CITIZENS' EVENTS REPORT

September 2024

Funded by
the European Union

DOCUMENT TRACKING DETAILS

Project acronym	SmartWins
Project title	Boosting Research for a Smart and Carbon Neutral Built Environment with Digital Twins
Starting date	01/10/2022
Duration	36 months
Call identifier	Twinning (HORIZON-WIDERA-2021-ACCESS-03)
Grant agreement number	101078997

Deliverable information	
Deliverable number	D3.2
Work package number	WP3
Deliverable title	Citizens events report
Lead beneficiary	KTU
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Due date	30/09/2024
Actual submission date	27/09/2024
Type of deliverable	R – document, report
Dissemination level	PU - Public

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VERSION MANAGEMENT

Revision table

Version	Name	Date	Description
1	Darius Pupeikis (KTU)	27/09/2024	The first version

LIST OF ACRONYMS AND ABBREVIATIONS

BIM	Building Information Modelling
BIM model	Building Information Model
DT	Digital Twin
IoT	Internet of Things
KTU	Kaunas University of Technology
CSCI	Centre for Smart Cities and Infrastructure at KTU

EXECUTIVE 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 report on the 1st and 2nd citizen's events organized in the scope of this project, described under T3.3 as a part of Work Package 3. The objective of these events was to bridge the gap between the research activities and citizen's needs, while encouraging their engagement in innovation.

LINKS WITH OTHER PROJECT ACTIVITIES

This deliverable is part of the Work Package 3 on linkages with businesses, citizens engagement and policy making, whose objective is to:

● Create linkages with citizens and provide access to the methodology to support open innovation.

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1. Motivation for citizens' events in scope of SmartWins project

People spend more than 90% of their time for one or another purpose in buildings (residential, non-residential). Moreover, when adding travelling to work, school or other places, people are in or in contact with a variety of buildings for almost all of their time. For example, roads, railways, subways, etc. The energy that people need so much (electricity, heat, cooling, water, sewage disposal, waste, etc.) is also supplied by specific type of buildings, i.e. utilities. All of the above points lead to the conclusion that the built environment is of significant importance to people's lives [1].

Humanity is urbanising. In the next 25 years, it is predicted that more than 70% of the population will already live in cities. The demands on cities are increasing and they face particular challenges (climate anomalies, growing populations, the need for clean energy, etc.). Therefore, cities, which are physically made up of the built environment, need to change, transfer the built environment into a smarter, more efficient that offers a new quality of life and responds to contemporary and future needs.

Public understanding of the built environment is usually quite limited due to the rather technical terms used, which are more understandable to professionals in the fields of AEC (architecture, engineering and construction). The application of technologies for the development of digital twins of buildings makes the built environment in which they live, work or have relevant interests more comprehensible to the general public (non-experts).

The life cycle of a building takes many years, so well-prepared digital building data retains its long-term value and provides a solid information basis for efficient use, maintenance and investment planning. On this basis, it is appropriate to mention the key areas of application of digital twins in the public interest:

Energy efficiency. This is often a high priority for building users (citizens) as it is a major part of the cost of maintaining a building. Monitoring changes in electricity consumption, thermal energy, water and waste water disposal or other forms of energy through digital twins, "triggers" the awareness effect for users. It makes people think about where and how much energy is being consumed for a given building, floor or even room. All this data has the potential to be an input for assessing the sustainability or cost of a building or part of a building at later stages [2,3].

Facility management and asset management. This is the area responsible for the efficient use, maintenance and repair of the building elements and the assets within it.

In this case, it is appropriate to integrate digital twins with the geometric and visual representation of the building, which is commonly expressed using technologies such as building information modelling (BIM), photogrammetry and 360 panoramic photo tours. It is common to have a 3D model of the building, but if the building is old and good quality data is not available, CAD-based plans, registry data and geo-information data may be used.

Indoor climate . A field that interacts quite closely with energy, but climate includes not only the required indoor temperature, but also other environmental parameters such as relative humidity, level of air CO_2, volatile organic compounds, luminance, noise, etc. A good indoor climate normally requires energy for heating and cooling, but also fresh air, light, and adequate indoor acoustics (sound insulation, echo reduction). All of the above indicators are of particular relevance to people who live, work or spend time in buildings. The transmission of this data, its proper representation, analytics, forecasting, and presentation with other relevant data is precisely the priority of the digital twin [4].

The few areas reviewed are more focused on buildings, but there are many applications in civil engineering structures (roads, ports, railways, solar or wind farms, hydro-structures, utilities). These are often the public facilities for which other applications of digital twin technologies are relevant.

Traffic management. A relevant application in transport structures, which allows real-time monitoring of the movement of different vehicles or people, recording of various indicators (climate, traffic volume, noise, etc.) and, on this basis, analytics, proactive actions and traffic management. For this application, the broadcast of data with the lowest possible delay is essential, as traffic is usually very dynamic.

Utilities management. We are surrounded by millions of kilometres of utilities (engineering networks), many of which are underground. These include various types of energy (district heating, gas supply, electricity supply, water supply, sewage networks) and means of communication (e. g. fibre optics). Their maintenance and management are of particular importance to the citizens in general and companies that maintain them, which work 24/7 to ensure an uninterrupted supply of energy. This is particularly important for medical sector buildings, various fire protection systems or other structures that require a high level of supply reliability. The utilities digital twin enables real-time monitoring of the behaviour of these networks, various parameters (flow, pressure, voltage, temperature, etc.), simulations, and, together with the

geometric representation of these objects, a complete digital twin for system management and other purposes.

The above examples of digital twins illustrate that the built environment and its digital twins have a significant impact on the citizens. Therefore, educating the public about the digital twins of the built environment is essential, and more applications of digitisation need to be explored with industry, academia, and the citizens in general. The built environment, real estate is the largest asset in the world, which counts approximately 380 trillion USD [6]. A large part of which is public real estate objects, and it is therefore necessary to take measures to ensure the efficient installation and use of these assets through innovation, thereby raising awareness and understanding of the built environment among the citizens.

2. 1st citizens' event: "SmartWins with DigitalTwins"

The first citizens' event "SmartWins with Digital Twins" took place in Kaunas city at University premises, taking advantage of the modern spaces of the KTU library and thus encouraging residents to participate more actively. The chosen date was 22 May 2023. The event was held in Lithuanian. A description of the event with registration links on the Eventbrite platform is provided in Fig. 1.

Fig. 1: Event description with registration window on the Eventbrite platform

Additional dissemination about the event was disseminated on the SmartWins official website https://smartwins-project.eu/smartwins-with-digital-twins-event/ and LinkedIn.

2.1. Aim and objectives of the event

The main aim of the 1st citizens' event "SmartWins with Digital Twins" was to bridge the gap between research, industry and citizens. The event's objectives included:

- Bringing together a diverse group of citizens from various expert fields to learn about and exchange knowledge on the benefits of Digital Twins in the built environment, both professionally and personally.
- Assessing participants' awareness levels regarding Digital Twins and related technologies.

- Sharing expertise from KTU professionals and introducing participants to current projects utilizing Digital Twins.
- Engaging in workshops and discussions on Digital Twins to identify application areas, benefits, implementation barriers, and to share practical examples.

2.2. Event participants

General questions on the field, profession and professional experience of the participants revealed that the majority (52.63%) of participants were from business enterprises, while academics accounted for 31.58% of the total number of participants. An important indicator that can be extracted from the questionnaire is that as many as 15.79% of the participants were from the Ministry of the Environment of the Republic of Lithuania, which shows the importance of the topics addressed by the SmartWins project at national level. Considering the professional background of participants, the audience was more diverse, only with civil engineers representing 40.91% of the total participants. Other attendees were evenly distributed in the fields of building services, IT sector, BIM technology (54.54%), while the rest represented architecture, GIS, policy formation, digital innovation, electrification and project management fields. Participants indicated that 31.58% of them have the experience from 1 to 5 years, 21.05% from 5 to 10 years, and the majority (47.37%) have more than 10 years of experience.

2.3. Event program/speakers

Speakers

Dean at KTU Faculty of Civil Engineering and Architecture Prof. Dr. Andrius Jurelionis

The event started with the opening speech by the Dean of the KTU Faculty of Civil Engineering and architecture Prof. Andrius Jurelionis. After welcoming the participants Prof. Jurelionis invited them to take part in an interactive questionnaire designed to understand their current knowledge on digital twins in the built environment, related technologies, and their applications. The results of the questionnaire were instantly revealed to the participants allowing them to open a

discussion regarding the current developments in the field as well as to understand the the professional readiness to implement such technologies.

After the questionnaire, Prof. Jurelionis started his presentation on the topic - "What are the Digital Twins of Buildings and Cities?". In his presentation, Prof. Jurelionis defined what are the digital twins of the built environment, and discussed whether building management systems (BMS) or building information modeling (BIM) could be considered as digital twins. He also introduced the life cycle of buildings and shared exemplary cases where digital twin technology has been successfully implemented. With his presentation, Prof. Jurelionis laid a solid foundation for understanding what are the digital twins and their potential for the built environment.

Fig. 2: Poster of the event speaker Andrius Jurelionis

Head of KTU Centre for Smart Cities and Infrastructure Prof. Dr. Darius Pupeikis

Following the presentation by Prof. Jurelionis, the head of the KTU Centre for Smart Cities and Infrastructure (CSCI), Prof. Darius Pupeikis introduced various projects related to the built environment's digital twins conducted at CSCI. Prof. Pupeikis highlighted 14 local and international projects, with particular emphasis on the "SmartWins" project.

In his presentation, Prof. Pupeikis introduced different technologies required to develop built environments' digital twins and discussed the integration challenges

associated with them. He outlined the technical and practical issues that need to be overcome to fully realize the potential of such technologies. Additionally, Prof. Pupeikis shared concrete examples of digital twins developed at KTU, showcasing their practical applications and the benefits they bring to smart city and infrastructure projects. His insights gave a better understanding for the participants of the advancements and ongoing efforts in the field of built environments' digital twins at KTU.

Fig. 3: Poster of the event speaker Darius Pupeikis

Advisor at the Ministry of Environment of the Republic of Lithuania Aušra Balsytė

An invited speaker - Aušra Balsytė, who is an Advisor at the Ministry of Environment of the Republic of Lithuania, highlighted the critical role of legislative frameworks and national policies in the implementation phase of digital twins. During her presentation, Ms. Balsyte discussed the potential of leveraging Lithuanian online access environment for site planning and construction - TPS gates, for the development of built environment's digital twins. She emphasized how aligning regulatory measures with technological advancements can facilitate smoother integration and more effective utilization this technology. Ms. Balsyte also provided insights into how these

tools could revolutionize site planning and construction processes, ultimately contributing to more efficient and sustainable built environment.

Fig. 4: Poster of the event speaker Aušra Balsytė

Researcher at KTU Faculty of Civil Engineering and Architecture PhD. Cand. Paulius Spudys

After a short break, the event continued wit a presentation by Ph.D. candidate Paulius Spudys. In his presentation, Mr. Spudys introduced the "SmartWins" project conducted at KTU, outlining its aims and objectives.During his presentation Mr. Spudys also introduced the project's partners, including their roles and contributions for the project. Further in his presentation, Mr. Spudys reflected on the activities that had already been completed within the “SmartWins” project and shared the future plans. To conclude his presentation, Mr. Spudys shared some useful sources with the participants, so they could find more information about the "SmartWins" project and its ongoing developments after the event.

Fig. 5: Poster of the event speaker Paulius Spudys

Technology transfer project manager at National Innovation and Entrepreneurship centre Mindaugas Kemzura

The final presentation of the event was delivered by Mindaugas Kemzura, the technology transfer project manager at the National Innovation and Entrepreneurship Centre. Mr. Kemzura introduced the European Digital Innovation Hubs (EDIH) for Lithuania and outlined their goals. He provided a detailed overview of the various industries eligible to participate in this program and the technologies employed within it. Mr. Kemzura's presentation highlighted the opportunities and benefits that the EDIH initiative offers to different sectors, emphasizing how these hubs can foster innovation and technological advancement across Lithuania.

Program preparation and relevance

Since the event was conducted in Lithuanian, most of the dissemination materials, including the event program, were prepared in the native language. The English translation of the program is available below:

Table 1: 1st citizens' event programme in English

8:30 - 9:00	Participant registration	
9:00 - 9:30	Presentation: "What are the Digital Twins of Buildings and Cities?"	Prof. Dr. Andrius Jurelionis
9:30 - 10:10	Presentation: "Built environment digital twins in Kaunas city"	Prof. Dr. Darius Pupeikis
10:10 - 10:30	Presentation: "Through TPS gates to digital twins"	Ms. Aušra Balsytė
10:30 - 10:45	Coffee break	
10:45 - 11:00	Presentation: "SmartWins project and digital twins"	PhD. Cand. Paulius Spudys
11:00 - 12:00	Workshop: "How digital twins can serve YOU?"	Prof. Dr. Andrius Jurelionis
12:00 - 12:15	Presentation: "European Digital Innovation Hubs (EDIH): What is it? Opportunities and benefits."	Mr. Mindaugas Kemzura
12:15 - 13:00	Networking	

The event program was designed to assess participants' understanding of digital twins at the very beginning. This allowed the organizers to adjust the event content accordingly, ensuring the core information was covered while delving deeper into more advanced topics where appropriate.

