EUDiTi

2023-1-MT01-KA220-HED-000166976

REPORT

MALTA - GENISTA RESEARCH FOUNDATION

UNIVERSITY OF WESTERN MACEDONIA

UCLL UNIVERSITY OF APPLIED SCIENCES

POLITEHNICA BUCUREȘTI CENTRUL UNIVERSITAR PITEȘTI 1818

fifty-fifty Social Innovation & Cohesion Institute

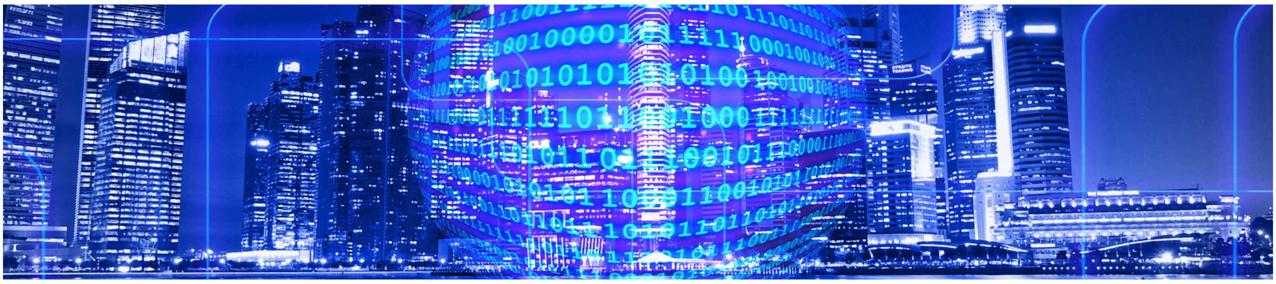
Europejska Fundacja na Rzecz Wspierania Rozwoju Innowacyjnego

Co-funded by the European Union

Content

Co-funded by the European Union

Introduction



Digital Twin (DT) technology has emerged as a revolutionary concept that bridges the physical and digital worlds. Digital Twins are virtual replicas of physical entities that enable real-time monitoring, simulation, and optimization, bridging the physical and digital worlds.

This technology transforms industries by enhancing decision-making and operational efficiency.

The EUDiTi project explores the implementation and impact of digital twins across Europe, with insights gathered from partner countries: Malta, Belgium, Greece, Poland, and Romania.

Our report emphasises the experiences and insights of all partner countries to highlight the benefits, challenges, and future expectations of this innovative and transformative technology.

Definition of Digital Twins

A digital twin is a virtual representation of a physical object, system, or process that exists in the real world. This digital replica is created using real-time data and advanced modeling techniques, allowing it to mirror the state, behavior, and lifecycle of its physical counterpart.

Digital twins enable continuous monitoring, simulation, and optimization, facilitating better decision-making and predictive maintenance.

Digital Twins are:

- **Physical Entity:** The physical entity is the real-world object, system, or process being represented. This could be anything from a machine or a factory production line to a human organ or an entire city.

- **Digital Replica:** The digital replica is the virtual model that accurately mirrors the physical entity. It is built using data from various sources, including sensors, CAD models, and historical records. This replica can range from simple 3D models to highly complex simulations.

- **Data Connection**: The link between the physical entity and its digital replica is maintained through continuous data exchange. Sensors and IoT devices collect real-time data from the physical entity, which is then transmitted to the digital twin. This data connection ensures that the digital twin remains up-to-date and accurately reflects the current state of the physical entity.

- **Analytics and Simulation:** Digital twins leverage advanced analytics and simulation techniques to process and interpret the data received. Machine learning algorithms and predictive analytics can identify patterns, forecast future states, and provide actionable insights.

Co-funded by the European Union

Digital Twins Evolution and Usage

Malta

Digital Twins Evolution

In Malta, digital twin technology has been embraced as part of the country's broader digital transformation strategy. The initial focus was on enhancing digital infrastructure and integrating digital twins in urban development and energy management.

DIGITAL TWINS USAGE

ENVIRONMENT:

Digital twins are used to simulate urban environments, helping in planning sustainable cities and improving infrastructure management.

ENERGY MANAGEMENT:

Malta uses digital twins to optimize energy distribution and monitor renewable energy systems, supporting the country's commitment to sustainability.

Belgium

Digital Twins Evolution

Belgium's adoption of digital twins began in the manufacturing sector, with early implementations focusing on optimizing production lines and improving product quality. The country's advanced technological infrastructure has facilitated the widespread adoption of digital twins across multiple sectors.

DIGITAL TWINS USAGE

MANUFACTURING:

Digital twins enhance predictive maintenance and improve the efficiency of manufacturing processes, contributing to cost savings and increased competitiveness.

