MANUFACTURING INDUSTRY 4.0

Sector focus

Digital twins

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Ajuntament de Barcelona

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Digital Twins: origin, projection and enabling factors

A Digital Twin is a **virtual replica** of a product, process or service – such as motors, cities and manufacturing and production processes. These virtual replicas are created with the technology of Internet of Things. They **simulate the actions of their real counterparts** and are used to make behaviour projections prior to the production or implementation of a service or a product. Therefore, simulations allow researchers to test digital twins' real counterparts without building prototypes, as well as to foresee their operation and to analyse their efficiency or behaviour in order to improve their performance.

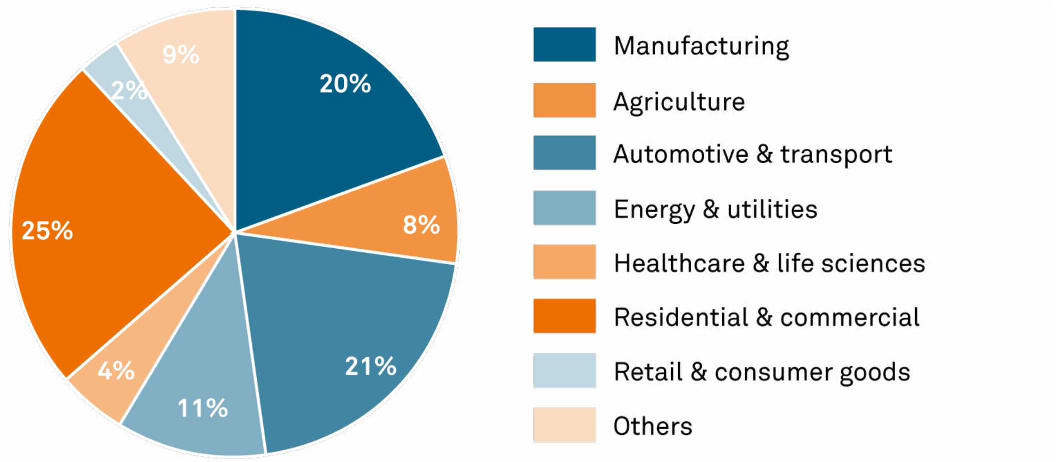
Digital twins need the technology of **Internet of Things** to function. Data is compiled through sensors applied to a physical object or through setting parameters of a process or service. Then, their behaviour is simulated. It is also important to point out that Digital Twins are **dynamic.** They are not diagrams or photographs of reality at a particular time – precisely, their value lies in their ability to represent how a subject responds to different stimuli and evolves throughout its lifespan.

Therefore, digital twins use software **based on real-world data to recreate simulations of functioning**. It is crucial to make sure that digital models continuously receive information from the sensors that gather data from real-world models. This way, digital twins create models that may be updated instead of or at the same time as physical, real models.

The concept of "digital twin" was first used in the field of industrial manufacturing in 2002 by **Michael Grieves**, a researcher specialised in advanced manufacturing at the Florida Institute of Technology. Seven years later, in 2010, NASA included this concept on their technological road map. They used this technology to predict the state of computer systems in rockets and satellites during flight time, as well as to simulate missions before launching and to remotely maintain and repair aircrafts. Therefore, it is obvious that Digital Twins are a **very powerful technology yet still emerging**, as a little over a decade ago they were only available to the most technologically advanced companies and organisations.

