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VERSION MANAGEMENT

Revision table

Version	Name	Date	Description
v.1.0	Andrius Jurelionis	30-09-2024	Report finalized

LIST OF ACRONYMS AND ABBREVIATIONS

AI	Artificial Intelligence
BIM	Building Information Modelling / Management
DT	Digital Twin
GIS	Geo-Information Systems
IoT	Internet of Things
ML	Machine Learning
R&D&I	Research, Development and Innovation

SANTRAUKA

Skaitmeniniai dvyniai – tai fizinio objekto ar sistemos skaitmeninė kopija, sinchronizuota su realiais duomenimis ir atnaujinama realiuoju laiku. Ši technologija taip pat apima jutiklių panaudojimą duomenims rinkti bei panaudoti sistemos eksploatacijai. Todėl skaitmeniniai dvyniai leidžia ne tik stebėti objekto parametrus, tačiau ir atlikti įvairias analizes, optimizuoti procesus bei pagerinti sprendimų priėmimą.

Skaitmeninių dvynių technologija jau aktyviai diegiama daugelyje šalių: Jungtinėje Karalystėje sukurta nacionalinė Skaitmeninių dvynių programa, kuri skatina susijusių technologijų diegimą ir vienija skirtingus sektorius bei institucijas. Vokietijoje ir Suomijoje taip pat vykdomos skaitmeninių dvynių iniciatyvos, ypač urbanistikos ir infrastruktūros srityse. Taikymo atvejai apima energijos sąnaudų mažinimą, saugumo ir piliečių įtraukimo didinimą bei daugelį kitų.

Lietuvoje skaitmeninių dvynių technologijos yra tik pradinėse stadijose, tačiau pažanga yra ryški viešajame sektoriuje, kur BIM (pastatų informacinio modeliavimo) technologijos pradėtos naudoti viešųjų statybos projektų valdyme.

Įgyvendinant SmartWins projektą, Lietuvoje buvo suorganizuoti du piliečiams skirti renginiai Kaune (2023 m.) ir Vilniuje (2024 m.). Juose dalyvavo universitetų tyrėjai, verslo atstovai, valstybinių institucijų ir ministerijų atstovai. Renginių metu buvo organizuojamos dirbtuvės bei apklausos, siekiant suprasti Lietuvos statybos ir infrastruktūros sektoriaus parengtį diegti skaitmeninių dvynių technologijas, bei suprasti rizikas bei kliūtis šių technologijų vystymui. Renginių dalyviai nurodė, kad skaitmeninės technologijos, tokios kaip GIS (geografinės informacijos sistemos) ir IoT (daiktų internetas), jau yra plačiai naudojamos Lietuvoje, tačiau dar nėra plačiai integruotos tarpusavyje.

Skaitmeninių technologijų taikymo duomenys Lietuvoje rodo, kad urbanistikos ir statybos sektoriai vis dar atsilieka nuo kitų ES šalių vidurkio pagal debesų technologijų, dirbtinio intelekto sistemų taikymą. Tačiau Lietuvos Respublika turi tvirtą strategiją BIM technologijų vystymui, tad skaitmeninių dvynių inovacijos galėtų atnešti valstybei daug naudos.

Skaitmeniniai dvyniai leistų pagerinti Lietuvos viešojo ir privataus sektoriaus veiklos efektyvumą, pagerinti piliečių dalyvavimą sprendimų priėmime, suteikiant galimybę vizualiai stebėti būsimas miesto plėtros projektų simuliacijas. Ši technologija dera su

nacionalinėmis strategijomis „Lietuva 2030“, „Lietuva 2050“ bei Lietuvos sumaniosios specializacijos prioritetais. Skaitmeninių dvynių technologiją leistų pakylėti Lietuvos Respublikos BVP per aukštųjų technologijų kūrimą ir diegimą. Valstybė taip pat gautų tiesioginę naudą iš sukurtų skaitmeninių dvynių sistemų, kurios padėtų didinti visuomenės įsitraukimą ir tvaresnius sprendimus miestų lygmeniu, ir svarbiausia – didintų sprendimų priėmimo skaidrumą.

Nepaisant galimybių, egzistuoja kelios svarbios kliūtys, stabdančios skaitmeninių dvynių diegimą Lietuvoje:

1. **Duomenų privatumas ir saugumas.** Skaitmeninių dvynių technologijos reikalauja realiuoju laiku rinkti ir apdoroti daug duomenų, tačiau tam reikalinga užtikrinti saugų šių duomenų laikymą ir prieigą, ypač kai kalbama apie viešuosius duomenis. Be aiškių taisyklių dėl duomenų apsaugos, visuomenė gali skeptiškai vertinti šių technologijų diegimą.
2. **Standartizacijos ir duomenų valdymo trūkumas.** Lietuvos viešojo ir privataus sektoriaus institucijos naudoja skirtingas duomenų valdymo sistemas, todėl trūksta vieningų standartų, kurie leistų efektyviai diegti skaitmeninių dvynių sprendimus.
3. **Aukštos technologijų diegimo sąnaudos.** Skaitmeninių dvynių technologijų plėtra ir diegimas yra brangus procesas, o mažos ir vidutinės įmonės dažnai neturi reikiamų išteklių šias technologijas įdiegti.
4. **Kompetencijų ir kvalifikacijos trūkumas.** Šiuo metu Lietuvoje trūksta specialistų, galinčių kurti ir valdyti skaitmeninių dvynių technologijas. Nors akademinės institucijos vykdo su skaitmeninėmis technologijomis susijusius mokymus, specialistų ugdymas vis dar atsilieka nuo rinkos poreikių.

Atsižvelgiant į barjerus ir Lietuvos rinkos parengtį, SmartWins projekto apimtyje vykdytas apklausas ir analizę, **suformuluotos šios rekomendacijos**:

1. **Toliau remti skaitmeninimo plėtrą statybos sektoriuje.** Skatinti platesnį BIM ir GIS technologijų naudojimą, jas integruojant į platesnę skaitmeninių dvynių ekosistemą.
2. **Užtikrinti skaitmeninių dvynių duomenų apsaugą.** Jautrios ir su valstybės sauga susijusios informacijos atvejais, užtikrinti saugias ir uždaras skaitmeninių dvynių sistemas. Tačiau skatinti atverti duomenis, kurie leistų įtraukti piliečius į urbanistinio planavimo procesus, naudojant viešai prieinamus duomenis. Tokios institucijos kaip Valstybės Saugumo Departamentas ar

Lietuvos Kariuomenė turėtų būti informuotos apie vystomas skaitmeninių dvynių sistemas Lietuvoje.

3. **Skatinti viešojo ir privataus sektoriaus bendradarbiavimą.** Suteikti finansines ir mokestines paskatas mažoms ir vidutinėms įmonėms, diegiančioms skaitmeninių dvynių technologijas.
4. **Vystyti nacionalinę standartizacijos strategiją duomenų valdymui.** Sukurti vieningus duomenų formatus ir valdymo protokolus, kurie palengvintų bendradarbiavimą tarp viešųjų ir privačių subjektų, maksimaliai išnaudojant skaitmeninių dvynių potencialą.
5. **Investuoti į turimų duomenų praturtinimą.** Panaudojant dirbtinį intelektą ir mašininį mokymąsi, pagerinti esamų statinių (kadastrų bei registrų) duomenų semantinį praturtinimą, siekiant optimizuoti jų panaudojamumą.
6. **Didinti kompetencijas skaitmeninių dvynių technologijų srityje.** Palaikyti aukštojo mokslo institucijų programas, orientuotas į BIM, GIS ir skaitmeninių dvynių technologijų mokymą, taip pat skatinti kvalifikacijos kėlimo ir profesinio mokymo programas.
7. **Įgyvendinti ir skatinti atvirojo duomenų naudojimo politiką.** Skatinti atvirojo duomenų naudojimo politiką, kuri leistų efektyviau dalintis duomenimis tarp viešojo ir privataus sektoriaus.

SUMMARY

This document is a deliverable of the SmartWins project, funded under the European Union's Horizon Europe research and innovation programme under grant agreement No 101078997.

The aim of this document is to offer policymakers insights on enhancing Lithuania's research output and making research more accessible to citizens, particularly through Industry 4.0 technologies. The strategic development of sustainability-focused digitalization practices, including areas like smart buildings and digital twins of the built environment, could empower the region to develop higher-value products and services through innovation. This policy report provides a birds-eye view on digital twin technology, combines the data from a questionnaire survey carried out during citizens events of SmartWins project, and provides insights on how modern technologies can be utilized for better alignment of national action plans towards the national strategy "Lietuva 2050" and the thematic areas of national Smart Specialisation strategy.