The second part of the event was designed to be more practical, allowing participants not only to hear our perspectives and insights but also to engage in knowledge exchange. The workshop was structured around four key questions related to the broader adoption of digital twins in the built environment:

1. Barriers to wider usage of digital twins.
2. Applications of digital twins.
3. Benefits of digital twins.

4. Examples of digital twins.

Each topic was displayed on separate white-boards placed around the venue, allowing participants to freely share their thoughts and ideas. Overview of the results is presented in section **2.4. Gained insights**.

Fig. 6: 1st citizens' event programme in Lithuanian

2.4. Gained insights

Insights from the questionnaire on current knowledge of participants on Digital Twins

A detailed questionnaire was designed to obtain generic information about the participants' professional background, experience and their knowledge and understanding of digital twins and their application. This section provides an overview of the key results as well as gained insights from the responses of the participants. Questionnaire and results are presented in the Annex 1. 1st citizen's event questionnaire on current knowledge of participants on Digital Twins.

As indicated in the section **3.2. Event participants** the results of the survey indicate that a large number of professionals from different fields participated in the survey, which shows that the topic of digital twins and their application is relevant to a broad segment of society and business. This allowed to gather a substantial number of participants' opinions and their current knowledge on digital twins and their application in different fields.

BIM, GIS, IoT, data analytics and predictive analysis tools application individually.

The questions regarding the adoption of the BIM methodology led to the general conclusion that the adoption of BIM remains neutral with respect to the individual applications of the participants. Regarding the contribution to the development of BIM solutions, it is evident that the audience is not familiar with such practices.

Although the use of GIS technologies is more varied in the group surveyed, it was observed that the audience is divided into two almost equal parts: some are more or less using GIS solutions and others are not. Respondents who do not use GIS individually are only slightly more numerous. However, the audience is more familiar with development of GIS solutions rather than in the case of BIM. This shows that although the development of GIS solutions is not widespread among participants, a certain segment is actively involved.

The survey results also reveal that participants are using Internet of Things (IoT) technologies quite widely. A large majority agree that they use of IoT technologies in their activities, indicating that IoT solutions are widespread across different sectors. However, half of the respondents remain neutral or indicate that they do not apply IoT practices in their activities. 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.

Most participants generally agree that data analysis and predictive analysis tools are used in their work, indicating a strong need for these technologies. However, there are also a significant number of respondents who are neutral or state that they do not apply such technology, indicating that while data analytics-based methods are becoming more and more widespread, they may not be used or practiced in all participants' areas or functions. This illustrates a varied level of integration and perception regarding data analytics and predictive tools.

The responses on the development of data analysis and predictive analysis tools among the participants suggest that although some participants are involved in the development of these tools, this is not common across the whole group of respondents.

BIM, GIS, IoT, data analytics and predictive analysis tools application at organisational or sector level.

Regarding the adoption of BIM in the participants' fields, it can be concluded that, in general, BIM technologies are widely used in a wide range of sectors, with almost half of the respondents indicating that BIM is used in their organisation or sector, while the rest remained neutral. It is also worth noting that almost identical responses were received on the application of GIS technologies in different areas.

In terms of IoT adoption, the results show that the vast majority of participants agree or strongly agree that IoT technologies are widely adopted in their work environment or specific sector, reflecting the high penetration, impact and integration of IoT technologies in many professional environments.

The results of the data and predictive analytics analysis show that the majority of participants indicates that data and predictive analysis technologies are widely adopted in their environment and sectors, which is similar to the previous case on IoT technologies. However, the level of agreement on the use of data analytics technologies is slightly lower than in the case of IoT, where a higher proportion of respondents expressed their agreement that these technologies are widely deployed.

Furthermore, a significant proportion of respondents remain neutral on the use of data analytics technologies, while a small proportion disagree, suggesting that while these technologies are noticeable, they may not be as universally integrated or valued across sectors as compared to IoT technologies. This comparison highlights the strong prevalence of both IoT and data analytics in today's professional environment, although IoT may have a slight advantage in terms of wider adoption or acceptance.

Audience opinion on the benefits of digital twin technologies application.

Furthermore, respondents were requested to provide their understanding of what benefits they see in applying digital twin technologies in their sector or organisations. Event participants see digital twin technologies as a one of a key tools for efficiency and optimisation in their various sectors. They highlight the advantages that technology can support advanced analysis, facilitate accurate forecasting, and help to adapt and implement strategies effectively, all of which are essential for active management. The ability to visually present complex data related to the built environment simplifies communication with stakeholders and improves the quality of information exchange. Respondents also recognise the value of integrating different data streams into a uniform system, which improves asset management and related decision-making. Additionally, centralising project data not only simplifies processes, but also helps to identify and mitigate potential failures or disruptions before they happen. Moreover, the technology is seen as a driving force for greater collaboration between science and business, improving data management and enabling timely problem solving. Overall, respondents acknowledge the time-saving benefits of this digital twin technology, recognising its wide range of benefits for a variety of stakeholders and highlighting its transformative potential across sectors.

Audience opinion on the obstacles of digital twin technologies implementation.

Participants were invited to identify the main obstacles preventing the wider adoption of digital twin technologies in their respective areas or organizations, and their insights provide a comprehensive picture of the challenges we face in different sectors of the built environment.

A common challenge identified by respondents is the lack of a unified data classification and integrated solutions, compounded by a general lack of understanding and expertise in these technologies.

Many point to the need not only to have the necessary knowledge to drive adoption, but also to educate customers and the public about the potential benefits of digital twins' application.

Financial barriers are a reoccurring concern in participants' responses, with high costs and the need for different implementation methods becoming an important reason why digitalisation technologies are not being adopted. In addition, the lack of end-to-end solutions hinders the uptake of the technology by potential users, who do not fully understand whether it will provide tangible value.

Attendees also felt that progress is limited by policy-related problems, such as a lack of involvement in policy-making and the government's inability to standardise or set clear strategies.

Some respondents believe that the sector or organisation they represent simply lacks the willingness to adopt new technologies.

Several respondents admit that they do not understand the exact barriers and believe that wider communication on digital twins' benefits should be further developed.

Overall, these factors underline the complex, multifaceted challenges that need to be addressed to increase the widespread adoption of digital twin technologies across sectors.

Audience opinion where the application of digital twin technologies would bring maximum benefit

Participants consider that digital twin technologies can be beneficial in the fields of urban and town planning, construction and infrastructure management. They consider digital twin technologies to be very important for improving the efficiency of spatial planning, property management, environmental protection and heritage preservation processes, and for improving data management. Digital twins are also positively evaluated in the private sector, with their application to the operational management of office buildings and shopping facilities, but there are some concerns about their suitability for critical infrastructure due to the potential security risks involved.

In addition, the benefits of digital twins are identified as extending from the design and actual use phase of buildings to real estate development and the operation of utilities. Efficient urban management, including renovation and maintenance of infrastructure, is another area where the potential for effective use of digital twins is highlighted.

In summary, digital twin technologies are perceived to be highly beneficial in a wide range of sectors related to the built environment, particularly those involved in the planning and management of cities and assets. Digital twin application stands on the promising path to revolutionize traditional methods and improve overall efficiency and sustainability of built environments.

Security and privacy concerns

Despite numerous advantages and possible adaptation fields in different sectors or organizations related to build environment, participants of the event expressed concerns that are related to data security when creating and managing digital twins. There was a strong agreement indicated on the statement that the security of digital twin data and their public accessibility can pose risks. Additionally, significant number of respondents perceive that it is challenging to ensure personal data privacy when digital twins are created, while others have neutral opinion on it. Such strongly

highlighted concerns may potentially become a barrier to a wider adoption of digital twins in everyday environments.

Conclusions

In summary, there is a growing public and stakeholders' awareness and understanding of the increasing importance and potential of digital twinning technologies in a wide range of sectors, in particular in urban planning, infrastructure management, digitisation of construction and other areas. While the benefits of these technologies, such as increased efficiency, data management and better decision-making, are generally acknowledged, society still faces significant challenges. The main barriers identified and perceived are the lack of uniform data standards, financial costs, limited expertise and concerns about data security and privacy. Addressing these issues will be key to the wider adoption and successful implementation of digital twin technologies, ensuring that they can reach their full transformative potential and bring the most of their benefits in a built environment.

Insights from the questionnaire sent to participants after the event

In order to gather participants' opinions on the event and the quality of its content and presentations, a detailed questionnaire has been distributed so that the organisers could take into account audience reflection when organising the next citizens' event. Questionnaire and the results are presented in **Annex 2. Survey on the 1st citizens' event "SmartWins with digital twins"**. The following section gives an overview of the results and presents the main insights gained from the survey.

- The majority of participants found the event to be well-organized and beneficial, with no respondents expressing dissatisfaction.
- While most attendees did not ask questions, those who did generally felt satisfied with the responses they received, though a small portion remained neutral.
- The interaction with the speakers was overwhelmingly positive, with all participants agreeing that the interactions were pleasant.
- Most attendees felt involved in the event's activities and gained new knowledge, with only a minor portion remaining neutral on these points.
- The depth of the presentations was well-received, aligning with the participants' levels of knowledge, although a small group found the content too simplistic.
- Regarding participation numbers, the majority felt that the event had a good turnout, with some expressing that more participants could have been involved.

- A significant majority of participants would recommend SmartWins events to their colleagues and friends, indicating strong approval and satisfaction with the event.
- Regarding the event's impact on bridging the gap between research and society, most participants agreed that it made a positive contribution. However, a notable portion of respondents remained neutral, suggesting that while progress was made, there is room for further improvement in this area.

Overall, the feedback suggests a highly positive perception of the event, that it was effective in engaging participants and highlighting its potential to strengthen the link between research and society. Furthermore, results provide information with opportunities for slight improvements in engagement and content complexity for the next events.

Insights from the workshop

The workshop organized intended to allow participants to interact with the researchers working on digitization and digital twin solutions and to discuss four key elements related to it. Table 2 provides a summary of the main ideas expressed by the audience.

Table 2: Summary of workshop results

Challenges in implementing digital twins. How to accelerate policy development, common classification, competency development?	**Application of digital twins. Where can we apply these technologies to maximise the benefits for society, the economy and the environment?**
• Data privacy/open data • Lack of data. • Lack of data structure on national level. • Data silos. • Lack of education on MSc level • Variety of different systems and data sources • Too ambitious when creating DT solutions	• Renovation. • Visualization. • BIM usage. • Decision making. • AI implementation. • Heritage. • City communications expansion. • Transport infrastructure.

Benefits of digital twins. The benefits of digital twinning are still hard to understand. How can we raise public awareness of this technology?	Examples of digital twins. Technologies, projects, suggestions on what we should consider.
• Digital city and its infrastructure. • Facility management. • Education of citizens. • Accessibility of tools.	• Rotterdam harbour. • London Olympics. • CERN. • Parking infrastructure. • ESO. • Rail Baltica. • Singapore. • The Edge NL.

In particular, regarding barriers of wider digital twin applications, participants identified several critical challenges in the development and implementation of digital twin solutions. It was discussed with the audience that the main concerns relate to data privacy and the handling of open data, underlining the need for robust systems to protect sensitive information. The lack of structured data governance at national level and the use of many different systems by different stakeholders, leads to the existence of many data sets, further complicating the development of effective DT systems.

In addition, there is a distinct lack of education at postgraduate level, which contributes to the shortage of qualified professionals capable of developing DT technologies. The diversity of systems and data sources, combined with sometimes over-ambitious goals of developing DT solutions, create further obstacles that need to be addressed to ensure the successful deployment and scalability of digital twins.

What concerns possible use cases of digital twins, participants see potential benefits in adapting them to renovation projects where society would be able to access the data on energy consumption before and after renovation, as well as to see potential energy and costs savings for their assets. To the perception of participants this could encourage citizens to participate in the renovation, which would lead to increasing energy efficiency. Participants also suggest that DT could be integrated into urban or infrastructure planning by visualising and integrating solutions into a unified system. When integrating BIM data to unified systems, it could also facilitate decision making, for planning, as well as for managing the assets. In overall, as the main advantage of DT is data accessibility in unified system, the participants emphasize that different data layers can be adapted for various use cases.

When considering raising public awareness of the benefits of digital twins and their potential applications, the audience suggests demonstrating real-life applications in urban planning and infrastructure to raise awareness of the benefits. Demonstrating

how digital twins are used in the planning and design of people's living environments and making them publicly available could contribute to the public's understanding of the technology. In addition, public participation in projects such as Structum's 'Smart City' or similar, where participants can have hands-on experience of the technology, can increase awareness. In addition, the complexity and low availability of digital twin tools would need to be addressed for the technology to become more widely adopted.

In addition, during the workshop, participants offered and shared with the organisers several examples of real-life applications of digital twins. This indicates that the audience is familiar with some of the real-life use cases and also provides useful information for the organisers by sharing their own experiences. The proposed models of digital twinning covers national and international levels.