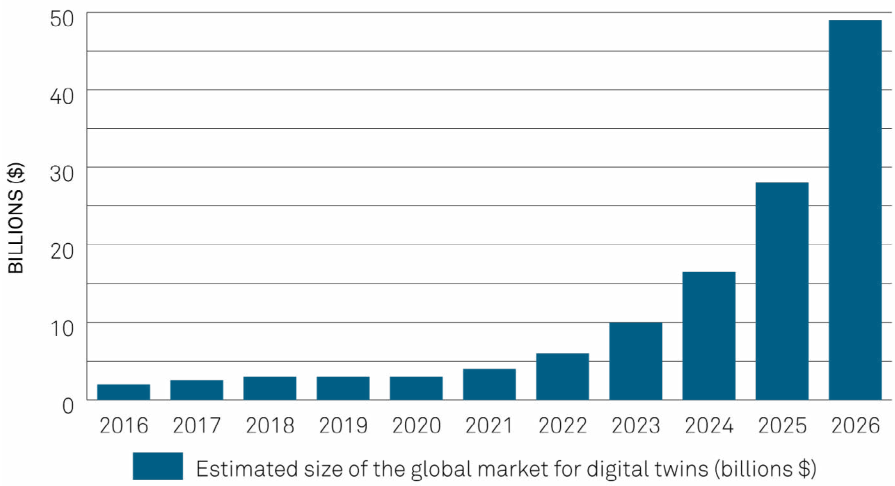
However, recent data suggests that the use of Digital Twins is now spreading through different sectors, such as logistics, construction, health sciences and, particularly, the manufacturing industry. Besides, **this technology is expected to grow exponentially in the upcoming years.** According to the estimations made by market research company MarketsandMarkets, the global value of Digital Twins will go from 3.1 B$ in 2020 up to 48.2 B$ in 2026, which implies a **yearly growth rate of 58%.**

Figure 1. Main fields of application of Digital Twins in 2020



Source: Prepared by the authors, based on data of the Digital Twin Market Size, Share & Trends Analysis Report By End-use by Grand View Research

Figure 2. Global market growth estimation for Digital Twins



Source: Prepared by the authors, based on data of the Digital Twin Market Report by MarketsandMarkets

But... why are digital twins expanding to the manufacturing industry now? This question has a complex answer. However, there is an agreement amongst experts that the popularisation of Digital Twins might be attributed to the convergence of **enabling factors** as well as to a **social and economic context that is prone to the uptake of this technology.**

Figure 3. Causes of the expansion of the Digital Twins market

ENABLING FACTORS	FAVOURABLE CONTEXT
The development and implementation of digital twins has accelerated because of higher maturity levels in related advanced technologies such as simulation, sensors, Internet of Things and cybersecurity.	The financial instability resulting from factors such as the rise of international political and financial conflicts, the Covid-19 pandemic and natural disasters has made it necessary to make production more flexible.
Although there is still room for improvement regarding the availability of qualified professionals in the field of digital twins, two key skills in this field are being promoted - communication and data analysis skills.	A higher market competition pushes companies to incorporate technologies that reduce costs, increase productivity and improve the quality of their final products or services.
Lastly, the introduction of new technologies is favoured by the development of a new business culture that is favourable to change, committed to long-term projects and oriented towards research, development and innovation.	Digital twins make it possible to train staff through virtual models. They also make factories safer because they enable an early detection of errors and breakdowns in the production process.

Source: Prepared by the authors

Although the context is overall favourable, there are also **factors that negatively interfere in the expansion** of digital twins.