LINKS WITH OTHER PROJECT ACTIVITIES

This deliverable D3.3. is part of Work Package 3 “Linkages with businesses, citizen engagement and policy making”. This report builds on the findings of discussions and surveys with external stakeholders – municipalities, governmental institutions, academics and business representatives. Two Citizens events were organized in Kaunas and Vilnius in 2023 and 2024, and the opinions and visions of participants of these events were integrated into the report. The information collected was cross-checked with the international strategies and reports on digital twin and technologies adoption levels. As the report aims to a broader audience, especially policy makers at municipalities and governmental levels, the introduction of the digital twin technology is provided within the report.

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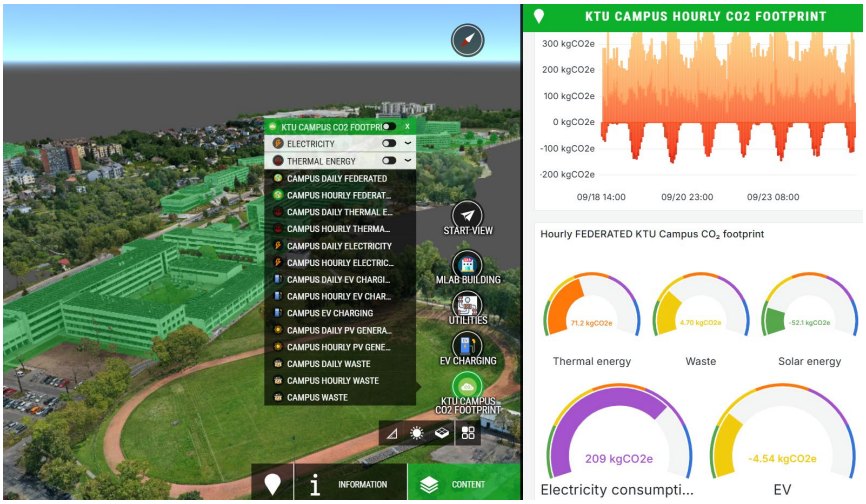

Kaunas University of Technology campus digital twin model for operational carbon footprint assessment

1. The Role of Digital Twins in Shaping National Digital Innovation Ecosystems

1.1. The Concept of Digital Twin. It's potential and enabling technology

Digital twins (DTs) are digital or cyber environments linked bidirectionally to their physical counterparts. The ISO/IEC 30173:2023[1] standard "Digital Twin - Concepts and Terminology", defines a Digital Twin as *a digital representation of a physical entity, with data connections that facilitate synchronization between physical and digital states at an appropriate rate*. Although the term is interpreted differently across industries and academic publications, they share common elements[2]: a) sensors or measuring devices that capture real-time data about the physical environment; b) a digital replica that updates based on the captured data; and c) the use of this digital replica for visualization, simulation and testing of solutions that can be applied to the physical environment or processes to facilitate data-centric decision-making. DTs mirror and evaluate a built asset's physical characteristics and behaviour in real-time. They not only provide information about individual structures but also predict broader impacts of different kinds of activities that may be implemented[3]. DTs are linked to real data sources from the environment, which means that the twin updates in real- or near real-time to reflect the current conditions of the asset or environment[4].

Digital twin technology has the capacity of delivering multifaceted benefits towards more sustainable and smart cities:

- **Increased productivity**. Through predictive maintenance and better-targeted troubleshooting, digital twins optimize production or business processes, reduce downtime, and enhance efficiency.

[1] ISO/IEC (2023). ISO/IEC 30173:2023 Digital Twin — Concepts and Terminology. Geneva: International Organization for Standardization.

[2] Borrmann, A., Schlenger, J., Bus, N., Sacks, R., 2024. AEC Digital Twin Data - Why Structure Matters, in: Skatulla, S., Beushausen, H. (Eds.), Advances in Information Technology in Civil and Building Engineering, Lecture Notes in Civil Engineering. Springer International Publishing, Cham, pp. 651–669. https://doi.org/10.1007/978-3-031-35399-4_46

[3] M. Shahzad, M.T. Shafiq, D. Douglas, M. Kassem. Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges. Buildings **2022**, *12*, 120. https://doi.org/10.3390/buildings12020120

[4] McKinsey&Company. What is digital-twin technology? **2023**, https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-digital-twin-technology#/

- **Improved decision-making and cost reduction.** Real-time observation and insights, data analytics, and alarms in case of deviations or unpredicted events lead to better resource utilization, schedule optimization, and cost reduction.
- **Increased sustainability.** By monitoring sustainability indicators, such as carbon footprint through energy usage, waste generation, etc., as well as promoting sustainable practices, digital twins can contribute to a greener economy and transitions of cities towards sustainability goals.
- **Resilience and Agility.** DTs can leverage not only the safety analysis and risk assessment, but also provide insights for a risk-informed decision-making process during accidents and emergencies[5].

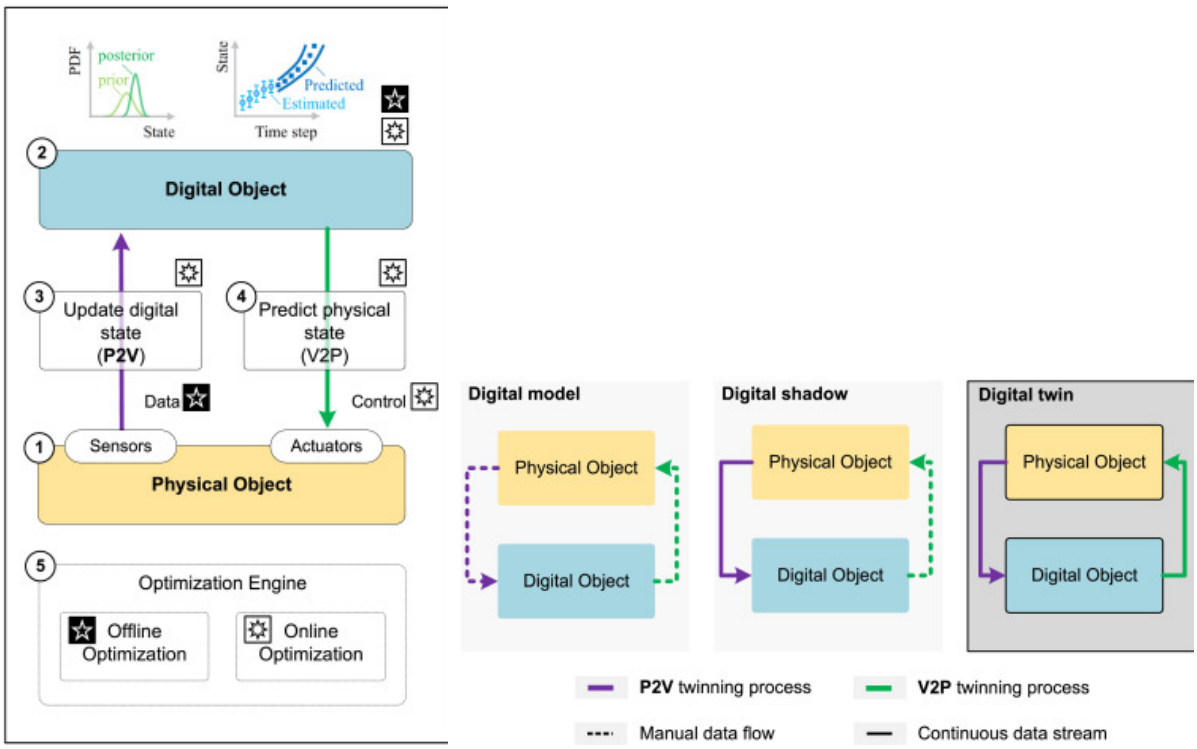

Figure 1. Five-dimensional digital twin conceptual model [3,6]

The conceptual model of five-dimensional DT (Figure 1): a physical system (PS); a digital system (DS); an updating engine (P2V); a prediction engine (V2P); and an

[5] E. Zio, L. Miqueles. Digital twins in safety analysis, risk assessment and emergency management, Reliability Engineering & System Safety, Vol. 246, 2024, 110040, 10.1016/j.ress.2024.110040.