HEALTHCARE:

The use of digital twins in personalized medicine and patient monitoring is gaining traction, with significant investments in research and development.

Greece

Digital Twins Evolution

In Greece, digital twin technology has gained a rise in recent years, driven by government initiatives to modernize infrastructure and promote digital innovation. The focus has been on integrating digital twins in sectors such as energy, transportation, and agriculture.

DIGITAL TWINS USAGE

ENERGY SECTOR:

Digital twins are used to monitor and optimize the performance of power plants and energy grids, ensuring a stable energy supply.

TRANSPORTATION:

Greece is exploring the use of digital twins for traffic management and infrastructure maintenance, aiming to improve urban mobility.

Poland

Digital Twins Evolution

Poland's journey with digital twins began with the integration of digital modeling and simulation technologies in the automotive and manufacturing industries. Their focus is on smart city initiatives and energy management.

DIGITAL TWINS USAGE

AUTOMOTIVE INDUSTRY:

Digital twins are used for vehicle design, testing, and predictive maintenance, enhancing product quality and reliability.

SMART CITIES:

Polish cities use digital twins to increase urban planning, traffic flow, and manage infrastructure efficiently.

Romania

Digital Twins Evolution

Romania has seen a gradual integration of digital twin technology, initially focused on digital modeling in manufacturing and automotive industries during the 2000s. The integration of IoT and big data analytics in the 2010s facilitated the development of dynamic digital twin models, with application to smart cities and energy sectors.

DIGITAL TWINS USAGE

MANUFACTURING:

Digital twins improve product processes, product designs, and increase maintenance plans, leading to reduced downtime and productivity.

SMART CITIES:

Digital twins are used to enhance urban planning, traffic management, and energy efficiency in cities like Bucharest and Cluj-Napoca.

Digital Twins in Industry Sector

Manufacturing

Malta uses DT in the manufacturing sector. A prominent example is the local electronics manufacturer, MME Ltd., which adopted digital twin technology to increase its production line. By creating digital replicas of their manufacturing processes, MME Ltd. achieved real-time monitoring and simulation of production plans. This allowed them to identify the traffic jams, optimize its function, and reduce downtime. The implementation of digital twins led to a 20% increase in production efficiency and a 15% reduction in operational costs.

Greece uses DT in the shipbuilding industry. The Hellenic Shipyards in Skaramangas uses digital twin technology to improve the design and manufacturing of naval vessels. By using digital twins, they simulate the entire lifecycle of a ship, from design to construction and its maintenance. This approach has enhanced precision in manufacturing, reduced the errors during assembly, and shortened project timelines. As a result, the shipyards have increased the percentage of orders from the available stock without any lost sales and improved customer satisfaction.

Romania's car sector has also adopted digital twins. Dacia, a major Romanian car manufacturer, uses digital twin technology in its vehicle production processes. By simulating different production plans and testing them virtually, Dacia has improved its car assembly line efficiency. This technology has led to a reduction in production time by 18% and has enabled faster adaptation to market demands.

Belgium's industrial sector benefits from digital twins in the chemical manufacturing industry. Solvay, a global chemicals company, has implemented digital twins to optimize their chemical processing plants. By creating virtual models of their production systems, Solvay can monitor and control chemical reactions in real time, improving safety and efficiency. This innovation has resulted in a 25% improvement in production and a significant decrease in operational risks.

Poland uses DT to enhance manufacturing precision. PZL Mielec, a leading aerospace company, uses digital twin technology in the production of aircraft components. By using virtual simulations to predict the components' performance, PZL Mielec has achieved a 30% reduction in material waste and improved overall product quality. This advancement has also allowed them to meet more rigid rules standards and customer expectations.

Co-funded by the European Union

Healthcare

Malta uses DT in personalized medicine. The Mater Dei Hospital in Valletta has integrated digital twins for pre-surgical planning. By creating virtual replicas of patients' anatomy, surgeons may practice complex procedures and tailor their approaches to patients' needs. This has led to improved surgical results and a reduction in patients' recovery period.

Greece uses DT in cancer treatment. The Thessaloniki-based research institution, Hellenic Pasteur Institute, uses digital twin technology to model the progression of cancer. This allows researchers to predict how tumors respond to different treatments, leading to more personalized and effective therapies. The application of digital twins in medicine has resulted in a 15% increase in the success rate of personalized treatment plans.

Romania uses DT in the field of surgical planning. The Elias University Hospital from Bucharest uses digital twin technology to create accurate 3D models of patients' organs and tissues. Surgeons use these to plan complex procedures, which have significantly reduced the number of complications and improved patients health results.