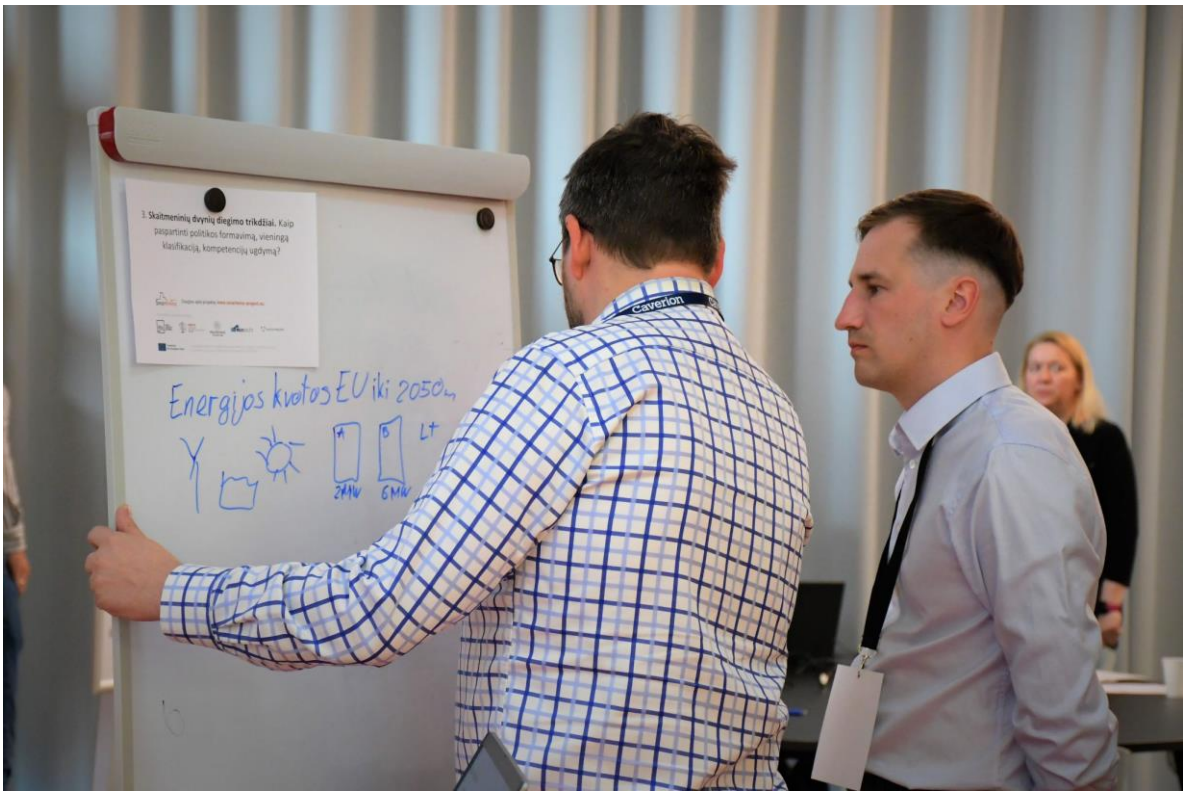

Fig. 7: Moments from the 1st citizens' event - workshop

Fig. 8: Moments from the 1st citizens' event - presentations

Fig. 9: Moments from the 1st citizens' event - introduction of CSCI activities

2.5. Recommendations for further events

Promote engagement and interaction: as some participants felt neutral about their involvement, future events could include more interactive elements such as breakout sessions, panel discussions, expert consultations to address practical Digital Twin implementation issues, workshops or live demonstrations to encourage participation.

Address complexity of content: while most participants were satisfied with the content of the event, a small group found it too simplistic. Recommendations for further events is tailoring content to different knowledge and expertise levels or offering parallel sessions for beginners and advanced participants.

Improve communication of the benefits and challenges associated with Digital Twins: given the mixed opinions on the effectiveness of the event in bridging the gap between research, industry and society, future events should focus more on sharing practical applications and real-world benefits of Digital Twin technology. This should be supported by relevant use cases demonstrating how challenges of different scales have been successfully addressed using Digital Twin solutions, while also highlighting the key issues and risks in the Digital Twin implementation process itself.

Broaden the diversity of the audience: to address the obstacles and risks to Digital Twin adoption highlighted by participants, future events should aim to expand the audience to include a wider range of stakeholders, such as policy makers, standardisation bodies, financiers, data security and AI experts, and representatives from under-represented industries such as manufacturing, facilities management, transport and urban planning.

Use feedback for improvement: use insights from post-event surveys to focus on topics preferred by the audience, and maintain ongoing communication with participants (if they wish) to provide guidance and consultation on emerging issues. This will help improve future events, increase participants satisfaction and strengthen collaboration between academia, industry and society.

2.6. Gained knowledge relevant for SmartWins project

Participants' awareness of the benefits of Digital Twins: participants generally see Digital Twins as essential tools for improving efficiency, optimisation and decision-making in their fields. This perspective is in line with the objectives of the SmartWins

project and highlights the need for further research, development and demonstration of Digital Twin applications.

Understanding barriers to implementation: key obstacles identified by participants include privacy concerns, lack of standardisation, high implementation costs, limited expertise, lack of suitable software solutions and resistance to change across sectors. These can inform the SmartWins project's strategies, such as developing targeted education initiatives, citizens and professionals engagement, and advocating for supportive policies.

Identification of priority application areas: based on event results, Digital Twins are seen as highly beneficial in urban planning, infrastructure management and environmental protection. However, these results reflect the expertise of the participant group and may not cover all potential application areas. Future events with a broader audience could uncover additional use cases. However, in the Lithuanian context, the SmartWins project should prioritise these areas to maximise its impact on local industry and society.

Need for public awareness and education: in order to increase the adoption of Digital Twins, the SmartWins project should prioritise public awareness campaigns, especially for renovation projects, to demonstrate the practical benefits of the technology. In addition, the development of educational programmes at post-graduate level is crucial to clarify the technology, manage expectations and illustrate practical applications. In both cases, special attention must be given to addressing data security and privacy concerns, which were significant issues for participants, by providing guidance on robust data protection mechanisms.

The importance of policy alignment: insights from the event highlighted the role of regulatory frameworks in facilitating the adoption of Digital Twins by industry. SmartWins should consider engaging with policy makers and standardisation bodies to advocate for supportive regulations and standards.

Ethical issues: although ethical issues were not explicitly highlighted by event participants, the use of IoT and AI in Digital Twin implementations may raise concerns such as profiling, systematic monitoring of individuals, and the influence of AI systems on human decision-making processes. These potential issues need to be considered and addressed proactively.

2.7. Future steps

Develop targeted educational materials: to address the need for greater understanding of technology among different stakeholders, SmartWins should develop targeted educational content. This could include workshops, online resources, updates on project progress and educational posts on social media to highlight recent research findings. Content should be tailored to different levels of familiarity with Digital Twins.

Promote cross-sector collaboration: encourage partnerships between academia, industry, software vendors and government to address identified barriers such as privacy issues, lack of standardization and gaps in software solutions. This may include organising consultations and forming working groups.

Expand real-world demonstrations and case studies: highlight additional examples and case studies of successful Digital Twin applications, particularly in urban planning, infrastructure, building renovation and energy management. This will illustrate Digital Twin's value and build trust among potential adopters. Target audiences include industry, policy makers and the general public. The content will be delivered through SmartWins and KTU newsletters, websites and social media posts.

Engage with policy makers and standardisation bodies: engage with local policy makers to advocate for enabling regulations and standardised frameworks that can support the implementation of Digital Twins.

Address financial and technical barriers: explore funding opportunities, such as grants or partnerships, to reduce financial barriers to Digital Twin adoption, including relevant EU calls. Highlight these funding opportunities at future events and project dissemination activities. In addition, interact with software vendors to better meet local industry and community needs and make the technology more accessible.

Organise a follow-up event: plan a future brokerage event, to be preliminarily scheduled for 14-15 May 2025, in conjunction with the BDTIC 2025 conference at KTU.

3. 2nd citizens' event

The event started by presenting the project's objectives, expectations and opportunities for public engagement, thus exploring the application of digital twins in

different life situations. The technological basis for the development of the digital twins was also presented, with an overview of popular technologies such as Building Information Modelling (BIM), Geo-Information Systems (GIS), photogrammetry (including UAV-based), 360 panoramic photography, Computer Aided Design (CAD), laser scanning (LiDAR), Internet of Things (IoT), data analytics and applied machine learning (artificial intelligence) and other technologies for the digitisation of built environment.

The next stages of the event focused on the potential applications of digital twins. Examples of built environment digital twin applications developed by the Centre for Smart Cities and Infrastructure at the KTU Faculty of Civil Engineering and Architecture were presented. For example, the simulation of site flooding, energy loss, shading on solar panels, the presentation of new projects to the public, the digitisation of valuable features of real-estate cultural heritage to preserve them for future generations, the monitoring of the CO2 footprint and indoor climate generated by the use of a building, etc.

The workshops organised during the event highlighted relevant issues that could be addressed by the digital twin technologies in the following three themes: energy efficiency and renovation (the latter is of particular relevance to the public), preservation of buildings of immovable cultural heritage and sustainability of buildings.

Fig. 10: 2nd citizens' event description and registration window on the Eventbrite platform

3.1. Aim and objectives of the event

The aim of the event was to introduce everyone to the world of digital twins in built environment and how they can directly benefit you, citizens. The event was tailored to the diverse Lithuanian community, making it suitable for everyone from experts in the field to curious citizens.

The event was disseminated through various media, such as the social networking platforms LinkedIn and Eventbrite (Fig. 11), local KTU dissemination channels, partner websites, etc.

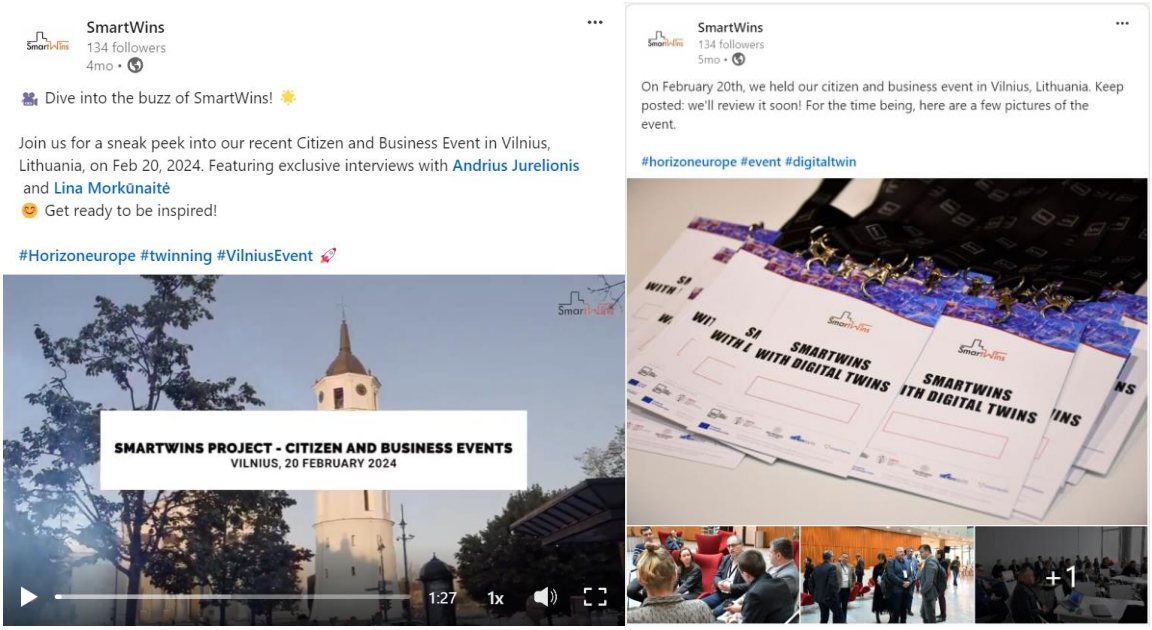

Fig. 11: Dissemination of 2nd citizens' event on the LinkedIn social media

The event featured interactive seminars, workshops and engaging discussions.

3.2. Event participants

The 2nd citizens' event attracted interested participants from a wide range of organisations or as private individuals interested in the digitisation of the built environment. This includes a wide range of public groups: students from engineering and other study fields, academics (professors, researchers), representatives of surveying and mapping associations, public sector actors responsible for digitising the built environment, policy makers, and representatives of various companies in the construction sector. The academic community was represented by researchers and professors from Vilnius Gediminas Technical University (Vilnius Tech) and Kaunas University of Technology (KTU). Policy makers and implementers were represented by persons from the Ministry of Environment of the Republic of Lithuania, the Construction Sector Development Agency, the Department of Cultural Heritage under the Ministry of Culture of the Republic of Lithuania. The event was also attended by

members of the public who were interested in the application of digital technologies in both their professional and private activities, in building maintenance, asset management, planning investments in renewable energy sources, renovation, and ensuring sustainable building operation.

Fig. 12: 2nd citizens' event participants

3.3. Event program/speakers

Representatives of Kaunas University of Technology (KTU) and the Lithuanian Builders' Association were speakers and moderated discussions at the citizens' event.