[6] A. Thelen, X. Zhang, O. Fink, Y. Lu, S. Ghosh, B.D. Youn, et al. A comprehensive review of digital twin – part 1: modeling and twinning enabling technologies Struct. Multidisc. Optim., 65 (2022), p. 354, 10.1007/s00158-022-03425-4.

optimization engine (OPT). In this approach, the P2V engine updates the state of the DS based on the sensed data. The DS, composed of an ensemble of models, is then employed to predict the future state of the PS using the V2P engine, enabling predictive decision-making by feeding back the control actions to the PS through actuators. The OPT engine supports the functionalities of the other DT entities by optimizing data collection, state estimation, and reward functions[3].

The digital twin approach can be used to manage any built environment or assets, from buildings, manufacturing lines, infrastructure, subsurface or aboveground networks, to urban neighbourhoods and cities, **enabling smart cities ecosystems**.

It is important to note that while DT is currently being rapidly developed and has many applications at different scales, there still exists a lack of understanding and familiarization with technology and market adoption for the technology is rather low.

The key enablers for digital twin systems to be created and used are:

- **Building Information Modelling (BIM).** It facilitates the creation of geometrically accurate and semantically rich representations of built assets. The BIM methodology supports the integration of hybrid geometries, combining design or 'as-built' models with reality-captured models, and creates a common data environment for collaboration.
- **Internet of Things (IoT).** IoT sensors enable continuous monitoring and predictive maintenance by collecting real-time multisource data from physical assets such as machinery, buildings, or vehicles, and feeding this information into DT.
- **Artificial Intelligence (AI) and Machine Learning (ML).** Enables analysis of data patterns (historical or real-time data), predicts asset behaviour, and optimizes processes of data processing and forecasting.
- **Cloud Computing, Edge Computing and Big Data Analytics.** Cloud computing's scalable storage and processing power, along with edge computing's capability for processing data closer to the source, significantly reduce latency and enhance the responsiveness of the systems. The big data analytics, through data fusion and predictive analytics, enrich the digital twin's performance by combining multisource heterogenous data and identifying patterns and trends within datasets to prevent failures of the system and optimize general performance.

Digital twins are a strategic technology blend for industries and communities seeking to adapt in increasingly complex and competitive landscape. It has been adopted by

cities, regions and countries as a strategic development objective. The **EU** is promoting and actively investing in local digital twins, such as electricity grids, and more complex frameworks such as the European Digital Twin Ocean[7]. Finland is one of the leading countries in the development of city-scale urban digital twins based on reality capture technology, with 3D **Helsinki** being a fully open-access model for citizens. **Luxembourg** developed a DT to improve urban planning, resource management, mobility, and enhance cities resilience. In the **Netherlands**, a Digital Twin for the Port of Rotterdam is created to support transition to autonomous shipping within the port by 2030. Outside the EU, **Singapore** has achieved a significant milestone by creating the world's first country-scale digital twin that integrates water agency resource management, planning, and coastal protection efforts, and renewable energy transition. The **UK**'s National Digital Twin Programme formulated a base for creating an ecosystem of connected DTs for better outcomes in the built environment. It focuses on secure data sharing between beneficiaries, effective information management and supporting organizations of different sizes in their digital transformation. In general, UK was one of the leaders in built environment digitalisation. Since 2011, the overall BIM usage in the UK has seen an increase from 11% to 88% as of 2023[8], and BIM is key enabler for digital twin technology. The **USA** is developing and promoting a national digital twin for building energy efficiency and improving the sustainability of buildings. There are more examples around the globe (Ireland, India, UAE, China) where technology is tested or applied for a variety of goals and challenges that industries, cities, and communities face. Construction digitalisation strategies are implemented in **Germany** as well, where government has emphasized the importance of education and training to develop the necessary skills for engineers and architects. to be fully BIM proficient. This initiative is supported by the National BIM Competence Centre in Germany. One of the great examples of campus-scale digital twin is *Siemenstadt* DT platform[9].

[7] European Digital Twin of the Ocean (European DTO) - European Commission. Accessed: Sep. 26, 2024. [Online]. Available: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters/european-digital-twin-ocean-european-dto_en

[8] NBS for specifiers. BIM for Construction Product Manufacturers. 2024. https://manufacturers.thenbs.com/resources/downloads/bim-construction-product-manufacturers?utm_source=Paid+Search&utm_medium=Google&utm_campaign=BIM+Guide

[9] https://www.siemensstadt.siemens.com/en/development/virtual-city/digital-twin

1.2. Compliance of Digital Twin adoption with EU policies and initiatives

The Digital Decade 2030 policy programme was established by Decision (EU) 2022/2481 of the European Parliament and of the Council on 14 December 2022 to guide the digital transformation of the EU countries[10]. It focuses on secure and sustainable digital infrastructure, digital skills development, digital transformation of enterprises and digital public services[11] (Figure 2). The State of the Digital Decade report in 2023[12] assessed the EU's progress towards digital transformation and emphasized the need to accelerate and deepen efforts. The report highlighted the importance of policies and investments in digital technologies, skills and infrastructure. It also underlined the urgency of increasing the uptake of digital technologies, especially among SMEs, in order to meet the 2030 targets. These targets include 75% of EU businesses using cloud, AI or big data, and over 90% of SMEs achieving at least a basic level of digital intensity.

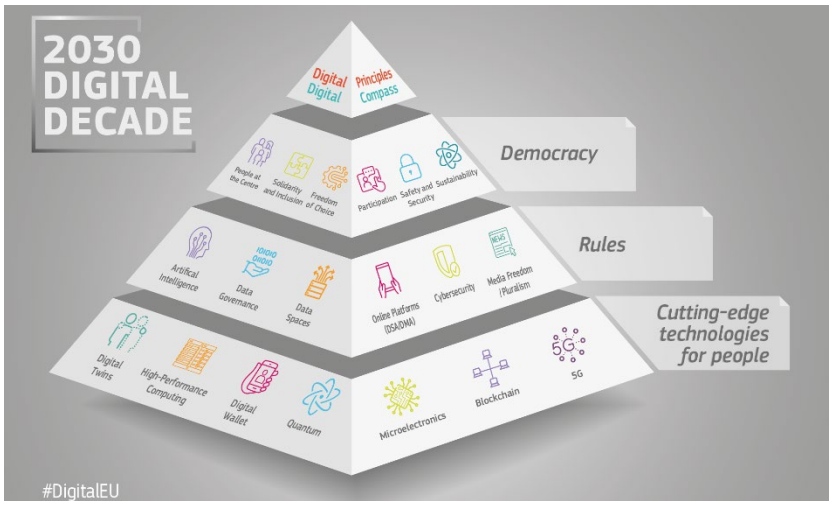

Figure 2. The Framework of Europe's Digital Decade[6]

[10] Europe's digital decade: 2030 targets | European Commission. Accessed: Sep. 25, 2024. [Online]. Available: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[11] Europe's Digital Decade | Shaping Europe's digital future. Accessed: Sep. 25, 2024. [Online]. Available: https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade

[12] Directorate-General for Communications Networks, Content and Technology (European Commission), 2030 Digital Decade: report on the state of the Digital Decade 2023. Publications Office of the European Union, 2023. Accessed: Sep. 25, 2024. [Online]. Available: https://data.europa.eu/doi/10.2759/318547

A) Digital intensity of SMEs

Historically, SMEs have played an important role in the construction industry. By definition, SMEs are companies with no more than 250 employees, a turnover of less than EUR 50 million and assets of less than EUR 43 million on their balance sheet[13]. Given their limited resources, it is essential to provide targeted support to help these businesses adopt digital technologies and remain competitive in the evolving digital landscape.

The more recent report on the State of the Digital Decade 2024[14] shows limited annual progress in the adoption of digital technologies by SMEs, with technology uptake remaining a key challenge. At the EU level, cloud adoption has increased by only 7%, falling short of the 9% annual increase needed to reach the 2030 target. There has been no significant improvement in AI adoption, and only 32% of European businesses are using data analytics. Digitalization of SMEs is progressing slowly across the EU, with an annual growth rate of just 2.5%, half of what is needed to meet the 2030 targets.

The Lithuania 2024 Digital Decade Country Report[15] shows a mixed performance in the adoption of digital technologies by SMEs, with 53.5% using AI, cloud or data analytics, compared to the EU average of 54.6%. Significant gaps remain in cloud adoption (33.6% in Lithuania vs. 38.9% in the EU) and AI adoption (4.9% in Lithuania vs. 8% in the EU). However, these data show the level of technologies adoption in general and not broken down by sector.