Belgium is a leader in integrating DT into healthcare research. The KU Leuven University uses digital twin technology to model human physiological systems for drug development. By simulating how new drugs interact with virtual representations of the human body, researchers can identify potential side effects and efficacy more efficiently. This approach has accelerated the development of new treatments and reduced the time required for clinical trials.

Poland uses DT in medicine. The Wroclaw Medical University employs digital twin technology to create virtual models of patients under rehabilitation. These models help therapists design customized exercise programs and track progress in real time. The use of digital twins has led to a 20% improvement in recovery times and increased patient satisfaction.

Co-funded by the European Union

Energy

In **Malta**, DT transforms energy distribution. The Malta Energy Authority has implemented digital twins to optimize the management of the island's energy grid. By creating real-time simulations of the grid, they can predict fluctuations and potential failures. This leads to a 10% reduction in energy losses.

In **Greece**, DT plays a crucial role in renewable energy management. The Public Power Corporation (PPC) uses digital twins to optimize the performance of wind and solar farms. By analyzing virtual models of these energy systems, PPC increases energy production efficiency and better integrates renewable sources into the national grid. This has resulted in a 15% increase in renewable energy contributions to the grid.

Romania uses DT to improve energy efficiency in its thermal power plants. The Romanian energy company, Transelectrica, has adopted digital twin technology to monitor and optimize the performance of their plants. By simulating different operational scenarios, they have identified ways to reduce fuel consumption and emissions, leading to a 12% improvement in plant efficiency.

In **Belgium,** digital twins increase energy sustainability through smart grid management. Elia, the Belgian transmission system operator, uses digital twin technology to create virtual models of the national electricity grid. These models help manage energy distribution, integrate renewable sources, and prevent outages.

In **Poland**, DT are used in the management of coal-fired power plants. The state-owned energy company, PGE, employs digital twin technology to monitor and optimize plant operations. By analysing virtual replicas of their plants, PGE can predict maintenance needs and optimize fuel usage. This has resulted in a 20% reduction in operational costs and improved environmental compliance.

Co-funded by the European Union

Transportation

In **Malta**, DT enhance traffic. The Malta Transport Authority has implemented such a technology to manage traffic flow and optimize public transportation. By creating virtual models of traffic infrastructure, they can predict congestion and implement effective traffic management strategies. This has resulted in a 15% reduction in travel times and improved public transport efficiency.

In **Greece**, DT improve transportation infrastructure. The Athens Metropolitan Transport Authority uses digital twin technology to manage and optimize the city's metro system. By simulating different scenarios, they can predict and address potential issues before they arise.

In **Romania**, DT enhances road safety and traffic management. Bucharest City Hall employs digital twin technology to monitor and analyze traffic in real time. Thus, they can implement targeted interventions to reduce congestion and improve road safety. This has resulted in a 10% decrease in traffic accidents and smoother traffic flow in the last few years.

In **Belgium**, Brussels Transport Company (STIB) uses DT to optimize bus and tram routes. By analysing virtual models of transportation networks, they improve the buses/trams scheduling and routes. This has resulted in a 12% increase in public transportation efficiency and enhanced commuter satisfaction.

In **Poland**, Warsaw City Hall especially, uses DT to monitor the traffic signals and public transportation systems. By simulating different traffic scenarios, they improve traffic flow and reduce congestion. This has resulted in a 15% reduction in a better public transport coordination.

Aerospace

Malta, uses DT in the aerospace industry to enhance aircraft maintenance. The Malta International Airport collaborates with local aerospace firms that implement digital twin technology for monitoring aircraft components. The engineers create virtual models of aircraft systems to help them predict maintenance needs and prevent potential failures, improving safety and reducing downtime.

In **Greece**, the Hellenic Aerospace Industry uses DT to create detailed simulations of new aircraft designs. These virtual models help engineers test aerodynamic performance and structural integrity before physical prototypes are built.

In **Romania,** the Romanian Air Traffic Services Administration (ROMATSA) uses DT to monitor the condition of aircrafts in real time. By analysing virtual models of aircraft systems, the engineers can spot and fix problems before they disrupt flights.

In **Belgium**, the Belgian aerospace company, SABCA, uses DT to create virtual models of aircraft throughout their operational life. These models help in monitoring performance, predicting maintenance needs, and planning upgrades. The use of digital twins has led to a 20% increase in maintenance efficiency and a reduction in operational costs.

In **Poland**, the Warsaw-based aerospace firm, PZL Warsaw, employs DT technology to simulate flight dynamics and to establish how an aircraft's structure responds during flight. This technology enables engineers to test various design configurations and optimize performance before manufacturing. The application of digital twins has improved the accuracy of simulations and reduced the time required for design validation.

