, and thus reducing the total costs of the economic institution, by making proactive improvements to products thanks to simulating the virtual version carried out by technology based on data derived from the physical version, and avoiding useless maintenance or sudden maintenance by predicting it before it occurs;

-Increase the revenue growth: Digital twin technology has the potential to increase the revenues of economic institutions by creating modern and new business models that are in line with all changes that occur in the supply and demand of their products, which can enhance their position in the market by facilitating access to some categories that they were unable to reach or increasing their market share by simulating market competition by taking all the variables that help them do so.

The indirect economic effects of applying digital twin technology are represented in increasing the productivity of economic institutions, because this technology enhances the effectiveness and efficiency of the production process by increasing production quantities with good quality, and with less consumption of resources. This leads to an increase in labor productivity, by introducing improvements in the form of appropriate changes to all requirements of the production process (workers, machinery and equipment, management, ...), by making better decisions based on data analysis by this technology, thus increasing the operational flexibility of economic institutions.

The digital twin technology has had a significant impact on the sectors that use it, and has a promising future for developing the global economy. We can analyze the role that this technology plays as one of the pillars of technological development for the global economy through some important statistics for the year 2025 published by "Hexagon", Hexagon (2025). the leading company in measurement technologies, on its website:

-Hexagon identified two main reasons for economic institutions interest in implementing digital twin technology:

-The First: Ease of obtaining data from the physical world compared to a previous period, as digital twin technology relies on some advanced technologies, the most important of which are the Internet of Things, cloud computing, and artificial intelligence;

-The second : The important impact of this digital twin technology on total revenues, improving operational efficiency, controlling costs, and the decision-making process has been improved since its application.

-The growth rate of demand for digital twin technology is witnessing a rapid increase. Global demand for this technology for the year 2025 has been estimated at \$16.55 billion, and is expected to reach \$242.11 billion by 2032, meaning that global demand for this technology is increasing at a compound growth rate estimated at 39.8%;

-The rate of implementation of digital twin technology over the next five years is 36%;

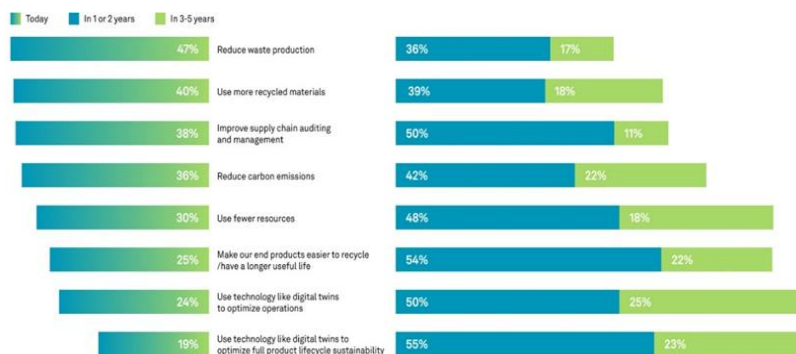
-Digital twin technology is being implemented by 70% of large technology companies by allocating budgets for it.

-By applying digital twin technology, the achievement of sustainability measures for economic institutions improved by 16% on average;

-Economic institutions that use digital twin technology have improved their sales, actual working hours, and operational efficiency by an average of 15%, and their revenues have exceeded 25%.

The benefits of economic institutions using digital twin technology can be summarized in the following figure.

Figure 07 : Benefits for economic institutions of using digital twin technology



Source: (Hexagon, 2025).

6.Conclusion:

Digital twin technology came to move the global economy from a traditional economy built and completely dependent on the human element in its various stages, to a very advanced and digital economy, by integrating all modern and advanced technologies, from the fourth major industry, to the Internet of Things, to the tremendous development in communication technologies, ..., so the economic institution also became forced to keep pace with the developments taking place in the global economy after liberation from some of its basic restrictions, most notably trade restrictions Under the rule of low costs and maximizing profits.

The term digital twin technology first appeared and was known by Dr. Michael Greaves. According to him, it is an integrated set of virtual information structures that give a complete description of an existing physical system, from its physical components to its external geometric shape in its normal (ideal) state, which enables appropriate examination and intervention in case of necessity through its digital (virtual) twin.

Digital twin technology has introduced major developments to various sectors of the global economy, and he, in turn, was able to benefit from it by reducing overall costs, increasing the percentage of profits, and saving time by reducing the time that was wasted at all stages of the economic institution's activity.

Despite the benefits that digital twin technology has provided to the global economy, the economic institution must meet some challenges in order to be able to continue its activity and continue the development taking place in the global economy based on digitalization. This confirms the validity of the study hypothesis.

In addition to previous research and development efforts, and as recommendations for economic institutions to overcome the challenges they face in implementing digital twin technology, they must:

- Adopt digital twin technology by developing their digital infrastructure, introducing digital networks to enable the digitization of all daily operations, including production, supply, and marketing processes, and installing all equipment and tools that facilitate information transfer between the physical and virtual systems;
- Training the organization's staff to assist in using all the equipment, tools, and software necessary to build its digital twin model, to ensure its optimal use;
- Establish unified data standards to avoid any disruptions in the coordination process between the components of the digital twin model, which may arise from the different sources of those components (Like various sensors);
- Enhance their cybersecurity by installing software that helps them secure their information, in cooperation with leading institutions in this field such as IBM Security;
- Phaseically implement pilot projects before embarking on the full expansion of this technology across all the economic institution's operations.

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