In 2023, Eurostat data shows[16] that only 32.2% of companies in Lithuania's construction industry use enterprise resource planning (ERP) for internal processes (Figure 3), 28.3% use cloud computing services (Figure 4) and only 2.4% use AI (Figure 5).

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[13] VIII-935 Law on the Amendment to the Law on Small and Medium-Sized Business Development. Accessed: Sep. 25, 2024. [Online]. Available: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.205051?jfwid=-wd7z6p7uy

[14] European Commission, Report on the State of the Digital Decade 2024. Luxembourg: Publications Office of the European Union, 2024. doi:10.2759/122170

[15] Lithuania 2024 Digital Decade Country Report | Shaping Europe's digital future. Accessed: Sep. 25, 2024. [Online]. Available: https://digital-strategy.ec.europa.eu/en/factpages/lithuania-2024-digital-decade-country-report

[16] Digital Decade DESI visualisation tool. Accessed: Sep. 25, 2024. [Online]. Available: https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/key-indicators/charts/maps-by-country?indicator=e_it_mext&breakdown=nace_f&period=2018&unit=pc_ent&country=AT,BE,BG,HR,CY,CZ,DK,EE,FI,FR,DE,EL,HU,IE,IT,LV,LT,LU,MT,NL,PL,PT,RO,SK,SI,ES,SE

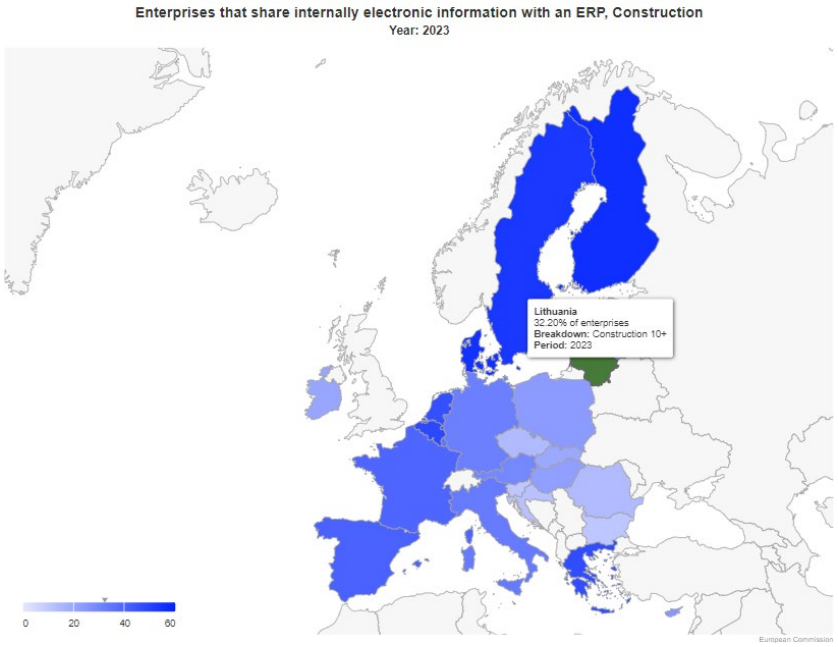

Figure 3. Enterprises that share internally electronic information with an ERP in Lithuania's construction industry in 2023

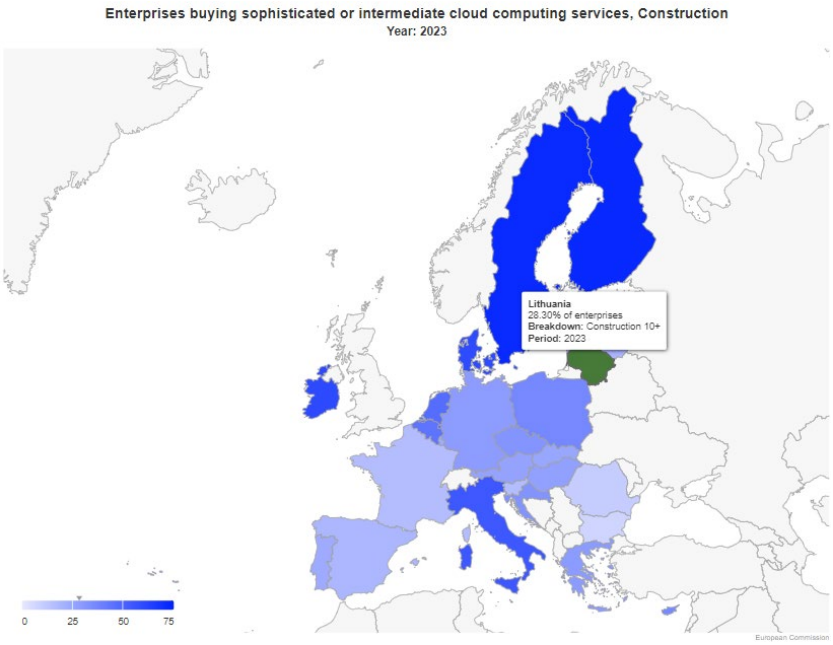

Figure 4. Enterprises using cloud computing services in Lithuania's construction industry in 2023

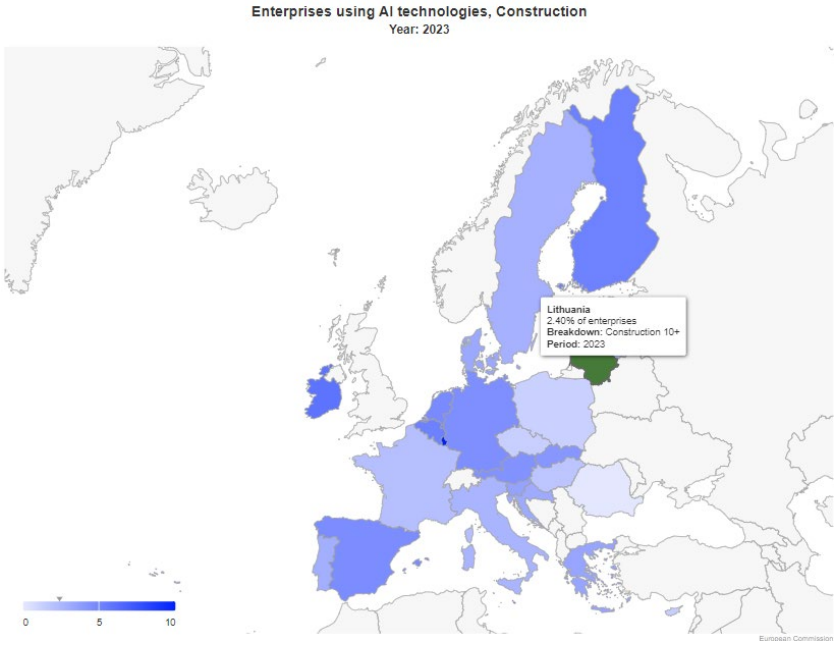

Figure 5. Enterprises using AI in Lithuania's construction industry in 2023

In accordance with Decision (EU) 2022/2481, Lithuania's National Digital Decade Roadmap[17] was established to monitor and evaluate the country's digital transformation. In 2023, the digital intensity index of Lithuanian SMEs showed significant growth but remained below the EU average, indicating that SMEs in the EU are on average digitizing faster. This suggests that without further action, Lithuanian SMEs risk being at a competitive disadvantage in terms of product development, service innovation and operational efficiency. The OECD 2021[18] study also highlighted that smaller businesses are less likely to adopt new technologies, mainly due to a lack of skills, limited financial resources and insufficient access to technology. Instead, large companies are more efficient adopters of cutting-edge technologies. For businesses that have not yet achieved a basic level of digital integration, the use of big data, cloud computing and AI remains unlikely.

[17] Government of the Republic of Lithuania, National Digital Decade Roadmap of the Republic of Lithuania. Protocol Decision No. 10.2, Mar. 13, 2024, Ministry of the Economy and Innovation.

[18] The Digital Transformation of SMEs, OECD. Accessed: Sep. 25, 2024. [Online]. Available: https://www.oecd.org/en/publications/2021/02/the-digital-transformation-of-smes_ec3163f5.html

To address these challenges, Lithuania's National Digital Decade Roadmap outlines several key actions and activities:

- Promoting the digitalization of SMEs: the development of digital skills in high-performance computing, AI and cybersecurity; supporting the automation of production processes and the adoption of digitalization technologies in industrial enterprises (industrial digitalization); and promoting the digitalization of business processes, especially in high value-added sectors.
- Support the transition to a low carbon economy: encourage the exchange of technological knowledge and solutions across industries to promote sustainable business practices.