Digital Twins Country Comparisons

This analysis helped us understand how Malta, Greece, Romania, Belgium, and Poland use digital twins in various industries. We took into consideration factors such as government policies, industry sector, and technological infrastructure to understand the similarities and differences of the partner countries.

All partner countries face similarities and differences in their journey toward technological advancement, which shapes their unique strategies for adopting and integrating digital innovations as follows:

Government Policies:

- **Similarities:** All five countries have government policies and strategies that aim at promoting digital transformation and advanced technologies. These include national digital strategies and EU-funded programs.
- **Differences:** Belgium, Poland, and Greece have more established, comprehensive policies and funding mechanisms for digital innovation. Malta and Romania are also supportive but have fewer resources and a less widespread policy implementation.

Industry Sector:

Similarities in Automotive Sector:

- In Malta, Greece, Romania, Belgium, and Poland, the automotive sector is increasingly adopting digital twins to enhance design processes, optimize manufacturing, and improve car performance. Digital twins are used to create virtual models of vehicles for simulation and testing, leading to innovations in autonomous driving, and electric vehicles.
- Across all partner countries, there is a strong emphasis on improving efficiency and sustainability within the automotive industry. Digital twins are used to optimize production lines, reduce waste, and enhance energy efficiency in vehicle design and manufacturing processes. The automotive sectors in all partner countries integrate digital twins to meet strict environmental regulations and market demands for greener technologies.

Differences in Automotive Sector:

- Belgium and Poland have more advanced and widespread adoption of digital twins in the automotive sector compared to Malta, Romania, and Greece. Belgium, with its strong automotive manufacturing base, and Poland, with its growing automotive industry, have integrated digital twins more extensively into their operations. Malta, Romania, and Greece are still in the early stages of digital twin adoption in automotive manufacturing.
- Belgium and Poland benefit from higher levels of investment in automotive innovation that represents advanced applications and a faster pace of adoption. Malta, Romania, and Greece face financial constraints that may slow down the implementation of digital twins in the automotive sector.

Similarities in Aerospace Sector:

- The aerospace industry in Malta, Greece, Romania, Belgium, and Poland supports digital twins for advanced simulation and testing. Digital twins enable the modeling of aircraft systems and components, allowing for rigorous testing and optimization before physical prototypes are built. This reduces development time and costs while enhancing safety and performance.
- Digital twins are used to monitor and maintain aircraft systems throughout their lifecycle in all partner countries. By creating real-time virtual models of aircraft, maintenance teams can predict and address potential issues before they arise, leading to improved operational efficiency and a reduced production time.

Differences in Aerospace Sector:

- Belgium has a more mature aerospace sector compared to Malta, Greece, and Romania. The advanced aerospace industry in Belgium has fully integrated digital twins into its design, simulation, and maintenance processes. In contrast, Malta, Greece, and Romania are still developing their aerospace capabilities and are in varying stages of adopting digital twin technologies.
- Poland has a strong focus on aerospace research and development, with significant investments in digital twin technologies for aircraft design and maintenance. Greece and Romania are making progress but may not yet match Poland's level.

Similarities in Healthcare Sector:

- In Malta, Greece, Romania, Belgium, and Poland, digital twins are used in personalized medicine. Virtual models of patients' physiological systems are created to simulate treatment results, medical interventions, and predict disease progression. This approach improves patient results and enables more effective and individualized healthcare solutions.
- Digital twins are used for surgical planning and training across these countries. By creating detailed virtual models of patients' anatomy, surgeons can practice and plan the surgical procedures more effectively. This not only enhances surgical precision but also provides valuable training tools for all medical professionals.

Differences in Healthcare Sector:

- Belgium and Poland have advanced integration of digital twins in healthcare, supported by great healthcare systems and substantial investment in medical technology. In contrast, Malta, Greece, and Romania are at different stages of adopting digital twins in healthcare, with varying levels of integration and technological infrastructure.
- Belgium and Poland have better access to funding and infrastructure for healthcare innovation, including digital twin technologies. Malta, Greece, and Romania face challenges related to funding and infrastructure, which may impact the pace and scale of digital twin adoption in healthcare.

Technological Infrastructure:

Similarities:

- All five countries are committed to enhancing their digital infrastructure and investing in digital transformation initiatives. Each country recognizes the importance of technology in driving economic growth and competitiveness, leading to national strategies focused on fostering innovation.
- Projects aimed at improving digital infrastructure, promoting research and development, and increasing digital skills are commonly funded by the EU, providing a shared framework for technological progress.
- Across these countries, there is a shared focus on integrating emerging technologies such as AI, IoT, and 5G into various sectors. These technologies strongly support industry-specific innovations.