- Prof. Dr. Andrius Jurelionis, Dean of the Faculty of Civil Engineering and Architecture at KTU
- Prof. Dr. Darius Pupeikis, Head of Centre for Smart Cities and Infrastructure at KTU
- PhD. Cand. Lina Morkūnaitė, Researcher of Smart Cities and Infrastructure Centre at KTU
- Dalius Gedvilas, President of the Lithuanian Builders Association

- Dr. Jurgita Černeckienė, Researcher of the Faculty of Civil Engineering and Architecture at KTU

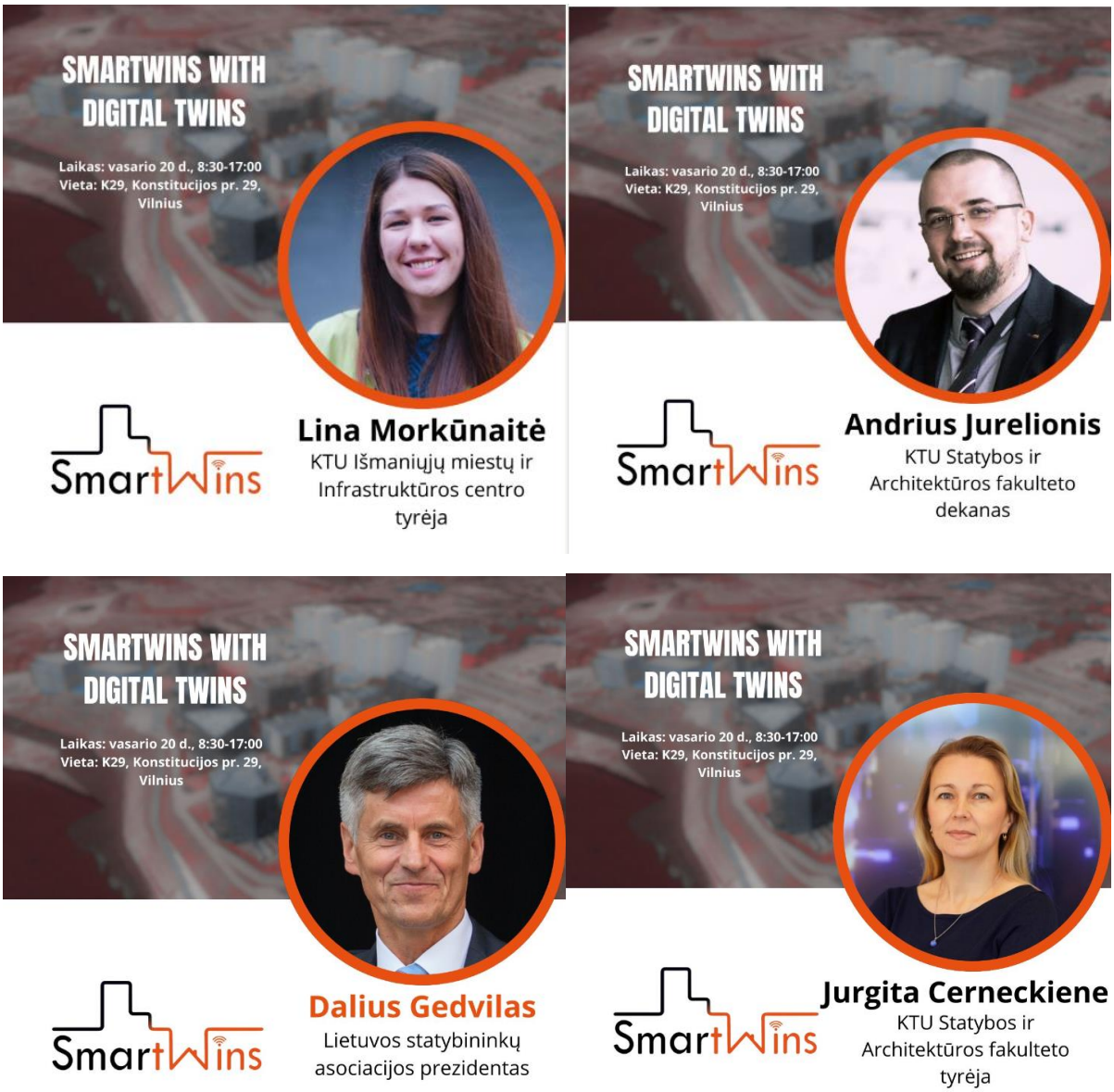

Fig. 13: Posters of the 2nd citizens' event speakers

Programme preparation and relevance

The event's programme has been developed based on citizens needs and relevant topics where digital twins could serve. In this way, topical issues encourage better engagement in discussions on possible solutions to problems. The programme of the event in Lithuanian is given in Fig. 14.

Renginys visuomenei – Užstatytos aplinkos skaitmeniniai dvyniai

8:30-9:00	Dalyvių registracija	
9:00-9:05	Renginio atidarymas ir sveikinimo žodis	KTU SAF dekanas Andrius Jurelionis
9:05-9:20	ES Horizon Europe projekto "SmartWins" pristatymas	KTU SAF dekanas Andrius Jurelionis
9:20-9:40	Kokią praktinę naudą gali suteikti užstatytos aplinkos skaitmeniniai dvyniai	KTU IMIC vadovas Darius Pupeikis
9:40-9:50	„SmartWins with Digital Twins" pirmojo renginio rezultatai	KTU IMIC tyrėja Lina Morkūnaitė
9:50-10:10	Skaitmeninės statybos vaidmuo užstatytos aplinkos skaitmeninių dvynių vystymo ir naudojimo kontekste	LSA prezidentas Dalius Gedvilas
10:10-10:30	Skaitmeninių technologijų taikymas tvarios užstatytos aplinkos kūrimui ir išlaikymui. Įvadas taikymo atvejams: · Nekilnojamo kultūros paveldo išsaugojimas ir pritaikymas · Pastatų energetinio efektyvumo gerinimas ir renovacija Statinių sukuriamo CO2 pėdsako vertinimas ir tvarumo gerinimas	KTU IMIC vadovas Darius Pupeikis
10:30-10:45	Kavos pertraukėlė	

10:45-11:30	Kūrybinės dirbtuvės: Kaip skaitmeniniai dvyniai gali pasitarnauti tvarios užstatytos aplinkos kūrimui?	KTU SAF dekanas Andrius Jurelionis
11:30-11:50	Pirmosios renginio dalies rezultatų apibendrinimas	KTU IMIC vadovas Darius Pupeikis
11:50-12:00	Projektas „Build Up Skills LT2030“ – iniciatyva statybos specialistų kvalifikacijos kėlimui	KTU SAF tyrėja Jurgita Černeckienė
12:00-13:00	Pietų pertrauka	

Fig. 14: 2nd citizens' event programme in Lithuanian

3.4. Gained insights

Insights from the questionnaire on current knowledge of participants on Digital Twins

A questionnaire was developed in order to obtain basic information about the participants' professional background, experience and their knowledge and understanding of built environment digitalisation technologies. This section provides an overview of the key results as well as gained insights from the responses of the participants. Questionnaire and results are presented in the Annex 3. 2nd citizen's event questionnaire on current knowledge of participants on Digital Twins.

As mentioned in section 3.2 (Event Participants), the survey results reveal that a considerable number of professionals from various sectors took part, highlighting the widespread relevance of digitalisation technologies, like BIM, digital twins, IoT and GIS and their application to society, public sector and business. This enabled the significant number of participants' perspectives and their current understanding of digitalisation and their possible applications across built environment.

The majority of respondents (about 2/3) are involved in BIM and feel experienced in applying the technology. Of these, an even higher proportion are in the process of developing their own BIM tools or adapting existing ones to specific tasks and organisational needs. As many as 80% of respondents indicated that BIM technologies are quite widely and increasingly used in their environment (organisation, projects). BIM interacts quite closely with other technologies such as GIS. Therefore, a proportion of respondents (about 1/3) reported actively using this technology as well. Of course, no building project can do without geographic data and the technologies that enable it. However, we can assume that the respondents were dominated by professionals focused on the design, construction and maintenance of buildings. Unfortunately, about 1/3 of respondents indicated that they had no experience with BIM and GIS technologies, despite the fact that all participants' activities are related to

construction industry or the built environment in general. Another relevant digitisation technology that respondents answered about is IoT - Internet of Things. In this question, the responses were split down the middle. 1/2 of the respondents use IoT in their practice and the other half do not. This shows that there is still untapped potential to exploit IoT technology more and to find possible interfaces with other digital data. In this way, developing the digital twin of an existing building or infrastructure. Interestingly, more than 40% of respondents use digital data for further development, i.e. analytics and forecasting of various processes or objects. As many as one third reported that they create their own analytical tools and forecasting models, indicating a high level of technical training and programming skills.

Discussion with participants before the presentations

Discussions with the participants before the presentations were more abstract, talking in general terms about the event itself, its purpose, and how a particular participant could benefit from solving his/her particular operational problems. Each participant, although driven by curiosity, is of course focused on their own interests. One group of participants was more interested in the legislative side, how the use and wider application of digital twins could be legalised in the country and technically how this could be implemented in governmental information systems. Another group of participants, already with some expertise in digitisation, was looking for relevant cooperation opportunities. Some participants were interested in a more transparent process for obtaining construction permits, and in the environmental and social impacts.

Fig. 15: Discussion with participants before the presentation

Discussion with participants after the presentations

Discussions with participants after the presentations were much more detailed and specific, as the presentations revealed the speakers' areas of expertise. In addition, the presentations stimulated creativity and the generation of new ideas. A key moment was how digital twins can support the activities of a particular participant or influence everyday decisions. Some of the presentations were followed by workshops on topics of public interest and possible applications of digital twins. The workshops were held in three groups, divided according to topics of public interest: real estate cultural heritage, energy efficiency and renovation of buildings, and assessing and improving the CO2 footprint and sustainability of buildings.

Fig. 16: Discussion with participants after the presentation

3.5. Recommendations for further events

The events have been fruitful and have provided valuable insights into the state and understanding of digitalisation of the built environment. A key factor to consider for future events is early stakeholder engagement. Informing and involving industry experts, local government and urban planners from the start would ensure a wide range of perspectives and potentially even higher participant count during the event. In addition, providing the context of the event in the planning stage to various citizens and community groups, such as architects and engineers, would raise potential key issues and concerns that can be addressed ahead of time and ensure a variety of interests are covered through the event. With early engagement, an effective communication strategy can be developed, where key stakeholders are reached through various means, including newsletters, social media or networking at other events. Conducting surveys or focus groups prior to the event can also allow for a more tailored approach to the event content and design. The next recommendation would

be including more interactive workshops and live demonstrations of the digital technologies which would foster deeper discussions and more practical learning. Giving the participants an opportunity to test the technologies themselves, maybe in some of their own existing work, would encourage more participation and collaboration between the industry stakeholders and the university in a project such as this one. To also encourage networking among the attendees and various stakeholders, round table discussions or small collaborative sessions could be included during the event. Offering a hybrid-style event could also increase participation from relevant stakeholders - accommodating virtual participants would expand the reach of the event.

3.6. Gained knowledge relevant for SmartWins project

From these events, it was possible to gain insights into how stakeholders view digitisation of the built environment. The diverse perspectives from the different participants allowed for the understanding of the specific needs or concerns about digitisation from industry experts. In addition, discussions offered information about the current rate of adoption of the various technology in industry and the challenges that are faced with the implementation. The events' participants indicated the problem of unpopularity of this building technology and outlined the clear issue of clients' financial constraints which leads to overlooking the benefits of digital twin technologies. This creates an opportunity to review the SmartWins project goals and better align them to support and foster the growth of the use of this technology in real-life applications through educating the general public (who are usually the beneficiaries of this technology), and industry experts. The SmartWins project could initiate training and certification programs conducted at Kaunas University of Technology for engineers, architects or IT specialists. Also, building a network from the event participants can be the start of partnerships to share knowledge and best practices all initiated by the SmartWins project. Policies are an instrumental part of standardizing the use of a technology and the SmartWins project could stand as an advocate for industry-wide standards and lobby for regulations through engaging with government agencies. Additionally, the feedback from the participants of these events forms a basis for the preparation of any future events.

3.7. Future steps

The SmartWins project could further develop the good practices of digital twins by deepening technical knowledge, addressing emerging challenges and issues, expanding application areas, prioritizing user-centered development, addressing key issues, promoting partnerships and collaborations, education and training.

To deepen the technical intricacies, there could be further focus on specific areas such as BIM, GIS or artificial intelligence, and more investment in research to discover new applications and advances. In addition, the impact of digital twins can be broader if we do not limit ourselves to the built environment, but also include areas such as transport, healthcare or agriculture, and involve communities in identifying specific challenges.

It is very important to prioritize areas that benefit users. For example, it is useful to implement continuous feedback mechanisms and creating accessible solutions to ensure that digital twin applications meet the needs and practices of different users. Addressing data privacy and security issues, as well as developing interoperability standards, are critical steps to building trust and facilitating wider adoption.

Encouraging collaboration and partnerships with businesses, government agencies and research institutions should increase the development of digital twins and accelerate innovation. International cooperation would also accelerate the sharing of good practices.