B) Digitalisation in SMEs and environmental sustainability

The European Union has initiated an important transition towards a greener, cleaner economy through the European Green Deal (EGD)[19], addressing climate change and environmental degradation. The EGD aims to decarbonize the economy and promote more efficient use of resources. As part of this effort, the EU's industrial strategy under the EGD focuses on supporting SMEs in their transition to sustainability. Digitalization plays a key role in helping SMEs make this transition. While the digitalization of business activities offers opportunities for SMEs, it also poses significant challenges as they face both sustainability and digital transformation pressures. These two transitions, often referred to as the 'twin transition', are closely intertwined, with digital solutions acting as powerful enablers for sustainable business practices[20].

Several key factors contribute to why SMEs struggle to digitalize their activities, including a lack of necessary skills and financing challenges. In contrast, SMEs that have started to digitize often report infrastructure and cybersecurity issues as significant barriers. The digitalization process for SMEs can follow two main strategies: relying on internal capacity and skills, or using external solutions. Typically, SMEs with minimal digitalization start their transition with external solutions. As their

[19] The European Green Deal - European Commission. Accessed: Sep. 25, 2024. [Online]. Available: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[20] CARSA et al., Annual report on European SMEs 2021/2022: SMEs and environmental sustainability. Publications Office of the European Union, 2022. Accessed: Sep. 25, 2024. [Online]. Available: https://data.europa.eu/doi/10.2826/451263

digitalization progresses and their experience increases, they tend to rely more on in-house capabilities, often using a mix of external and internal resources.

The challenges of SMEs digitalization can be mitigated through policy support, such as technical advisory services, knowledge platforms, public financial support and the development of the necessary information and communication technology (ICT) infrastructure. In addition, two critical considerations for the adoption of digital solutions are:

- Availability of off-the-shelf solutions: readily available digital solutions must meet the specific needs of SMEs. Due to their smaller size, many SMEs are not in a position to develop customized digital solutions.
- Integration with business processes: digital solutions need to be aligned with SMEs' existing business processes and models. Policy support should therefore also focus on ensuring the availability of relevant digital solutions and their compatibility with SMEs' business processes.

Finally, the creation of a supportive regulatory and legal framework by local authorities and standardization bodies is important to facilitate the digital and environmental sustainability transformation of SMEs.

C) Networked Local Digital Twins

The Local Digital Twins - CitiVERSE EDIC was established by the Implementing Decision (EU) 2024/459 of 1 February 2024[21]. The objective of this initiative is to establish the European Digital Infrastructure Consortium (EDIC) for Networked Local Digital Twins. The LDT CitiVERSE EDIC is in line with the European Commission's priorities on digital and green transitions and the New European Bauhaus initiative. It contributes to the development of a common data infrastructure and services, with a particular focus on the transversal Data Space for Smart Communities. The consortium ensures an open digital infrastructure environment, promotes an industrial ecosystem for digital twins and creates a market to support EU SMEs and industries. As a new instrument, the EDIC will facilitate the development of large-scale, multi-country projects under the Digital Decade programme. The founding members of the EDIC are Belgium, Croatia, the Czech Republic, Estonia, France, Latvia, Luxembourg,

[21] Implementing decision - 2024/459 - EN - EUR-Lex. Accessed: Sep. 25, 2024. [Online]. Available: https://eur-lex.europa.eu/eli/dec_impl/2024/459/oj

Portugal, Slovakia, Slovenia and Spain, with the possibility for other Member States to join over time.

The LDT CitiVERSE EDIC is particularly relevant for local and regional authorities as it leverages digital infrastructure developed across the EU, promoting technical interoperability of data and services and the establishment of common standards. This approach aims to address digital fragmentation within the EU by enabling local digital twin components developed in one Member State to be purchased and used across the single market. This will create opportunities for digital SMEs to operate across national borders and allow cities and regions to choose the best solutions.

The strategic priorities for the LDT CitiVERSE EDIC focus on several key areas:

- Technical developments: the design, development, deployment and scaling of EU infrastructures for digital twins; the implementation of a common EU architecture blueprint for the Smart Communities data space; the development of AI-based solutions for Smart Communities; the establishment of sustainable mechanisms for EU infrastructures; and the creation and maintenance of an open-source community.
- Collaboration: identifying opportunities for digital transformation between Member States; implementing an EU-based data strategy and common governance; defining funding schemes and designing common procurement strategies.
- Communication and dissemination: supporting cities in adopting and implementing digital twins, facilitating knowledge transfer and sharing expertise on scalable solutions across Europe, including standardization efforts.

According to the LDT CitiVERSE EDIC goals, Living-in.EU is an initiative that unites cities, regions and Member States to promote a "European way of digital transformation", supported by the European Commission and the European Committee of The Regions (COR)[22]. One of the key priorities of the initiative is to promote the twin green and digital transformation at the local level. The Local Digital

[22] Declaration on joining forces to boost sustainable digital transformation in cities and communities in the EU | Living in EU. Accessed: Sep. 25, 2024. [Online]. Available: https://living-in.eu/declaration

Twins and CitiVerse are one of the key tools of the initiative to support using virtual representations of city assets, data analytics and machine learning.

The Lithuanian Green Municipalities Network is already contributing to this initiative[23] as a member of the Smart Communities Network[24]. The Smart Communities Network specifically targets cities and local communities that are in the early stages of their digital transformation, with a focus on improving connectivity and operational efficiency in city management. Activities within the network are expected to continue until September 2025. At the end of this period, the network will be integrated into the EDIC on Connected Local Digital Twins towards CitiVERSE.

The EU's Digital Decade 2030 policy program emphasizes the need for increased adoption of digital technologies, particularly among SMEs, to meet ambitious targets, with Lithuania showing progress but still lagging behind EU averages in areas like cloud and AI adoption. To address these challenges and align with broader EU initiatives like the European Green Deal, Lithuania's National Digital Decade Roadmap focuses on promoting SME digitalization, fostering sustainable practices, and leveraging new digital infrastructures like the Local Digital Twins (LDT) initiative to enhance data integration, collaboration, and technological innovation across sectors.

[23] Increasing Digitalisation Awareness and Readiness of Lithuanian Communities | Living in EU. Accessed: Sep. 25, 2024. [Online]. Available: https://living-in.eu/events/increasing-digitalisation-awareness-and-readiness-lithuanian-communities

[24] L. Garrido, 'Smart Communities Network | Living in EU. Accessed: Sep. 25, 2024. [Online]. Available: https://living-in.eu/eu-support-services/smart-communities-network

1.3. Enabling Lithuania's National Strategy through Digital Twin Technology

The national progress strategy “Lithuania 2050” outlines a comprehensive national vision and strategic framework aimed at transformative developments to be implemented in the country by the year 2050. It follows the previous strategy “Lithuania 2030”, which remains relevant as of this publication, and emphasizes the importance of fostering a smart society, smart economy, and smart governance as pivotal areas for the nation's development.

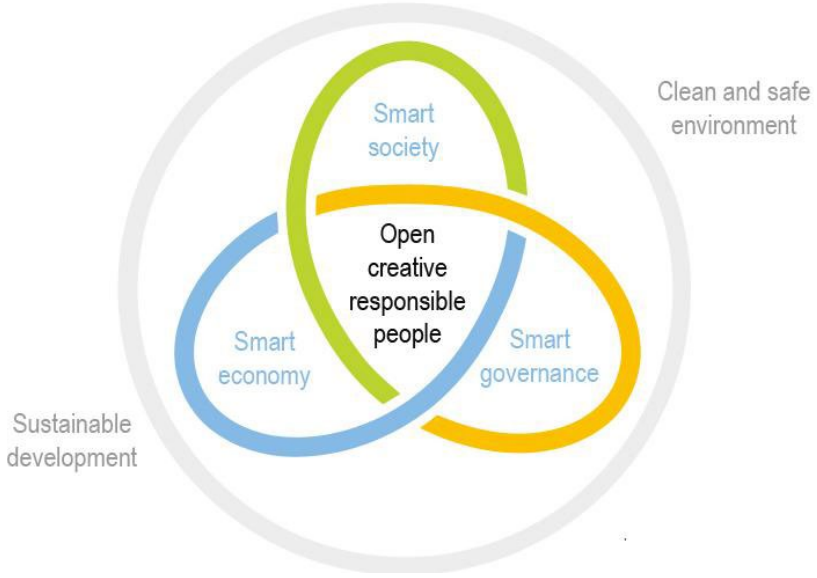

Figure 6. The main priorities outlined in the “Lithuania 2030” strategy[25]

There's a direct connection between Lithuania's national strategy and digital transformation, focusing on the shift towards services with higher added value and the transformation of the industry.