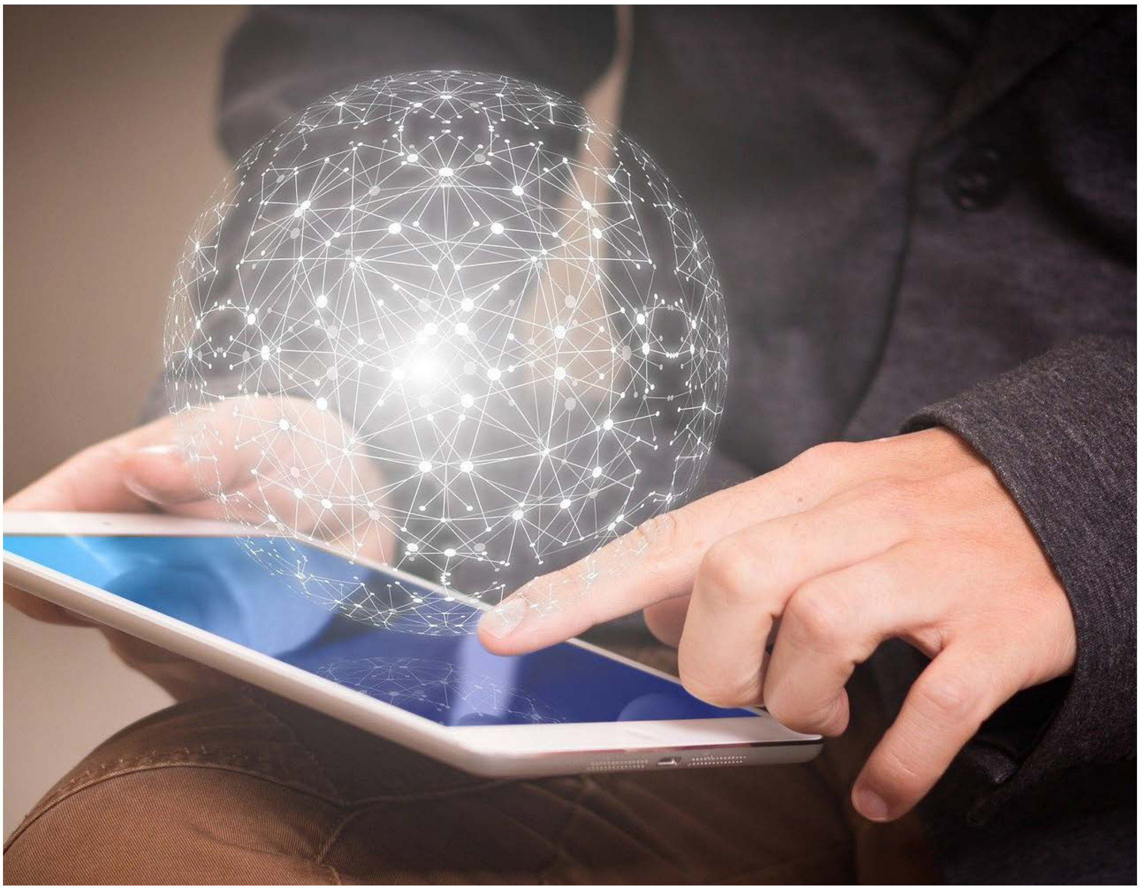
- This technology favours a **degree of coordination and integration** within a company which **may be difficult to achieve** in some organisations.
- The fact that digital twins are a fairly recent technology **makes it harder for companies to estimate their potential earnings.** This uncertainty may stop them from incorporating this technology.
- Technology **advances at a faster pace than many companies and professionals can invest,** update their skills or evaluate its reach and potential.

These factors perpetuate both the notion that technological advances are a threat as well as a business culture resistant to change.

Implications of digital twins for the production process

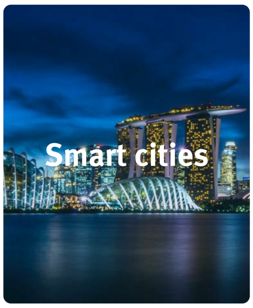
Digital twins are on the path to becoming a regular tool for professionals in the fields of **engineering** and **industrial design**. As more devices are created for an interconnected world, assets and systems linked to the production process become more complex. In the face of this, it is obvious that the development, management and maintenance of industrial activity also has to evolve accordingly, and digital twins are one of the technologies making it possible.

One of the advantages of digital twins is that they **shorten prototyping time and therefore the design process**. By exclusively using simulations, it is possible to determine the specs of the product, define how it will be manufactured and with which materials, and check that the design complies with the applicable standards and regulations. Additionally, **quality and durability problems may be spotted** even before the product design is finished. Beyond design, digital twins can potentially transform **predictive maintenance tasks**. Installing sensors allows gathering real-time data on industrial machinery performance or on final products, which makes it possible to fix breakdowns before they even take place. The result? A more agile and efficient production process, manufacturing plants that are safer for workers, and the possibility to offer better service and maintenance plans to final customers.



Below are some real **examples of the application** of digital twins in different production areas:

German company Math2Market has developed a computer programme that **simulates materials** with different features, such as fabric, foam and ceramics. Digital twins are obtained from microscopic digital scans and may be used to analyse the resistance and hardness of the materials as well as to study the efficiency of gas and fluid filters, amongst others.