Differences:

- Belgium and Poland benefit from higher levels of public and private investment in technology with high tech ecosystems and support advanced research and development activities. They also use digital twin technologies in sectors like healthcare, manufacturing, and aerospace, leveraging advanced analytics and AI to drive innovation.
- Greece and Malta make progress, they face challenges in attracting large-scale foreign investment, which can limit the pace of technological advancement and infrastructure development. They use digital twin in sectors like tourism, agriculture, and energy, with a growing emphasis on digital innovation and entrepreneurship.
- Romania attracts increasing investment in technology, particularly in IT and software development.

Digital Twins Recommendations

This chapter provides strategic recommendations for stakeholders in Malta, Greece, Romania, Belgium, and Poland to overcome challenges and maximize the benefits of digital twins. We took into consideration policy recommendations, industry best practices, and collaboration opportunities tailored to each partner country. Strategic recommendations for Malta, Greece, Romania, Belgium, and Poland focus on addressing regulatory issues, overcoming financial barriers, and tackling cultural resistance. Policy recommendations focus on funding to support projects, while the best industry practices focus on starting small and providing training.

Malta

Policy Recommendations:

- The Maltese government should think about financial help to companies that invest in digital twin technologies. This could reduce the financial burden and encourage more businesses to adopt these innovations.
- More funding for research and development in digital twins may foster innovation and support local companies and overcome financial barriers.

Industry Best Practices:

- Companies should start with pilot projects to demonstrate the value of digital twins before full-scale implementation. This approach allows businesses to assess the technology's impact and refine their strategies based on initial results.
- Investment in training programs for employees will ensure that businesses have the necessary skills and knowledge to implement and manage digital twins effectively.

Collaboration Opportunities:

- Collaboration with local universities and research institutions can provide access to research and expertise.
- Form industry networks focused on digital twin technologies that can facilitate knowledge sharing and collaboration among Maltese companies, enhancing their collective competences.

MALTA - GENISTA RESEARCH FOUNDATION · UNIVERSITY OF WESTERN MACEDONIA · UCLL UNIVERSITY OF APPLIED SCIENCES · POLITEHNICA UNIVERSITY OF BUCUREȘTI CENTRUL UNIVERSITAR PITEȘTI · fifty-fifty Social Innovation & Cohesion Institute · Europejska Fundacja na Rzecz Wspierania Rozwoju Innowacyjnego · Co-funded by the European Union

Greece

Policy Recommendations:

- The Greek government should make rules more flexible and adaptable to the environment.
- Introducing specific support measures for SMEs, such as low-interest loans or grants for digital twin projects, can help smaller companies overcome financial barriers and invest in advanced technologies.

Industry Best Practices:

- Businesses should focus on integrating digital twins with existing systems and processes to maximize their benefits as this ensures a smoother transition and helps in achieving tangible results quickly.
- DT implementation creates consistent and reliable digital twin applications.

Collaboration Opportunities:

- Using EU funding programs for digital innovation provide additional resources and support for Greek companies.
- Projects and research initiatives between Greek industries and education institutions can lead to the creation of new applications and innovations.

Romania

Policy Recommendations:

- The Romanian government should create a more supportive regulatory environment.
- Government initiatives to enhance internet connectivity and data processing capabilities are essential.

Industry Best Practices:

- Companies should adopt digital twin solutions that can grow with their needs.
- Companies from different industries can share best practices and learn from each other’s experiences with digital twins.

Collaboration Opportunities:

- Collaboration between the Romanian government and private sector can lead to successful projects and innovations.
- Establishing regional innovation hubs can serve as centers for research, development, and collaboration.

MALTA - GENISTA RESEARCH FOUNDATION
UNIVERSITY OF WESTERN MACEDONIA
UCLL UNIVERSITY OF APPLIED SCIENCES
fifty-fifty Social Innovation & Cohesion Institute
Europejska Fundacja na Rzecz Wspierania Rozwoju Innowacyjnego
Co-funded by the European Union

Belgium

Policy Recommendations:

- Specific support for digital twin projects can help businesses adopt and scale these technologies.
- Use clear guidelines and regulations for digital twin technologies can h can reduce uncertainty and facilitate faster DT integration.

Industry Best Practices:

- Companies should integrate digital twins with advanced analytics and artificial intelligence to maximize their potential and enhance decision-making processes.
- Businesses should focus on demonstrating the return on investment (ROI) from digital twin technologies.