[25] Lithuania’s Progress Strategy “Lithuania 2030”.

***Smart society**: society that is open to the ideas of each citizen, to innovations and challenges, demonstrating solidarity, self-governance and political maturity.*	Education, lifelong learning, and civic empowerment are crucial for national progress. Digital twin ecosystems enable transparency, citizens engagement, mutual learning environments for businesses and academia. DTs can boost civic engagement through simulations of urban and social systems.
***Smart economy**: economy that is flexible and able to compete globally, generating high added value, based on knowledge, innovations entrepreneurship and social responsibility as well as "green" growth.*	DT ecosystems offer advanced tools for businesses to innovate, improve product design and manufacturing processes, optimize supply chains, and reduce environmental impacts. Additionally, digital transformation efforts can help integrate Lithuania's economy into global value chains by enhancing the country's technological readiness and innovation capacity, thus attracting foreign investment. DT ecosystems are empowered by various components and tools, that could become export products and services.
***Smart governance:** governance that is open and participatory, delivering, meeting public demands and ensuring high quality services, as well as competent government, able to take targeted strategic decisions.*	Many cities that have agreed upon digitalization and digital twin strategies see DT ecosystems as major facilitators of smart governance by improving decision-making through real-time data and analytics, enhancing public service delivery through digital platforms, making data available under "fair, reasonable, and non-discriminatory" (FRAND) terms, support governmental data reusability and openness, and enabling greater public participation in governance processes through interactive and accessible digital tools. Urban digital twins enable citizens inclusion, transparency and high value services.

The follow-up national strategy for Lithuania was published in 2023, entitled "Roadmap for the State Progress Strategy 'Lithuania 2050.'" This document highlights priorities similar to those of the 2030 strategy and outlines several important areas where digital twin technology could be leveraged.

- **Promotion of innovation and higher added value creation.** The strategy emphasizes the critical role of innovation in driving economic growth and competitiveness by supporting new technologies and fostering an innovative ecosystem. The plan seeks to transition the economy towards higher added value by supporting high-value industries and encouraging investments in sectors with significant economic returns.
- **Focus on digitalization.** It aims to digitize public services, enhance the business environment through digital tools, and develop digital skills among the population for widespread technology adoption.
- **Development of a smart society.** The goal is to build a smart society where technology integrates into daily life, encouraging lifelong learning and adaptable, smart education systems.
- **Advancement of a smart economy.** The strategy promotes a smart economy characterized by high productivity, efficiency, and sustainability through the adoption of advanced technologies and the growth of knowledge-intensive sectors.
- **Establishment of smart governance.** It advocates for smart governance practices leveraging technology for improved decision-making, transparency, and responsive public administration.
- **Fostering technological adoption and development.** The strategy highlights the adoption of cutting-edge technologies, such as AI, clouds and quantum computing, to maintain global competitiveness and enhance technological integration across sectors.
- **Encouraging a Sustainable and Resilient Economy.** It focuses on creating a sustainable economy that balances growth with environmental protection through green technologies and practices, ensuring resilience against economic and environmental challenges.
- **Support for Knowledge and Creativity.** The strategy supports a knowledge-based economy driven by creativity and intellectual capital, integrating scientific research with cultural and creative industries for unique value creation.

The priorities listed above require novel approaches and tools aimed at supporting the transformation of industries and society. If meaningfully implemented and supported by policymakers and standardization bodies, the digital twin concept can significantly strengthen Lithuania's prospects of achieving its 2050 goals.

One of the best examples of integrating DTs in the national agenda, is the National Digital Twin Programme in the UK[26]. The program highlights the following benefits:

A) Benefits to Society

The greater level of transparency allows more members of society to be involved and have their say during the progression of specific projects, ultimately resulting in better communication and outcomes for everyone involved. Improving public service delivery in health, safety, security and overall societal well-being by ensuring cross-sector access to information. This in turn leads to citizen trust, ultimately building a better quality of life for society through higher-performing infrastructure and the services it provides.

B) Benefits to Economy

Digital twins are aimed to enhance decision-making by improving data quality, management and sharing in a secure environment. This high-quality data can be leveraged to better measure project outcomes and improve future project performance. By doing so, national productivity increases from higher-performing and resilient infrastructure operating as a single system. The enhancement of information security also builds more resilience in cybersecurity, meaning both citizens and businesses can operate in a sustainable and secure environment. As a result, the overall economic impact of the adoption of the technology will be positive, ensuring that the UK is able to meet its various economic objectives.

C) Benefits to Risk management

Secure data built using digital twins will also reduce uncertainty and nurture better risk management. Businesses can monitor their operations using a single source of truth. This will result in higher-performing infrastructure, optimized delivery efficiency, and improved immediate and longer-term planning, which benefit the whole construction chain, including investors, owners, consultants and suppliers.

[26] https://blog.govnet.co.uk/technology/what-is-the-national-digital-twin-programme

D) Benefits to Environment

Digital twins enable the UK to deliver on Net-Zero 2050 objectives by reducing social inequalities and reducing waste disruption. Greater resource efficiency and the ability to reuse technology for different projects are critical enablers in making this happen. In addition, the digital twin supports improved management and preservation of both the natural and built environment to promote sustainability and resilience. As a complex system that integrates many aspects, it provides insights into biodiversity, climate change and natural resource use, enabling evidence-based environmental management[27]. The National Digital Twin Programme allows members to share best practices and initiatives they've inherited to make a difference to the environment. This ensures society and businesses are aware of what can be done to optimize the environmental impact of their activities by using digital twins.

The active development of the technology and the numerous initiatives that have been launched across countries for its adoption suggest that Lithuania could significantly benefit from the experience of the UK, Singapore, Finland, and other countries, by including the digital twin ecosystems in the national agenda.

[27] National Digital Twin Programme (NDTP) principles. GOV.UK. Accessed: Sep. 26, 2024. [Online]. Available: https://www.gov.uk/government/publications/what-a-digital-twin-is-and-how-you-can-contribute/national-digital-twin-programme-ndtp-principles

2. Findings from the citizens events

Two citizens events, organized in Kaunas and Vilnius in 2023 and 2024 respectively drew a diverse audience interested in the digital transformation of the built environment, ranging from students and academics to professionals across the construction sector and policymakers from various government departments. Highlights included presentations on digital twins' potential in scenarios such as energy management, cultural heritage preservation, and sustainable building practices, featuring technology overviews like BIM, GIS, and AI. Practical applications developed by Kaunas University of Technology, showcased digital twins in action, from simulating environmental impacts to preserving historical sites. Workshops focused on leveraging digital twin technology for energy efficiency, renovation, and the sustainable preservation of cultural heritage.

Figure 3. Two citizens events were organized in Kaunas and Vilnius under the scope of SmartWins project

During the citizen events, a questionnaire survey was conducted to assess the market's readiness in Lithuania to adopt digital twin technologies, understand the

potential benefits of digital twin ecosystems, and identify the existing barriers to integrating digital twins. The Citizens' event sessions were attended by key figures from the built environment sector, including Dalius Gedvilas, President of the Lithuanian Builders Association; members of the State Territorial Planning and Construction Inspectorate under the Ministry of Environment of the Republic of Lithuania; Ausra Balsyte, Advisor at the Ministry of Environment of the Republic of Lithuania; and others. Participants from Lithuania's largest technological universities (KTU and VilniusTech) also attended, alongside industry representatives offering solutions for the digitalization of the built environment, as well as those involved in construction, facilities management, and development.

Findings of the workshops and surveys are provided in the following sections.

2.1. Lithuanian market readiness for digital twin adoption

Key enabling technologies for Digital Twins include BIM (Building Information Modelling/Management), GIS (Geo-Information Systems), IoT (Internet of Things), and Data Analytics and Predictive Tools. Multiple sources confirm these technologies are crucial to the development and operation of Digital Twins in the built environment sector. In the following table, trends and responses gathered during citizens' events were analysed, and each technology was evaluated based on its adoption level – categorized as high, average, low, or in-between.