The project Virtual Singapore is **virtual recreation of Singapore city** and, at the same time, a **collaborative database.** Once it is completed, it will be a free platform mainly dedicated to research. Its potential applications include analysing urban mobility patterns, designing evacuation routes in emergency situations and strategy planning of telecommunication networks.

In the field of medical research, **digital twins of human body parts** are created to understand their structure and functioning better without carrying out invasive procedures. For instance, Siemens Healthineers have developed digital twins of human hearts that, in the long term, could be used to d**iagnose cardiovascular diseases and treat them before they appear.**

Multinational company Unilever has launched a digital twins project in which they will create virtual models of their factories. Their goal is to implement measures of **predictive maintenance** and restrict waste through the early detection of products that do not comply with quality standards.

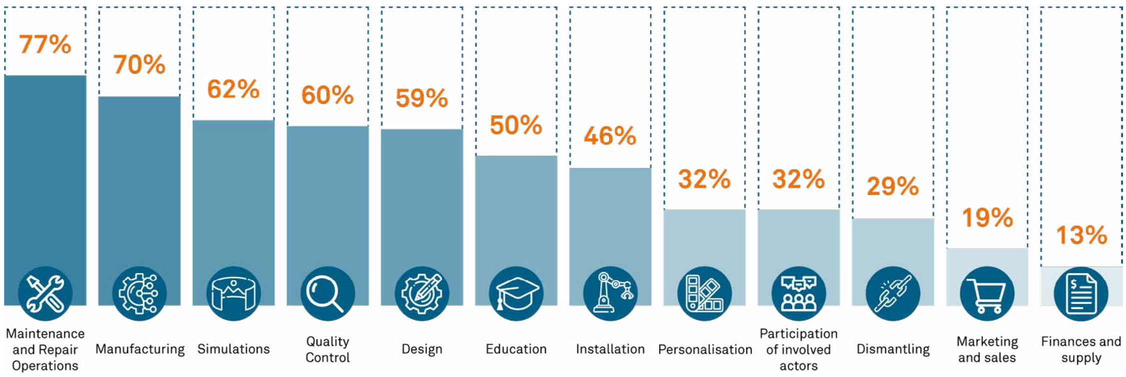
Impact of digital twins in professional profiles

Digital twins are a clear example of how quickly technological advances are transforming the manufacturing industry. In the 2000s, the concept of digital twins was a little more than incipient, and in the 2010s it was only at the reach of the world's richest and leading companies. But **since 2020 this technology is indisputably predicted to expand** not only in the industrial field, but also in many others – such as the logistics and aerospace fields.

Adopting a new technology may have an impact on more than one phase of the production process and, therefore, **transform the jobs of several professional profiles** to a greater or lesser extent. Specifically, the popularisation of this technology is resulting in the emergence of a professional **specialisation** in digital twins engineering. A digital twins engineer creates virtual representations of physical elements connected to Internet of Things and is also in charge of their dynamics, which describe how they function and interact with the environment throughout their life span.

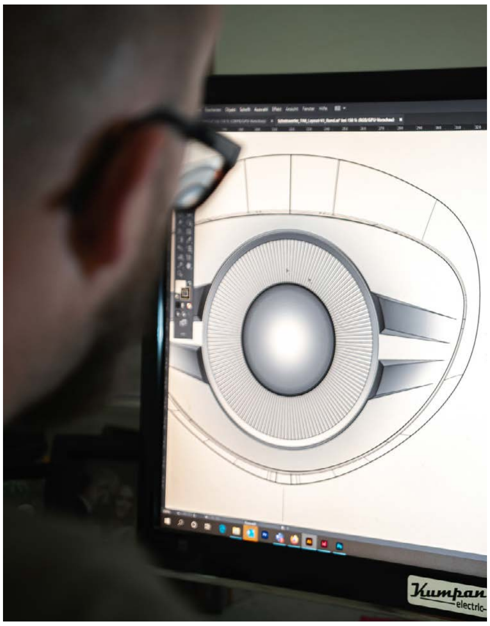
Besides virtual simulations, **digital twins engineers** gather and analyse real-time data of objects and processes in order to optimise their functioning and contribute to the design of new products and business models. They develop a cross-cutting task in a company as they work hand in hand with the design department and the marketing and sales department. For this reason, besides having advanced technical knowledge of simulation, AI and other technologies related to digital twins, these professionals must have strong data analysis skills and be good communicators in order to deliver information in a clear way to non-experts in digital twins and effectively coordinate mutual actions.