Collaboration Opportunities:

- Collaboration on pan-European initiatives can drive innovation and technology development.
- Joint research projects can lead to valuable innovations.

Poland

Policy Recommendations:

- The Polish government should support both large enterprises and SMEs to facilitate broader innovation.
- Creating a clear regulatory framework that addresses data privacy, security, and industry-specific requirements is essential.

Industry Best Practices:

- Polish companies should consider incremental implementation of digital twins, starting with smaller projects and gradually scaling up.
- Training and development for employees is crucial for successful digital twin integration.

Collaboration Opportunities:

- All industry associations can provide resources, best practices, and networking opportunities to develop DT.
- Collaboration with research institutions and other companies can lead to the development of advanced digital twin applications.

The Future of Digital Twins

This chapter explores the future of digital twins in Malta, Greece, Romania, Belgium, and Poland. We focus on technologies that could increase the use of digital twins, predict potential new sectors for their application, and consider global trends that might influence their integration and evolution in Europe. AI, DT, and 5G will increase digital twin capabilities, while expansion into new sectors such as tourism, agriculture, and healthcare offers significant opportunities and become global trends.

Malta

Technological Advances:

- The integration of AI and machine learning with digital twins is expected to revolutionize industries by providing more accurate predictions, automated decision-making, and optimize processes in real-time.
- The 5G networks improve the performance of digital twins by enabling faster data transmission and real-time communication.

Expansion to New Sectors:

- Digital twins could be applied to enhance visitor experiences and optimize resource management in hotels, tourist attractions, and improve operational efficiency and customer satisfaction.
- Digital twins can be used to model urban infrastructure, optimize traffic management, and improve public services.

Greece

Technological Advances:

- AI will significantly increase the use of digital twins in Greece by improving accuracy in forecasting and decision-making.
- Advances in IoT and sensor technology will improve the data collection capabilities of digital twins.

Expansion to New Sectors:

- Digital twins have the potential to transform Greek agriculture by providing detailed simulations of crop growth, soil conditions, and resource management. This can lead to more efficient farming practices and improved yields.
- Greece's rich cultural heritage can benefit from digital twins in the preservation and restoration of historical sites. Virtual models can aid in the management and conservation of archaeological sites and monuments.

Romania

Technological Advances:

- Integration of AI with digital twins will drive more sophisticated simulations, with added value in the automotive and healthcare sectors.
- The development of 5G networks enhances the performance of digital twins by enabling high-speed data transfer and real-time interaction.

Expansion to New Sectors:

- Digital twins in construction and real estate sectors provide detailed virtual models of buildings and infrastructure.
- The retail sector can also benefit from digital twins by optimizing supply chains, and better increase customer experiences through virtual simulations and interactions.

Belgium

Technological Advances:

- The integration of AI with digital twins is valuable in sectors like chemical manufacturing and aerospace.
- It supports efficient digital twin applications in various industries.

Expansion to New Sectors:

- Virtual simulations of patient conditions improve treatment results and patient care.
- Virtual models can simulate energy grids and optimize resource distribution for a greater efficiency.

Poland

Technological Advances:

- The application of AI provides more accurate simulations and results in sectors like aerospace and energy.
- This technology will improve the data collection and monitoring capabilities of digital twins, creating more precise and dynamic virtual models for various industries in Poland.

Expansion to New Sectors:

- Transport and logistics sectors are much more improved. Virtual models can increase their operational efficiency and reduce costs.
- Digital twins can be applied to manage public services and infrastructure in Poland, including utilities, transportation systems, and urban planning.

Conclusion

Digital twins represent a transformative technology with the potential to revolutionize various sectors across Europe. By bridging the physical and digital worlds, they enable real-time simulation, analysis, and control, driving operational efficiency and innovation. As Europe continues to invest in digital transformation, the adoption of digital twin technology will play a crucial role in enhancing industrial and technological capabilities. Digital twins' underlying technology is expected to become more and more integrated with other technologies still under development, like artificial intelligence, machine learning, and augmented reality as their growth continues.

Malta, Belgium, Greece, Poland, and Romania are all on unique journeys toward enhancing their technological capabilities and embracing digital innovation. Despite facing different challenges and opportunities, these countries share a common goal of leveraging technology to drive economic growth, improve efficiency, and enhance the quality of life for their citizens.

All five countries have demonstrated a strong commitment to digital transformation, recognizing the critical role that technology plays in shaping their future. This commitment is reflected in national strategies and initiatives aimed at improving digital infrastructure, fostering innovation, and enhancing digital literacy.

The focus on integrating emerging technologies such as AI, IoT, and digital twins is prevalent across these countries. These technologies are seen as essential tools for enhancing competitiveness and enabling industry-specific innovations that can drive progress in key sectors.