Stakeholder education and training through specialized workshops, online training and case studies can empower individuals and organizations to effectively use digital twin technologies.

By taking these steps, the SmartWins project can continue to be a leader in the field of digital twins and contribute to the development of more sustainable, efficient, and resilient cities.

4. Overview of both events

4.1. Lessons learned

The citizens' events organized under the SmartWins project likely offered valuable insights into the needs, views, and concerns of various users and stakeholders regarding the digitizalisation of the built environment. Some key aspects that have emerged include:

- Collaboration opportunities. The interactions at the events have fostered opportunities for collaboration, knowledge sharing, and partnership development to advance the use of digital twin technologies.
- Adoption barriers. Key barriers to the widespread adoption of digital twin technologies, such as lack of awareness, standardization challenges, or data privacy concerns, have been brought to light.
- Public awareness: The events have highlight on the public's understanding of digital twin technologies, as well as their perceived advantages and drawbacks.
- Stakeholder needs. The diverse viewpoints from participants would have helped identify the specific needs and expectations of various stakeholders, including engineers, architects, IT professionals, and the general public.

By reflecting on these insights, the SmartWins project can refine its future initiatives to better address these challenges, raise public awareness, and encourage the broader adoption of digital twin technologies in the built environment.

4.2. Impact for SmartWins project

The main impact insights would be as follows:

- The main challenges to the sophisticated adoption of digital twin technologies are identified, such as lack of citizens awareness, information, standardization or data privacy.
- The interaction at the events encouraged opportunities for collaboration, knowledge sharing and partnership development to advance the use of digital twin technologies.

- The diverse perspectives and expertise of the participants helped identify the specific needs and expectations of stakeholders, including engineers, architects, IT professionals and the general public.

Reflecting on these insights, the SmartWins project can drive future initiatives to better address the aforementioned challenges, raise public awareness, and encourage wider adoption of digital twin technologies in the built environment.

4.3. Future steps

Further progress on digital twin technologies should focus on specialised education and training, as well as cooperation with industry, policy makers and standardisation bodies, involving research and development organisations such as universities, research institutes or specialised laboratories.

By preparing special training and qualification improvement programs, initiating public awareness campaigns and cooperating with educational institutions, the initiative could develop into a new generation of specialists.

In addition, working with industry associations and legislative bodies in developing standards, regulations, guides, how to apply technologies, what essential principles should be followed and transfer of good practices would be extremely useful.

Further activities could focus on exploring the integration of technologies such as AI, IoT and blockchain into digital twins. Also, identifying innovative software and compatibility, addressing data management and privacy issues, and collecting regular feedback from users can help improve practices.

By adopting these steps, technologies of digital twins could be accelerated and adapted to more practical and beneficial use cases.

5. References

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6. Santrauka

Žmonės daugiau nei 90 % savo laiko praleidžia pastatuose (gyvenamuosiuose ir negyvenamuosiuose). Be to, keliaudami į darbą, mokyklą ar kitas vietas, žmonės beveik visą savo laiką būna įvairiuose pastatuose arba turi sąlytį su jais. Pavyzdžiui, keliai, geležinkeliai, metro ir kt. Žmonėms taip reikalingą energiją (elektrą, šilumą, vėsinimą, vandenį, nuotekų šalinimą, atliekas ir t. t.) taip pat tiekia tam tikro tipo pastatai, t. y. komunalinės paslaugos. Visi šie dalykai leidžia daryti išvadą, kad užstatyta aplinka yra labai svarbi žmonių gyvenimui [1].

Žmonija urbanizuojasi. Prognozuojama, kad per ateinančius 25 metus miestuose gyvens jau daugiau kaip 70 proc. gyventojų. Miestams keliami vis didesni reikalavimai, jie susiduria su ypatingais iššūkiais (klimato anomalijos, didėjantis gyventojų skaičius, švarios energijos poreikis ir t. t.). Todėl miestai, kuriuos fiziškai sudaro užstatyta aplinka, turi keistis, perkelti užstatytą aplinką į išmanesnę, efektyvesnę, siūlančią naują gyvenimo kokybę ir atitinkančią šiuolaikinius ir ateities poreikius.

Visuomenės supratimas apie užstatytą aplinką paprastai yra gana ribotas dėl vartojamų gana techninių terminų, kurie labiau suprantami architektūros, inžinerijos ir statybos sričių specialistams. Taikant technologijas, skirtas pastatų skaitmeniniams dvyniams kurti, plačiajai visuomenei (ne specialistams) tampa suprantamesnė užstatyta aplinka, kurioje jie gyvena, dirba ar turi atitinkamų interesų.

Statinio gyvavimo ciklas trunka daugelį metų, todėl gerai parengti skaitmeniniai statinių duomenys išlaiko savo ilgalaikę vertę ir yra tvirtas informacinis pagrindas efektyviam naudojimui, priežiūrai ir investicijų planavimui. Tuo remiantis tikslinga paminėti pagrindines skaitmeninių dvynių pritaikymo viešojo ar privataus intereso labui sritis:

Energijos vartojimo efektyvumas. Pastatų naudotojams (gyventojams) tai dažnai yra labai svarbus prioritetas, nes tai sudaro didžiąją dalį pastato išlaikymo išlaidų. Elektros energijos, šiluminės energijos, vandens ir nuotekų šalinimo ar kitų energijos rūšių vartojimo pokyčių stebėjimas naudojant skaitmeninius dvynius naudotojams „sukelia“ sąmoningumo efektą. Tai priverčia žmones susimąstyti apie tai, kur ir kiek energijos suvartojama konkrečiame pastate, aukšte ar net patalpoje. Visi šie duomenys gali tapti įvesties duomenimis, kuriais vėliau galima įvertinti pastato ar jo dalies tvarumą ar sąnaudas [2,3].

Patalpų valdymas ir turto valdymas. Tai sritis, atsakinga už efektyvų pastato elementų ir jame esančio turto naudojimą, priežiūrą ir remontą. Šiuo atveju tikslinga integruoti skaitmeninius dvynius su geometriniu ir vizualiniu pastato vaizdavimu, kuris paprastai išreiškiamas tokiomis technologijomis kaip pastato informacinis modeliavimas (BIM), fotogrametrija ir 360 panoraminių nuotraukų turai. Įprasta turėti pastato 3D modelį, tačiau jei pastatas yra senas ir nėra geros kokybės duomenų, galima naudoti CAD pagrindu parengtus planus, registro duomenis ir geoinformacinius duomenis.

Patalpų mikroklimatas. Tai sritis, kuri glaudžiai siejasi su energija, tačiau klimatas apima ne tik reikiamą patalpų temperatūrą, bet ir kitus aplinkos parametrus, tokius kaip santykinė oro drėgmė, CO2 kiekis ore, lakieji organiniai junginiai, apšviestumas, triukšmas ir kt. Geram patalpų mikroklimatui užtikrinti paprastai reikia ne tik energijos šildymui ir vėsinimui, bet ir šviežio oro, šviesos ir tinkamos patalpų akustikos (garso izoliacijos, aido mažinimo). Visi minėti rodikliai ypač svarbūs žmonėms, kurie gyvena, dirba ar leidžia laiką pastatuose. Būtent šių duomenų perdavimas, tinkamas jų atvaizdavimas, analizė, prognozavimas ir pateikimas kartu su kitais svarbiais duomenimis yra skaitmeninio dvynio prioritetas [4].

Komunalinių paslaugų valdymas. Mus supa milijonai kilometrų inžinerinių tinklų, kurių daugelis yra po žeme. Tai įvairių rūšių energijos (centralizuoto šildymo, dujų tiekimo, elektros tiekimo, vandentiekio, nuotekų tinklai) ir ryšių priemonės (pvz., šviesolaidžiai). Jų priežiūra ir valdymas ypač svarbūs visiems piliečiams ir juos prižiūrinčioms įmonėms, kurios dirba 24 valandas per parą, 7 dienas per savaitę, kad užtikrintų nenutrūkstamą energijos tiekimą. Tai ypač svarbu medicinos sektoriaus pastatams, įvairioms priešgaisrinės apsaugos sistemoms ar kitoms struktūroms, kurioms būtinas didelis tiekimo patikimumas. Komunalinių paslaugų inžinerinių tinkle skaitmeninis dvynys leidžia realiuoju laiku stebėti šių sistemų elgseną, įvairius parametrus (srautą, slėgį, įtampą, temperatūrą ir t. t.), modeliuoti ir kartu su šių objektų geometriniu atvaizdavimu sukurti išbaigtą skaitmeninį dvynį, skirtą sistemos valdymui ir kitiems tikslams.

Apžvelgtos kelios sritys labiau orientuotos į pastatus, tačiau yra nemažai pritaikymo būdų inžineriniuose statiniuose (keliai, uostai, geležinkeliai, saulės ar vėjo jėgainės, hidrotechniniai statiniai, komunalinės paslaugos). Dažnai tai yra viešieji objektai, kuriems aktualūs kiti skaitmeninių dvynių technologijų taikymai.

Eismo valdymas. Transporto statiniuose aktualus taikymas, leidžiantis realiuoju laiku stebėti įvairių transporto priemonių ar žmonių judėjimą, fiksuoti įvairius rodiklius

(klimatą, eismo intensyvumą, triukšmą ir pan.) ir tuo pagrindu atlikti analizę, imtis aktyvių veiksmų ir valdyti eismą. Šiam taikymui labai svarbu transliuoti duomenis su kuo mažesniu vėlavimu, nes eismas paprastai būna labai dinamiškas.

Pateikti skaitmeninių dvynių pavyzdžiai rodo, kad sukurta aplinka ir jos skaitmeniniai dvyniai daro didelį poveikį gyventojams. Todėl labai svarbu šviesti visuomenę apie užstatytos aplinkos skaitmeninius dvynius ir kartu su pramonės atstovais, akademine bendruomene ir gyventojais apskritai ieškoti daugiau skaitmenizavimo taikymo būdų. Užstatyta aplinka, nekilnojamasis turtas yra didžiausias turtas pasaulyje, kuris skaičiuojamas maždaug 380 trilijonų JAV dolerių [6]. Didelę dalį sudaro viešieji nekilnojamojo turto objektai, todėl būtina imtis priemonių, kad pasitelkus inovacijas būtų užtikrintas veiksmingas šio turto įrengimas ir naudojimas, taip didinant gyventojų informuotumą ir supratimą apie užstatytą aplinką.

Apibendrinimas ir įžvalgos. Atsižvelgiant į projekto „SmartWins“ pagrindu organizuotus piliečių renginius, galime teigti, kad tai suteikė vertingų žinių apie įvairių naudotojų ir suinteresuotųjų šalių poreikius, požiūrį ir problemas, susijusias su užstatytos aplinkos skaitmeninimu. Dalį svarbių aspektų verta pažymėti:

Bendradarbiavimo galimybės. Renginių metu vykęs bendravimas paskatino dalijimosi žiniomis ir partnerystės plėtojimo galimybes, kad būtų sparčiau naudojamos skaitmeninių dvynių technologijos.

Priėmimo kliūtys. Išryškėjo reikšmingi iššūkiai ir kliūtys, trukdančios plačiai taikyti skaitmeninių dvynių technologijas, pavyzdžiui, informuotumo stoka, standartizavimo problemos arba susirūpinimas dėl duomenų privatumo.

Visuomenės informuotumas. Renginiai išgrynino visuomenės supratimą apie skaitmeninių dvynių technologijas, taip pat jų numanomus privalumus ir trūkumus.

Suinteresuotųjų šalių poreikiai. Įvairūs dalyvių požiūriai būtų padėję nustatyti konkrečius įvairių suinteresuotųjų šalių, įskaitant inžinierius, architektus, IT specialistus ir plačiąją visuomenę, poreikius ir lūkesčius.

Apibendrinant paminėtas įžvalgas, projektas „SmartWins“ ateityje galėtų patobulinti iniciatyvas, kad būtų geriau sprendžiami šie uždaviniai ar iššūkiai, didinamas visuomenės informuotumas ir skatinamas platesnis skaitmeninių dvynių technologijų taikymas statiniams.

Tolesnė pažanga skaitmeninių dvynių technologijų srityje turėtų būti sutelkta į specializuotą švietimą ir mokymą, taip pat į bendradarbiavimą su pramonės atstovais,

politikos formuotojais ir standartizacijos institucijomis, įtraukiant mokslinių tyrimų ir plėtros organizacijas, pavyzdžiui, universitetus, mokslinių tyrimų institutus ar specializuotas laboratorijas.

Rengiant specialias mokymo ir kvalifikacijos tobulinimo programas, inicijuojant visuomenės informavimo kampanijas ir bendradarbiaujant su švietimo įstaigomis, ši iniciatyva galėtų išugdyti naują specialistų kartą.

Be to, būtų labai naudinga bendradarbiauti su pramonės asociacijomis ir teisėkūros institucijomis rengiant standartus, reglamentus, vadovus, kaip taikyti technologijas, kokių esminių principų reikėtų laikytis ir perduoti gerąją patirtį.