Figure 4. Most benefited activities from the implementation of digital twins



Source: Prepared by the authors, based on data by New Equipment Digest

In terms of employment, the most direct effect of the implementation of this technology is the emergence of a new professional profile specialised on creating and managing digital. However, it is not the only one. Figure 3 summarises the results of a survey conducted by the British research facilities network Catapult Network. They surveyed 150 professionals with the aim to have a better understanding of the perception of companies in this sector regarding the requirements and potential benefits of the implementation of Digital Twins. According to the data gathered, the **product life cycle stages that will gain the most value** from adopting digital twins are maintenance and repair processes, quality control and design. As a result of the implementation of digital twins, professionals in these areas will be encouraged to obtain specific training in this technology.



A few examples of this are detailed below:

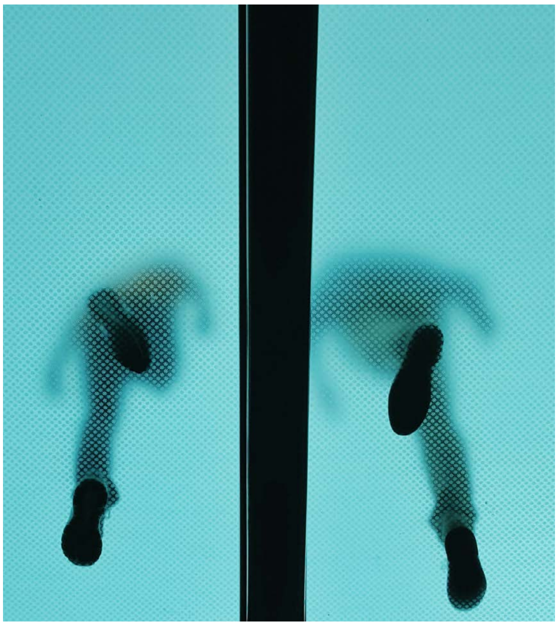
Quality control, Maintenance and Repair: Digital twins make it possible to automate boring tasks such as conducting inspections or writing technical reports, in which humans are more prone to make mistakes. With this technology, employees may dedicate their time to tasks with more added value. Besides, early detection of anomalies in the functioning of machines and products will promote preventive maintenance tasks with a specific focus.

Product design and development: This is one of the areas in which digital twins may have a higher transformative power, since design and prototype processes will evolve towards a mainly virtual format. As technology advances, it is likely that industrial designers will have to learn to use software to create or modify digital simulations. It will be more necessary than ever to have knowledge of computer-assisted design and modelling.

Research and decision-making: Tests with digital twins - such as the simulation of products, services and processes - result in a large amount of data. When this technology is applied to prototyping processes, all this information must be analysed to foresee changes or alterations in physical elements and to find ways to improve the attributes and functioning of products and services. Besides, the wide range of data available and the ability to forecast will lead to a more analytical leadership, whose decisions will be based on matters such as production management and corporate strategy in quantitative criteria. These factors indicate that the expansion of Digital Twins will promote a higher demand for Big Data professionals.

Digital twins, in focus

The manufacturing industry is leading the expansion of digital twins. As this trend accelerates in the upcoming years, more companies will explore the possibilities of this technology to **optimise processes**, make **decisions based on real-time data** and **create new products, services and business models.**



In the future, besides expanding to other economic sectors, larger and more complex digital twins will be created, which will model whole production lines and facilities.

Regarding employment, there will be new profiles expert in this topic. At the same time, it will be increasingly required for professionals of all phases of the production chain to have **a grasp of digital twins or underlying technologies** - such as IoT, Cloud, AI and VR. There will also be an evolution towards **less fragmented corporate structures** that will promote shared knowledge and cooperation amongst departments.

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