HIGH AVERAGE LOW

None of the technologies were assessed as having a low adoption level, as all are being utilized to some degree within the industry. High adoption was defined by both widespread industry use and strong support from governmental bodies, making the technology an integral part of national strategies.

BIM Adoption **HIGH** *BIM provides the foundational data structure for the creation and management of a Digital Twin by offering detailed 3D models and object-based representations.*	Lithuania has a clear BIM adoption strategy, National Classificatory, as well as accompanying systems in place. The government mandated the use of BIM in public procurement with an estimated cost of buildings, incl. renovation projects starting from 5 million EUR, and engineering structures from 10 million EUR[28]. Although BIM applications are quite widely used in Lithuanian market, only half of the participants indicated that BIM is used in their organisation or sector. The audience was not confident in BIM tools development. The BIM-LT project, running from 2019 to 2023, aimed to digitalize Lithuania's construction sector by developing BIM standards, a national construction information classification system, and guidelines for public procurement. It also included training programs to educate stakeholders on BIM practices[29]. Lithuania has made significant progress in adopting BIM over the past few years. However, the market still needs to catch up and enhance skills to meet the required standards. With BIM now mandated by the government and applied in larger projects, Digital Twins could represent the next evolutionary step towards sustainable asset management in the built environment sector.

[28] Government of the Republic of Lithuania. *Resolution on the Requirements and/or Criteria for the Application of Static Information Modeling Methods*; Government of the Republic of Lithuania.

[29] https://statyba40.lt/titulinis/bim-lt-projektas/

GIS Adoption **HIGH** *GIS integrates geographical and environmental data into urban Digital Twins, enabling city-scale models that enhance urban planning, infrastructure development, and large-scale construction projects.*	Europe's construction sector is increasingly recognizing the role of GIS for integrating spatial data in planning and construction. However, there is still room for greater integration and standardization. The Lithuanian government's broader "Construction 4.0" strategy, which covers digitalization in the construction sector, supports the integration of various technologies, including GIS, in tandem with BIM and IoT[30]. Half of the participants of the citizens events were familiar and were using GIS solutions. Recent developments in GIS adoption in Lithuania are represented by growing integration across multiple sectors, driven by national initiatives and increasing awareness of its potential. The public institution National Centre for Remote Sensing and Geoinformatics (GIS-Centras) has played a central role in managing the country's national geographic databases and the geoportal.lt, the primary platform for accessing spatial data[31]. Lithuania has made significant strides in GIS applications, particularly in infrastructure monitoring, urban planning, and environmental management. Major national projects like the *Rail Baltica* construction, leverage GIS for overseeing complex construction activities. GIS usage varies from drone-based agricultural monitoring to urban service management. While GIS in Lithuania does not yet have as detailed normative framework as BIM, its adoption across various sectors is extensive, demonstrating strong market readiness for digital twin development.

[30] Ministry of Environment of the Republic of Lithuania – Construction 4.0 Website - https://statyba40.lt/.

[31] National Centre for Remote Sensing and Geoinformatics "GIS-Centras" - https://www.gis-centras.lt/.

IoT Adoption **AVERAGE** *to* **HIGH** *Internet of Things enables real-time data collection and monitoring of physical assets through connected sensors.*	The relevance of IoT in Europe, especially in the context of the Smart Readiness Indicator (SRI) [32], is well established as it plays a crucial role in assessing and enhancing the smart capabilities of buildings. The SRI, introduced under the 2018 Energy Performance of Buildings Directive (EPBD), and launched in 2020, focuses on how buildings can adapt and optimize their energy performance using smart technologies, including IoT systems. IoT facilitates the monitoring and control of various building systems (e.g., heating, lighting, and ventilation), which is a core element of the SRI evaluation process[33]. The survey carried out during the citizens events revealed that half of the participants are using Internet of Things (IoT) technologies quite widely, and IoT solutions are widespread across different sectors. With regard to the development of the IoT, the results of the questionnaire indicate that while some professionals are involved in the development of IoT solutions, there is a significant group that either does not participate in such activities or considers them irrelevant and unnecessary for their work. Overall it shows that IoT usage is yet quite specific to the use case and field, and the value of this technology still has to be further explored and communicated. As of now, the Smart Readiness Indicator (SRI) initiative has not been formally adopted or integrated into national standards in Lithuania

[32] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator_en

[33] Evaluation of the Smart Readiness Indicator for Educational Buildings. G.Plienaitis et al., 2023, https://www.mdpi.com/2075-5309/13/4/888.

Data Analytics & Predictive Tools **AVERAGE** *These tools process the data collected via IoT and other sources to generate actionable insights on future conditions, maintenance needs, or failures.*	According to the Gemini Principles from the Centre for Digital Built Britain (CDBB), one of the core aspects of digital twins is their ability to provide predictive insights through the continuous integration of data. Predictive analytics is positioned at the top of the hierarchy of Digital Twin technology, because it transforms real-time and historical data into actionable insights, enabling making decisions about future states and potential issues across the lifecycle of an asset[34,12]. Data analytics is a growing trend in the digital transformation of the construction sector, with increasing emphasis on predictive analytics for building performance. However, consistent adoption across Europe is still uneven, with the need for more training and standardization. Many participants of citizens events acknowledged the use of data analytics tools, though some remain neutral or do not apply these technologies in their professional practice. Lithuanian research institution is making significant progress in incorporating AI within digital twins, particularly through academic and international collaborations, aligning with broader European trends in digital transformation, however, the market adoption can be described as average.

2.2. Potential benefits of digital twin ecosystems in Lithuania

The development of digital twin ecosystems in Lithuania presents significant potential for driving national growth through higher value products and services and support the country's transition towards a carbon-neutral economy, aligning with European sustainability goals. DT technology can act as a catalyst for attracting high-tech industries and elevating the country's position in the global market. One of the key priorities of SmartWins project is to highlight these capabilities to the decision makers. This was also a focus point for discussions during the citizens' events organized in Kaunas and Vilnius in 2023 and 2024.

[34] The Gemini Principles (Centre for Digital Built Britain), 2018.

Participants of citizens' events recognized Digital Twins as transformative tools with the potential to enhance urban planning, construction, and infrastructure management in Lithuania. These technologies offer numerous benefits across sectors by improving real-time data management and decision-making capabilities. Key points indicated:

1. **Enhanced Efficiency.**
   Digital Twins can significantly improve spatial planning, property management, environmental protection, and heritage preservation through real-time data insights. The technology already facilitates dialogue with the public on upcoming projects, enabling the visualization of architectural competitions and city development plans. It allows city residents to be actively involved in decision-making processes and integrates elements of citizen science to enhance community participation.
2. **Operational Optimization**.
   Digital Twins applications span from the design and operational phases of buildings and infrastructure assets to real estate development and utility management. The technology supports more efficient renovation and maintenance of infrastructure, further promoting sustainable urban management.

The participants of the events were very positive about the use of Digital Twins in the private sector, particularly for office buildings and residential neighbourhoods. However, concerns were raised regarding their suitability for critical infrastructure, due to potential security risks involved.

The implementation of Digital Twins in Lithuania's built environment has the potential to bring substantial value in several key innovation areas, aligning with the country's national strategies and broader EU objectives for digitalization, sustainability, and economic growth. Within the priorities for Lithuania's Smart Specialization Strategy 2021-2027, majority of areas for R&D&I (Research, Development and Innovation) activities should be focused on the following priorities and thematic fields[35]:

[35] Smart specialization 2021-2027, approved on August 2022 – Ministry of The Economy and Innovation of the Republic of Lithuania. Smart specialization - Ministry of the Economy and Innovation of the Republic of Lithuania (lrv.lt).