EU funding and initiatives have been instrumental in supporting technological advancements in these countries. This shared support framework helps address infrastructure gaps, promotes research and development, and encourages cross-border collaboration.

Malta, Belgium, Greece, Poland, and Romania navigate their unique paths toward digital transformation. By building on their strengths, addressing challenges, and fostering collaboration, they can ensure continued progress and remain on top positions of digital innovation in Europe.

References:

Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., ... & Zaharia, M. (2010). A view of cloud computing. Communications of the ACM, 53(4), 50-58.

Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. Computer Networks, 54(15), 2787-2805.

Batty, M. (2018). Digital twins for smart cities. In Environment and Planning B: Urban Analytics and City Science, 45(5), 817-820.

Boschert, S., & Rosen, R. (2016). Digital Twin—The Simulation Aspect. In Mechatronic Futures. Springer, Cham. This book chapter discusses the simulation aspects of digital twins and their role in mechatronics, providing insights into the practical applications and benefits of the technology. In: Hehenberger P, Bradley D (eds) Mechatronic futures, Springer, Cham, pp 59–74. https://doi.org/10.1007/978-3-319-32156-1_5.

Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., & Brandic, I. (2009). Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Generation Computer Systems, 25(6), 599-616.

Chen, M., Mao, S., & Liu, Y. (2014). Big data: A survey. Mobile Networks and Applications, 19(2), 171-209.

Constantinescu, D., & Andrei, P. (2019). Leveraging Digital Twins for Smart Manufacturing in Romania. International Journal of Advanced Manufacturing Technology. This paper discusses how digital twin technology is being leveraged for smart manufacturing in Romania, highlighting case studies and best practices.

Fuller, A., Fan, Z., Day, C., & Barlow, C. (2020). Digital Twin: Enabling Technologies, Challenges and Open Research. IEEE Access. This article reviews the enabling technologies behind digital twins, such as IoT and big data analytics, and discusses the challenges and future research directions in the field.

Georgescu, L., & Marin, R. (2018). The Role of Digital Twins in Enhancing Healthcare Services in Romania. Romanian Journal of Medical Informatics. This study investigates how digital twin technology can enhance healthcare services in Romania, including personalized medicine and surgical planning.

Glaessgen, E., & Stargel, D. (2012). The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles. 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference. This conference paper discusses the early applications of digital twins in aerospace, particularly for NASA and the U.S. Air Force, highlighting the technology's potential in advanced engineering.

Grieves, M. (2014). Digital Twin: Manufacturing Excellence through Virtual Factory Replication. White paper. This seminal paper by Dr. Michael Grieves outlines the foundational concepts of digital twin technology and its applications in manufacturing, providing a comprehensive introduction to the subject.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems, 29(7), 1645-1660.

Hao, G., Shin, S. J., Jain, S., & Araujo, S. (2019). Data analytics using simulation for smart manufacturing. In Proceedings of the 2019 Winter Simulation Conference (WSC) (pp. 1858-1869). IEEE.

Hughes DJ, Keir S, Meggs C. (2018). Digital twin methodology for compression moulded thermoplastic composite optimisation. In: Flow processes in composite materials (FPCM), Lulea ̊, Sweden, pp 14–15.

Liu J, Zhou H, Tian G et al. (2019). Digital twin-based process reuse and evaluation approach for smart process planning. Int J Adv Manuf Technol 100(5/8): 1619–1634.

Liu, Q., Liu, J., & Zhang, J. (2019). The application of finite element analysis in digital twin of injection mold. Procedia CIRP, 83, 767-771.

Lupulescu, C., & Anghel, A. (2020). Digital Twins and Cybersecurity: Ensuring Data Integrity in Romanian Industrial Applications. Romanian Cybersecurity Journal. This article examines the importance of cybersecurity in digital twin applications in Romania, discussing strategies to ensure data integrity and protect against cyber threats.

Marinescu, D. C. (2013). Cloud computing: Theory and practice. Morgan Kaufmann.

Miller AMD, Alvarez R, Hartman N (2018). Towards an extended model-based definition for the digital twin. Computer- Aided Des Appl 15(6): 880–891.

Mu ̈ller F, Deuerlein C, Koch M. (2021). Cyber-physical-system for representing a robot end effector. Procedia CIRP 100:307–312.

Nedelcu, M., & Iliescu, D. (2019). Digital Twin Applications in the Romanian Automotive Industry. Proceedings of the Romanian Automotive Engineering Conference. This conference paper highlights the applications of digital twins in the Romanian automotive industry, focusing on vehicle design and predictive maintenance.