Tolesnė veikla galėtų būti sutelkta į tokių technologijų, kaip dirbtinis intelektas (AI), daiktų internetas (IoT) ir blokų grandinės, integravimo į skaitmeninius dvynius tyrimus. Novatoriškos programinės įrangos ir suderinamumo nustatymas, duomenų valdymo ir privatumo klausimų sprendimas ir reguliarus naudotojų atsiliepimų rinkimas gali padėti tobulinti praktiką.

Pritaikius šiuos veiksmus, skaitmeninių dvynių technologijas būtų galima paspartinti ir pritaikyti praktiškesniems ir naudingesniems naudojimo atvejams.

Disclaimer

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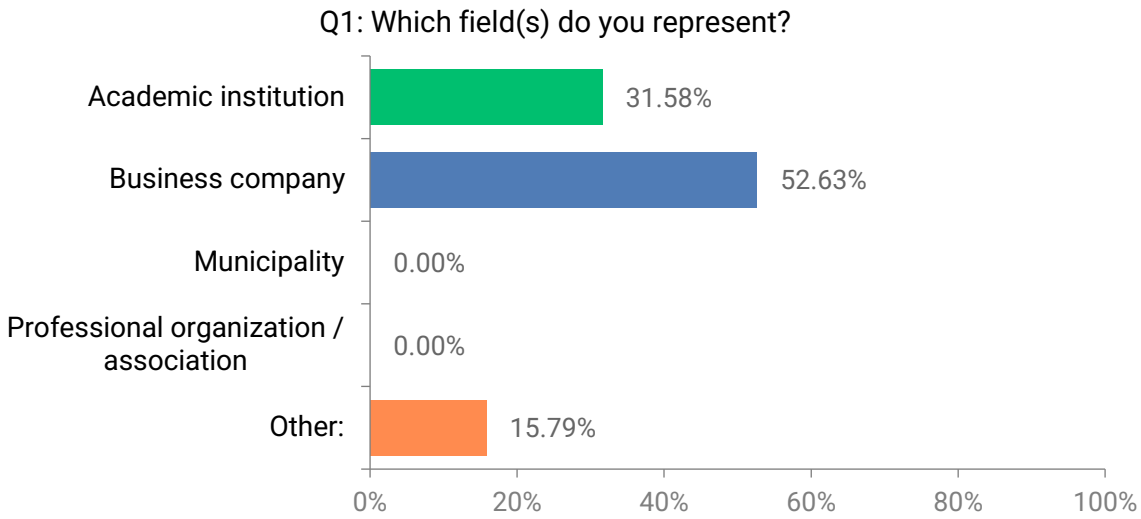
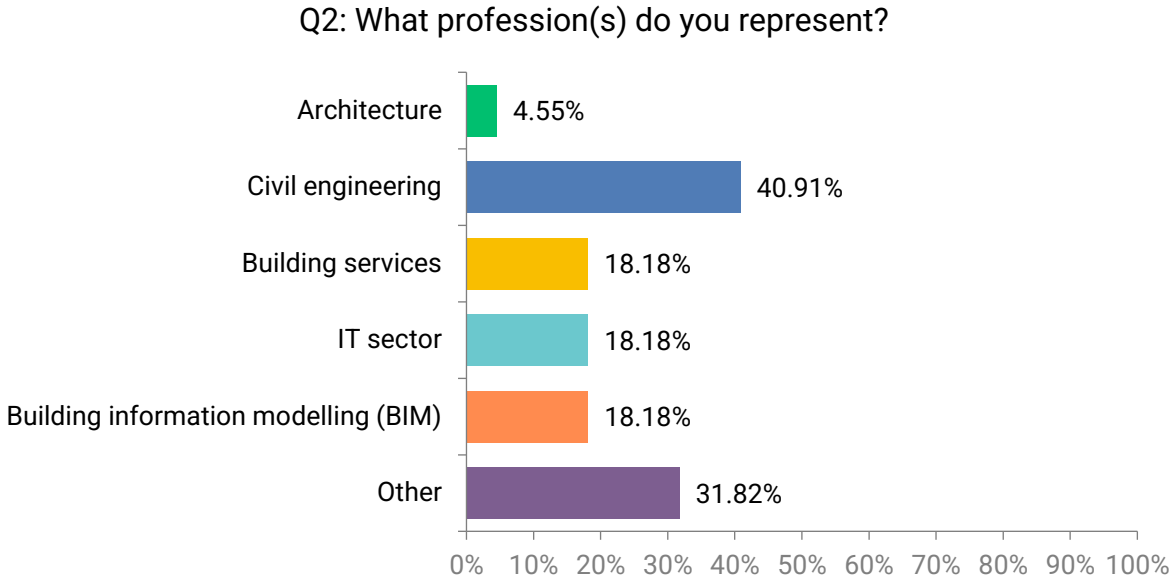
7. Annexes (All)

Annex 1. 1st citizens' event questionnaire on current knowledge of participants on Digital Twins.

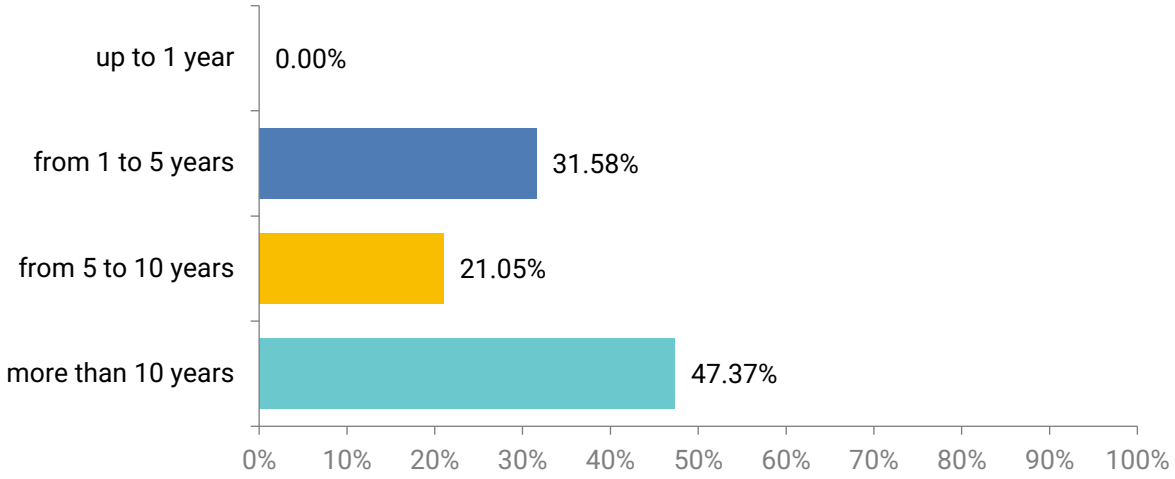


Other: Representatives from the ministries

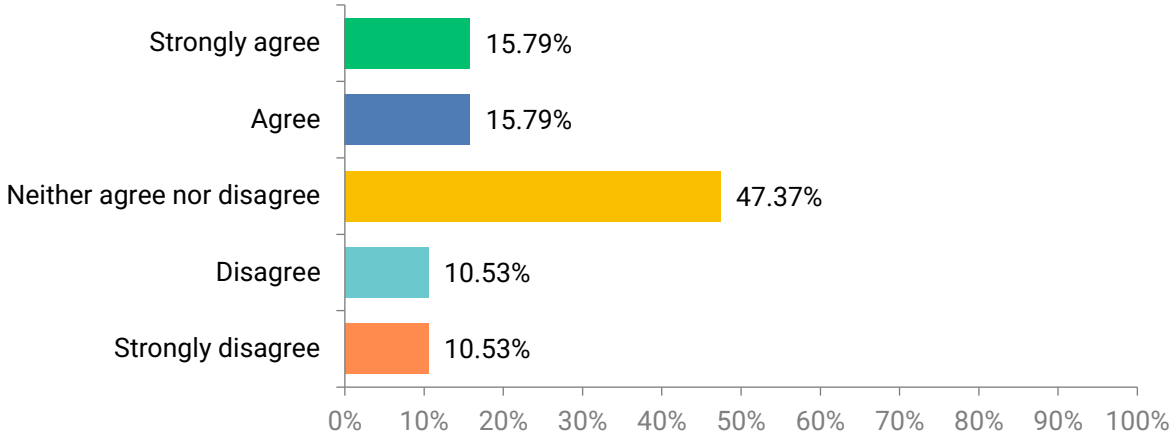


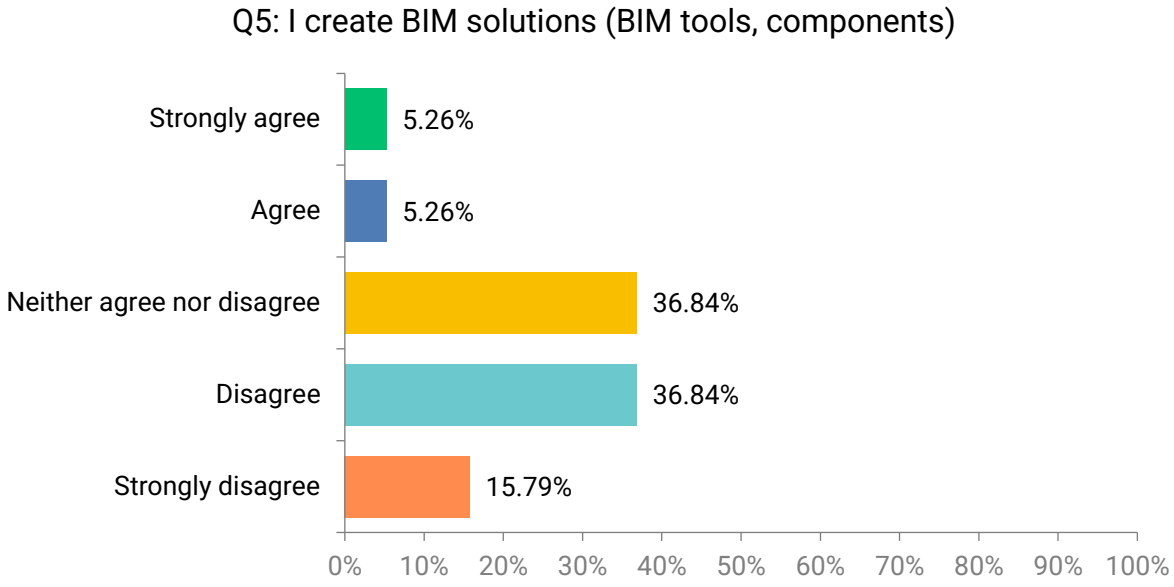
Other: Creation, management, and regulation of spatial data; 2x GIS (Geographic Information Systems), Policy formation, European Centre for Digital Innovation, Electrification, Project manager

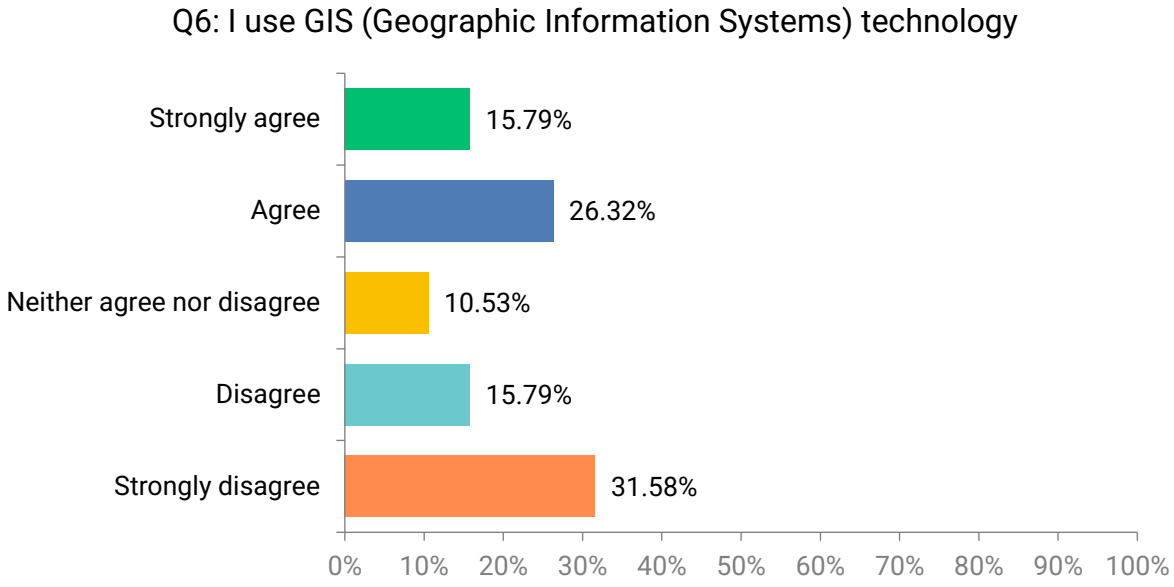
Q3: How many years of experience do you have in your main profession?