R&D&I priority	R&D&I thematic field	Relation to Digital Twins
Health technologies, biotechnologies and safe food	1. Molecular technologies for medicine and biopharmaceuticals	LOW
	2. Advanced applied technologies for personal and public health	HIGH Telemedicine, patient monitoring
	3. Advanced medical engineering for early diagnosis and treatment	AVERAGE Diagnosis simulation, optimization
	4. Safe food and sustainable agro-biological resources	AVERAGE Real-time monitoring, agriculture optimisation
New production processes, materials and energy efficiency	1. Photonic and laser technologies	LOW
	2. Advanced materials and construction	HIGH Structural integrity analysis, failure predictions
	3. Flexible product development, production and process management technologies	HIGH Production efficiency and optimisation
	4. Strengthening energy efficiency and smart energy solutions	HIGH Energy grid optimisation and predictive maintenance
	5. Use of renewable energy sources	HIGH Predictive modelling, performance optimisation
ICT technologies, inclusive and creative society	1. Artificial intelligence, big and distributed data, multidisciplinary analysis, processing and implementation	HIGH AI-driven analytics and decision making
	2. The Internet of Things	HIGH Sensors, connected systems
	3. Cyber security	LOW
	4. Financial technologies and block chains	LOW
	5. Audiovisual media, design technologies and social innovation	AVERAGE VR design, user interaction simulations
	6. Smart transport systems	HIGH Traffic management, infrastructure planning

The table above reflects consolidated data from SmarWins citizen event discussions and incorporates insights from the project's researchers. It is evident that Digital Twin technology holds significant potential for a wide range of applications and aligns closely with the thematic areas of Lithuania's Smart Specialisation strategy.

2.3. Barriers to integrating digital twins in Lithuania

Despite the promising potential of Digital Twin (DT) technologies in various sectors, several barriers have been identified that may hinder their integration within Lithuanian ecosystems. These obstacles, as outlined by stakeholders in various discussions, range from technical and financial challenges to societal and regulatory concerns. Addressing these barriers is crucial to ensuring the successful implementation and scalability of Digital Twin technologies in Lithuania.

1. **Data Privacy and Security Concerns**
   One of the most significant barriers raised by participants is the issue of data privacy and security. Digital Twins, which rely heavily on real-time data collection and processing, often involve sensitive data. Concerns about the security of this data, particularly in publicly accessible systems, are frequently highlighted. Participants expressed apprehension about the potential risks associated with making digital twin data available to the public. Without robust data protection mechanisms, the widespread adoption of Digital Twin technologies could be hindered due to the fear of exposing sensitive information.

2. **Lack of Standardization and Data Governance**
   Another key obstacle is the lack of standardization and structured data governance at the national level. Digital Twins require the integration of diverse data sources, yet in Lithuania, various stakeholders, such as public institutions and private entities, utilize different systems and formats. This fragmentation complicates the development of cohesive Digital Twin solutions. The absence of unified standards and protocols makes it difficult to manage and harmonize large data sets across sectors.

3. **High Implementation Costs**
   The high costs associated with developing and deploying Digital Twin technologies present a significant financial barrier. The initial investment in software, hardware, and data infrastructure can be prohibitively expensive for many organizations, particularly small- and medium-sized enterprises (SMEs). Additionally, ongoing maintenance, data management, and updates further

increase the financial burden. Participants suggested that this could deter organizations from adopting DT technologies, especially in sectors where the immediate return on investment may not be apparent.

4. **Limited Expertise and Education**
   A major challenge in Lithuania is the limited availability of qualified professionals with expertise in developing and managing Digital Twin technologies. The lack of education and specialized training, particularly at the postgraduate level, exacerbates this issue. This shortage of skilled personnel slows the development and deployment of DT systems, as organizations struggle to find experts who can effectively design, implement, and manage these complex systems. Without a concerted effort to enhance educational programs and professional development in this field, the capacity for growth in Digital Twin applications remains constrained.

5. **Resistance to Change**
   Resistance to change is another barrier impeding the adoption of Digital Twin technologies in Lithuania. Many sectors, particularly those with long-established processes and legacy systems, may be reluctant to adopt new technologies like Digital Twins. This resistance can stem from a lack of understanding of the benefits or from concerns about the disruptive nature of such innovations. Participants in the discussions suggested that sectors like construction, manufacturing, and public administration, where traditional methods are deeply entrenched, may face significant internal resistance to integrating Digital Twin solutions.

6. **Lack of Interoperability within Software Solutions**
   The complexity of Digital Twin tools would benefit from readily available, interoperable software solutions. While there are existing tools and platforms, they are often either designed for broader applications, making them less user-friendly, or they are case-specific and lack interoperability and data exchange functionalities. Current technological inconsistencies prevent organizations from fully leveraging Digital Twins effectively; however, they also present opportunities for innovation.

7. **Over-Ambitious Goals and System Complexity**

Some participants highlighted the issue of over-ambitious goals in the development of Digital Twin technologies. Attempting to implement highly complex systems without adequate planning, resources, or expertise can lead to project failures or underperformance. This is particularly true in large-scale initiatives, such as urban planning or national infrastructure projects, where the scale of data and integration challenges may be underestimated. Simplifying goals and creating phased approaches to implementation could help mitigate these risks.

Despite these barriers, there are significant opportunities to raise public awareness and demonstrate the value of Digital Twin technologies. Participants noted that showcasing real-life applications of Digital Twins in urban planning, infrastructure management, and energy efficiency projects could help overcome resistance and increase public understanding. For example, Digital Twins could be used in renovation projects to show energy consumption data before and after renovations, encouraging citizens to participate in energy-saving initiatives. Demonstrating tangible benefits, such as cost savings and improved efficiency, can help build trust and drive adoption.

3. Summary and recommendations

While the integration of Digital Twin technology in Lithuania offers considerable benefits, particularly in areas like energy efficiency, urban planning, and healthcare, several barriers must be addressed. Overcoming challenges related to data privacy, standardization, costs, expertise, and resistance to change will require coordinated efforts across sectors. Strategies such as developing targeted education initiatives, engaging citizens and professionals, and advocating for supportive policies will be essential to ensuring that Digital Twins can achieve their full potential in enhancing Lithuania's technological and economic landscape.

Recommendations for policy makers:

1. **Continue supporting digitalisation in the built environment and further improve the digital ecosystem (BIM, GIS integration)**
   Building on Lithuania's existing BIM and GIS advancements, policymakers should continue to promote their use, integrating them into broader digital twin ecosystems to enhance urban planning, infrastructure management, and smart city initiatives. Providing incentives for public-private partnerships and expanding digital skills training will help increase adoption and further develop this ecosystem.

2. **Ensure the security and privacy of digital twins, especially for sensitive data**
   Digital twins should operate in secure, closed systems when dealing with critical infrastructure or sensitive data. Simultaneously, non-sensitive data twins should be used to engage citizens in urban planning and decision-making, increasing transparency while safeguarding national security. Respective institutions, such as State Security Department, Lithuanian Armed Forces, should be aware of digital twins developed within the Republic of Lithuania.

3. **Promote the creation of an ecosystem and legislation to accelerate the utilization of open data**
   To fully realize the potential of open data, a robust ecosystem supported by comprehensive legislation is needed to promote transparency, accessibility, ethical use, and secure data sharing across sectors, fostering collaboration and innovation through standardized formats and interoperability in areas like urban planning, public services, and smart cities.

4. **Promote public and private sector collaboration to overcome high costs of digital twin technology**
   To address the financial barriers to digital twin adoption, Lithuania should encourage public-private collaborations and provide funding mechanisms, especially for SMEs. This should lower the entry costs and foster innovation in critical sectors such as energy, healthcare, and infrastructure.

5. **Develop standardized frameworks for data governance to ensure cohesive integration across sectors**
   A national standardization strategy for data governance is essential to streamline digital twin adoption. Establishing unified data formats, protocols, and governance structures will enable smoother collaboration between public institutions and private enterprises, maximizing the potential of digital twin technology. Lithuania could follow good practice examples, e.g. the experience of UK Centre for Digital Built Britain (CDBB), through the establishment of centre of taskforce for such a task. Promote cooperation between public authorities to ensure the integrity and usability of built environment data for the development of public information systems.

6. **Invest in the semantic enrichment of historical building data**
   To maximize the value of historical building data, investing in the semantic enrichment of datasets like GIS, land registries, and cadastres using AI and machine learning can enhance machine-readability, improve data integration, and facilitate more efficient use in heritage conservation, urban planning, and real estate development, while ensuring relevance in a digital ecosystem.

7. **Invest in education and upskilling initiatives to build local expertise in digital twin technologies**
   There is still a skill gap between those companies and individuals who has adopted digital workflows in construction, architecture and urban planning, and those who still function under more traditional methodologies. Digital twin technologies enable elevating the digital ecosystems to the next level, therefore, skills gap needs to be reduced. BIM, GIS, digital twin, IoT, and AI-related courses should be promoted and ensured in higher education and vocational training. Expanding postgraduate programs and professional development will ensure a skilled workforce capable of driving future digital innovations.

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