Negri, E., Fumagalli, L., & Macchi, M. (2017). A Review of the Roles of Digital Twin in CPS-based Production Systems. Procedia Manufacturing. This review paper examines the role of digital twins in cyber-physical systems (CPS) and their applications in production systems.

Parrott, L., & Meyer, W. S. (2012). Future landscapes: managing within complexity. Frontiers in Ecology and the Environment, 10(9), 512-519.

Pop, E., & Dragomir, I. (2020). Enhancing Urban Mobility in Romania through Digital Twin Technology. Romanian Journal of Transport Infrastructure. This study investigates the use of digital twin technology to enhance urban mobility in Romania, focusing on traffic management and public transportation systems.

Popescu, D., & Ionescu, G. (2019). Digital Twins in Romanian Manufacturing: Opportunities and Challenges. Journal of Manufacturing Technology Research. This paper examines the adoption of digital twin technology in Romanian manufacturing, discussing both the opportunities and challenges faced by the industry.

Qi, Q., & Tao, F. (2018). Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison. IEEE Access. This article compares digital twin technology with other Industry 4.0 technologies, discussing their synergies and potential in smart manufacturing.

Rodic ̆ B. (2018). Creating the digital twin with general purpose simulation modelling tools. In: The 2nd international scientific conference on IT, tourism, economics, management and agriculture (ITEMA 2018), Graz, Austria, pp 20–25. https://doi.org/ 10.31410/itema.2018.20.

Scheibmeir J, Malaiya Y. (2019). An API development model for digital twins. In: IEEE 19th international conference on software quality, reliability and security companion (QRS-C), Sofia, Bulgaria, pp 518–519. https://doi.org/10.1109/QRS-C.2019.00103.#

Schleich, B., Anwer, N., Mathieu, L., & Wartzack, S. (2017). Shaping the Digital Twin for Design and Production Engineering. CIRP Annals. This paper explores the integration of digital twin technology in design and production engineering, emphasizing its impact on product lifecycle management.

Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge computing: Vision and challenges. IEEE Internet of Things Journal, 3(5), 637-646.

Sivalingam K, Sepulveda M, Spring M et al. (2018). A review and methodology development for remaining useful life pre- diction of offshore fixed and floating wind turbine power con- verter with digital twin technology perspective. In: The 2nd international conference on green energy and applications (ICGEA 2018), Singapore, pp 197–204. https://doi.org/10.1109/ ICGEA.2018.8356292.

Stan, M., & Dumitrescu, C. (2020). Implementing Digital Twin Technology in Romanian Smart Cities. Romanian Journal of Urban Planning. This article explores the implementation of digital twin technology in smart city initiatives across Romania, with case studies from Bucharest and Cluj-Napoca.

Tao, F., Zhang, H., Liu, A., & Nee, A. Y. C. (2019). Digital Twin in Industry: State-of-the-Art. IEEE Transactions on Industrial Informatics. This paper provides a comprehensive overview of the state-of-the-art applications of digital twin technology in various industries, with a focus on manufacturing.

Vasilescu, A., & Petrescu, V. (2021). Digital Twins for Predictive Maintenance in Romanian Energy Sector. Energy Procedia. This paper discusses the use of digital twin technology for predictive maintenance in Romania's energy sector, focusing on power plants and energy grids.

Wang, K., Zhang, Y., Li, X., & Gao, R. X. (2018). Dynamic maintenance decision making based on real-time data. Robotics and Computer-Integrated Manufacturing, 49, 36-47.

Wilhelm J, Beinke T, Freitag M. (2020). Improving human-ma- chine interaction with a digital twin adaptive automation in container unloading. In: Proceedings of the 7th international conference of dynamics in logistics, Bremen, Germany, pp 527–538. https://doi.org/10.1007/978-3-030-44783-0_49.

Williams R, Erkoyuncu JA, Masood T et al. (2020). Augmented reality assisted calibration of digital twins of mobile robots. IFAC-Papers OnLine 53(3): 203–208.

Yun S, Park JH, Kim WT. (2017). Data-centric middleware based digital twin platform for dependable cyber-physical systems. In: The 9th international conference on ubiquitous and future net- works (ICUFN), Milan, pp 922–926. https://doi.org/10.1109/ ICUFN.2017.7993933.

Zhao G, Cao X, Xiao W et al. (2019). Digital twin for NC machining using complete process information expressed by STEP-NC standard. In: Proceedings of the 2019 4th interna- tional conference on automation, control and robotics engi- neering (CACRE 2019), Shenzhen, China, pp 1–6. https://doi. org/10.1145/3351917.3351979.