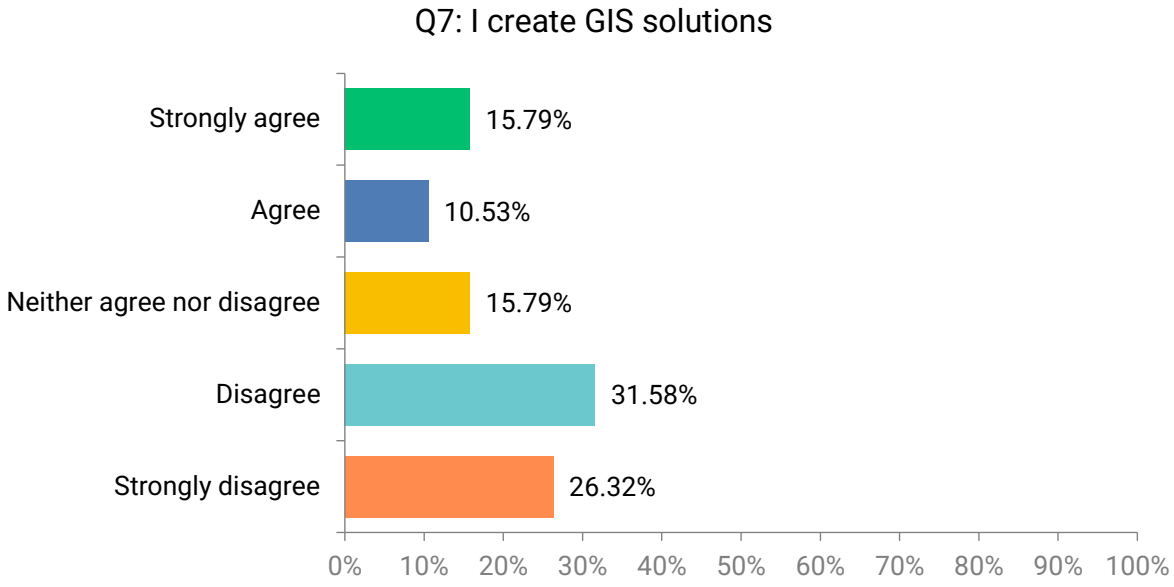


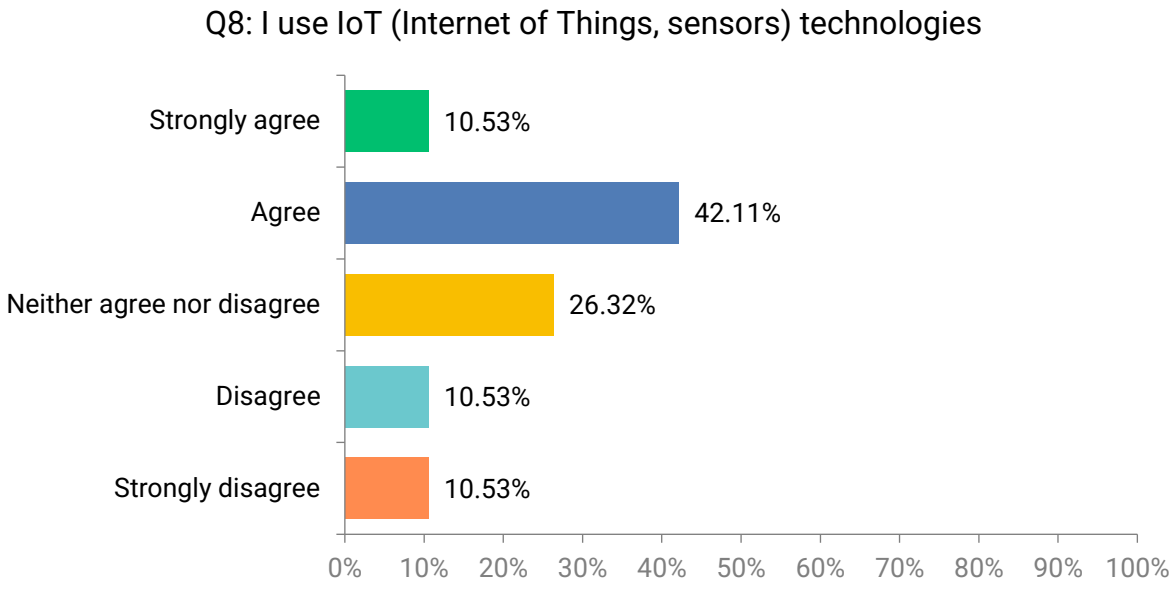
Q4: I work using BIM (Building Information Management) methodology (digital design, data exchange, data transfer for operation).

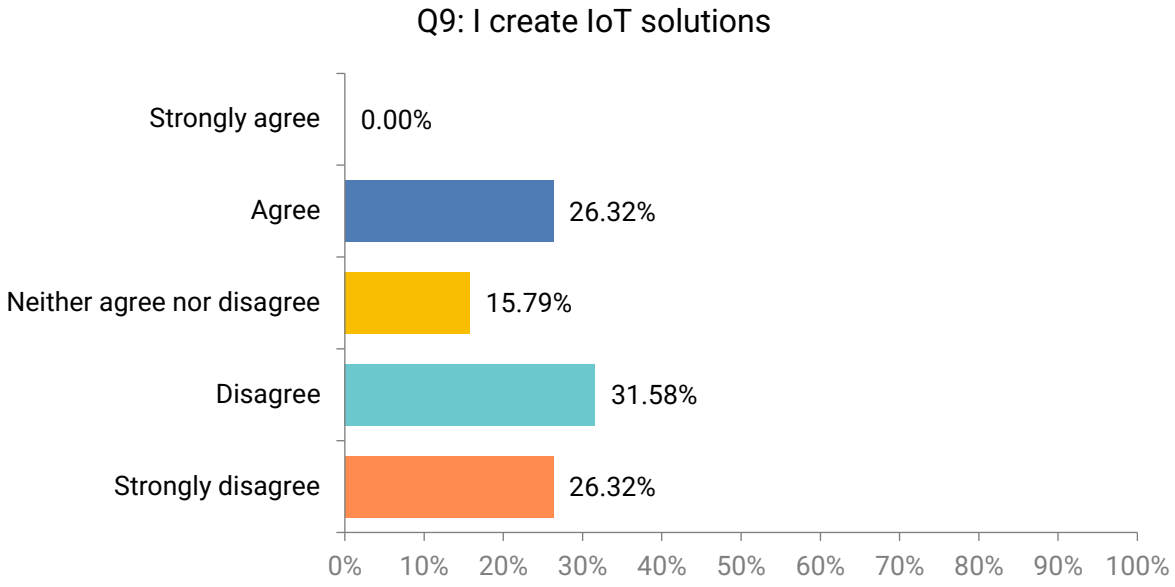


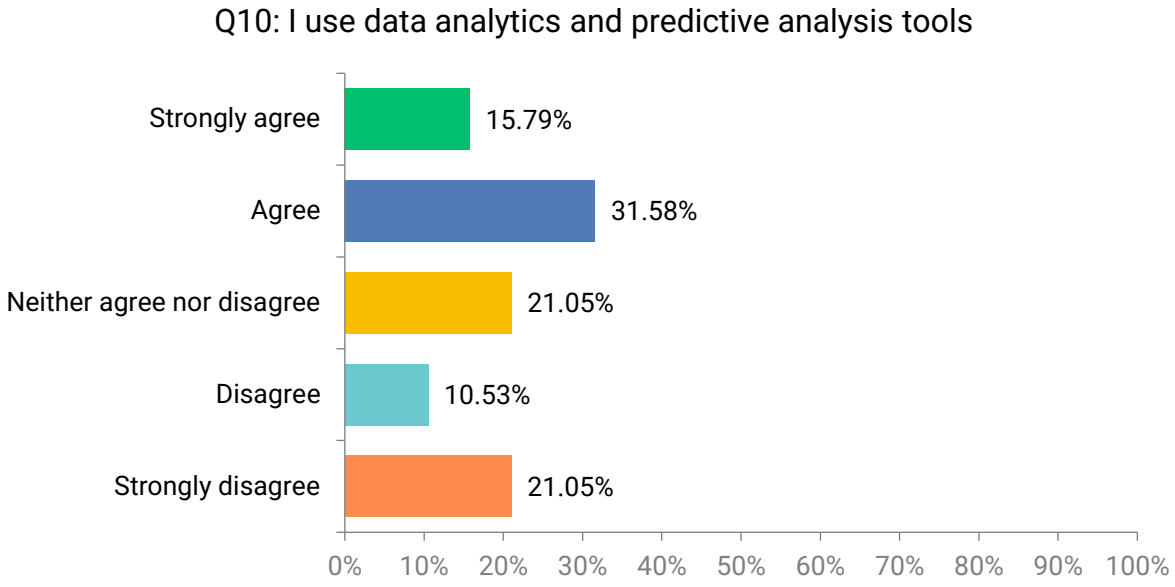

Q5: I create BIM solutions (BIM tools, components)
Strongly agree
5.26%
Agree
5.26%
Neither agree nor disagree
36.84%
Disagree
36.84%
Strongly disagree
15.79%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q6: I use GIS (Geographic Information Systems) technology
Strongly agree
15.79%
Agree
26.32%
Neither agree nor disagree
10.53%
Disagree
15.79%
Strongly disagree
31.58%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

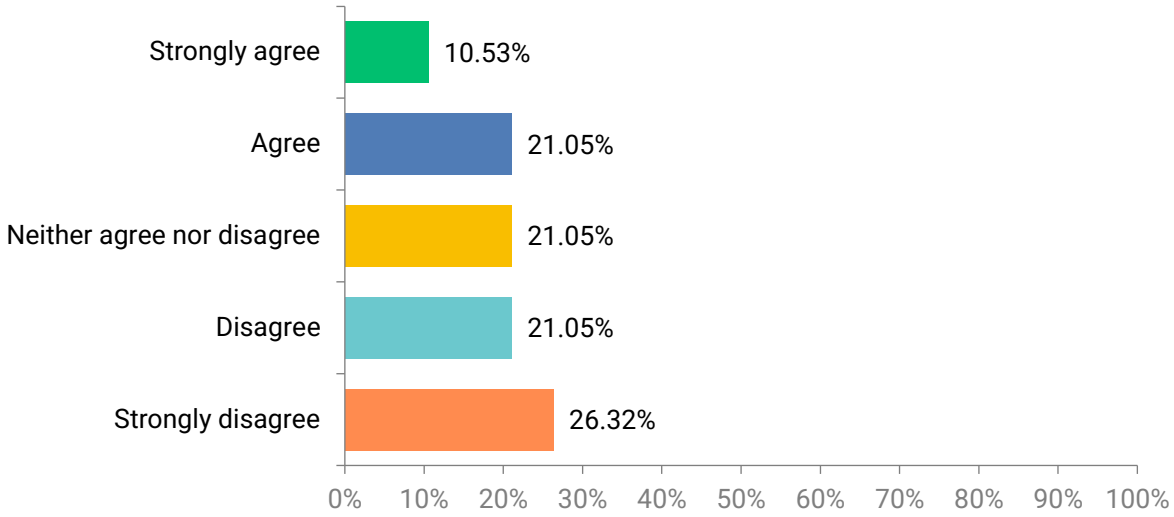

Q7: I create GIS solutions
Strongly agree
15.79%
Agree
10.53%
Neither agree nor disagree
15.79%
Disagree
31.58%
Strongly disagree
26.32%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q8: I use IoT (Internet of Things, sensors) technologies
Strongly agree
10.53%
Agree
42.11%
Neither agree nor disagree
26.32%
Disagree
10.53%
Strongly disagree
10.53%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

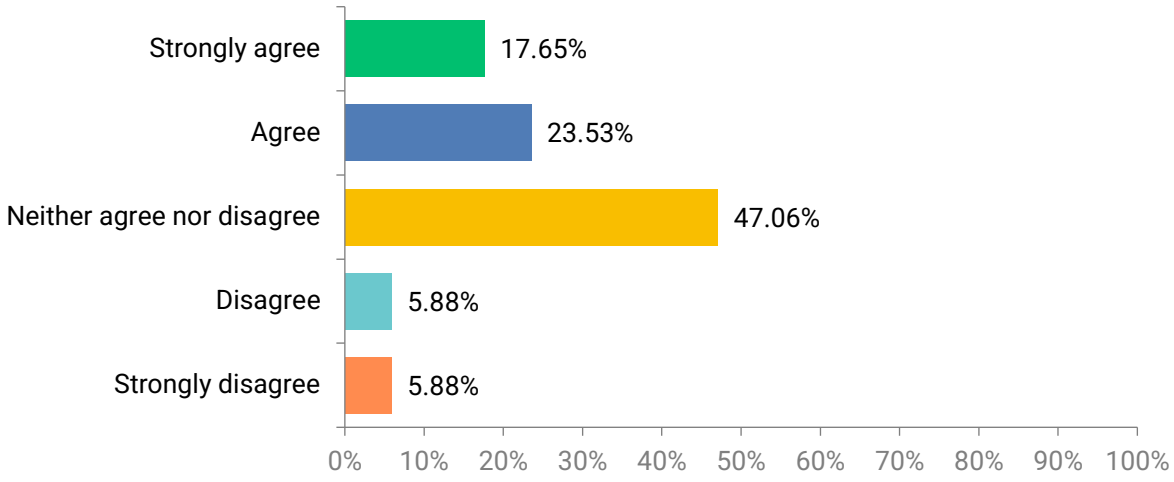

Q9: I create IoT solutions
Strongly agree
0.00%
Agree
26.32%
Neither agree nor disagree
15.79%
Disagree
31.58%
Strongly disagree
26.32%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q10: I use data analytics and predictive analysis tools
Strongly agree
15.79%
Agree
31.58%
Neither agree nor disagree
21.05%
Disagree
10.53%
Strongly disagree
21.05%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

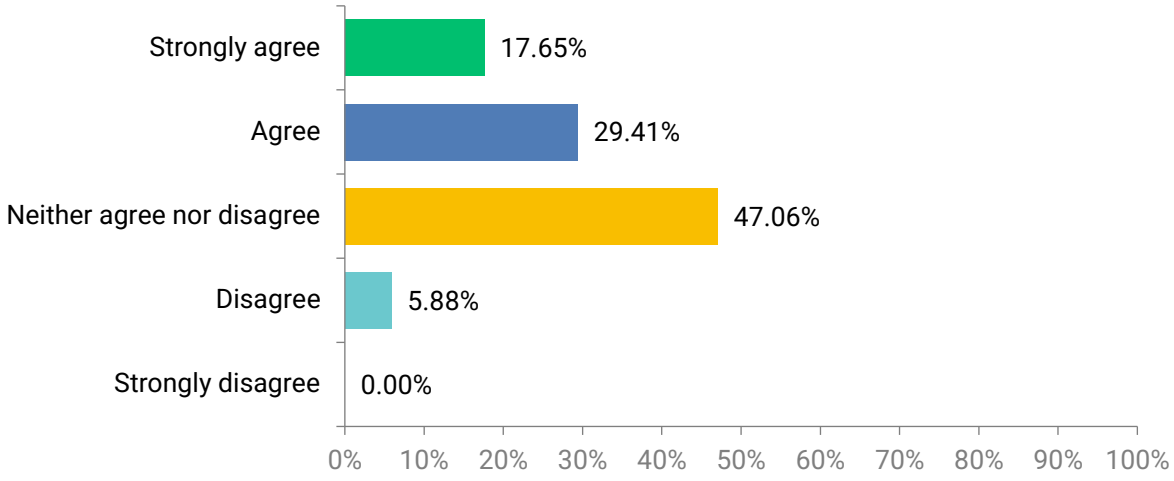
Q11: I create data analytics and predictive analysis tools



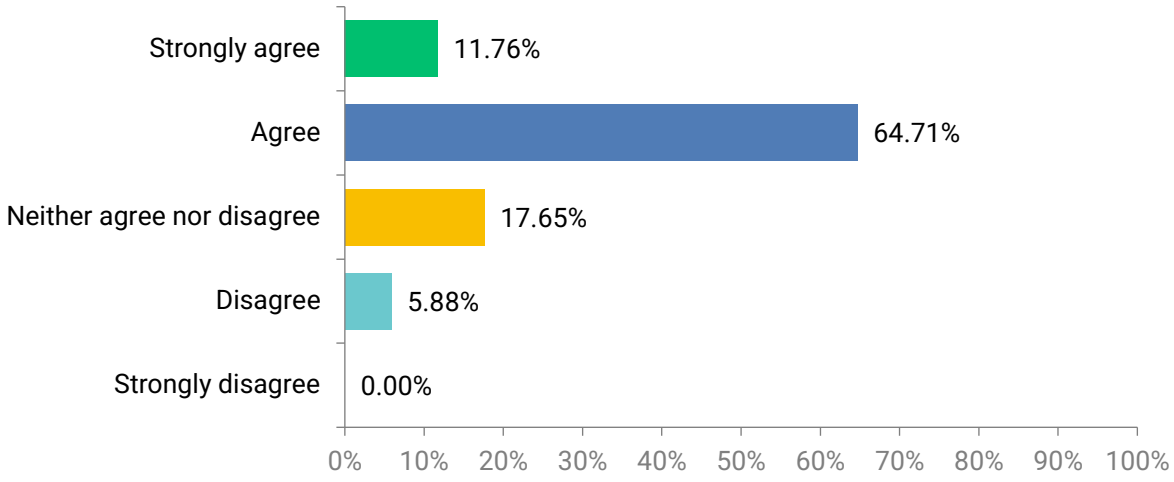
Q12: BIM technologies are widely applied in my environment (organization, sector)

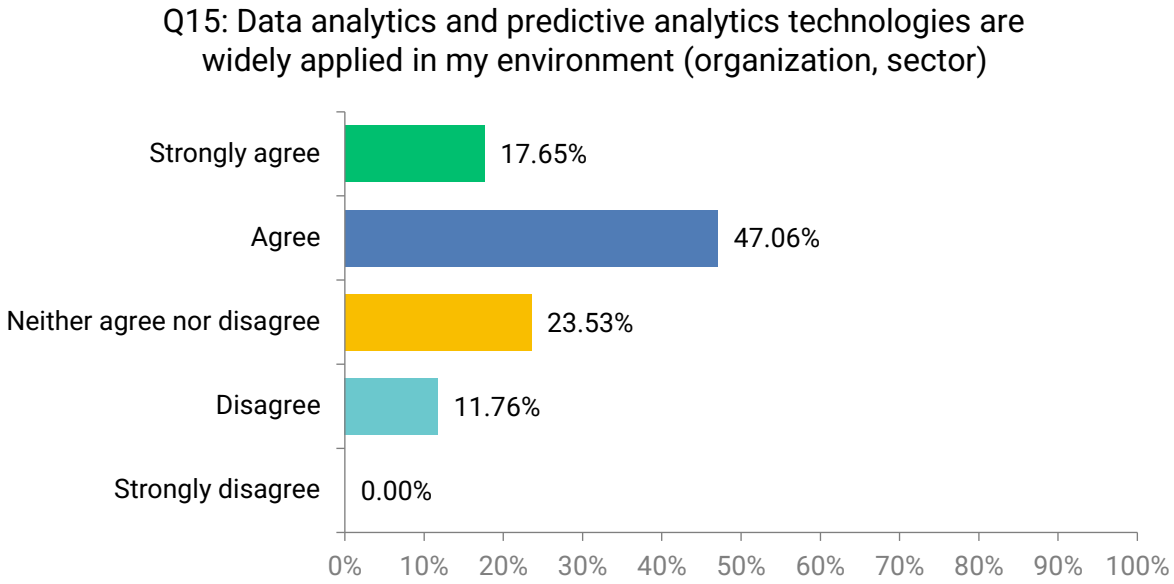


Q13: GIS technologies are widely applied in my environment (organization, sector)



Q14: IoT technologies are widely applied in my environment (organization, sector)





Q16: What benefits do you see in the application of digital twin technologies in your represented sector?

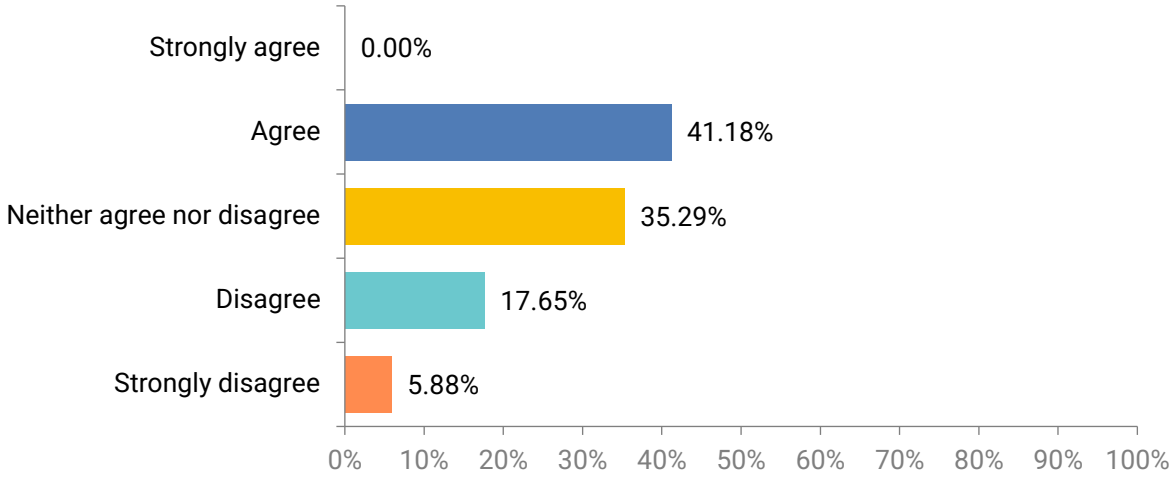
- More efficient, optimal operation, decision making, publication...
- Analysis, prediction, adaptation, execution, analysis
- Ability to visually present material to the client about their object
- Quality
- Since the topic is broad, I will answer abstractly: many benefits
- Asset accounting, data integration, decision quality
- Building exploitation
- Digitalization of projects, data accumulation in one place, prediction and avoidance of potential faults or failures.
- Data and information collection, analysis. Decision making.
- Broad question. Many benefits according to different interest groups
- Efficiency, reliability
- Opportunities for broader cooperation between science and business
- Data management and timely problem solving

- Historical data
- Time-saving,
- Don't know

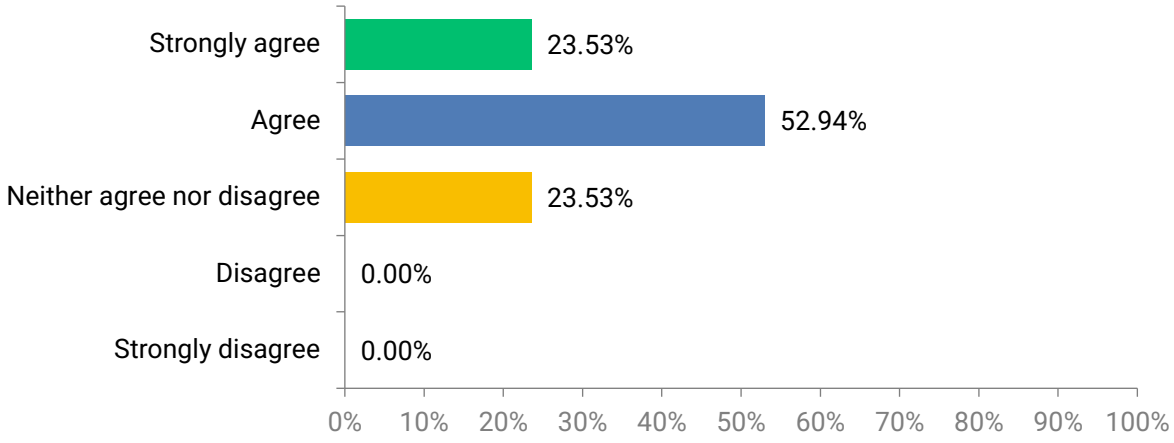
Q17: What are the main obstacles to the implementation of these technologies in your represented sector?

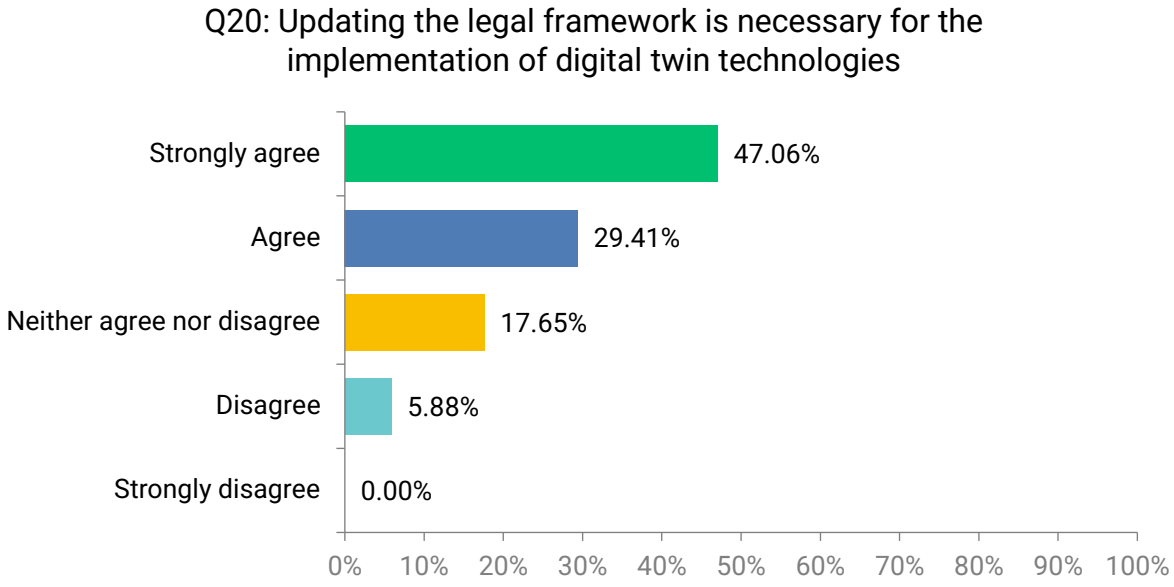
- Lack of a unified data classifier, lack of integrated solutions.
- Lack of understanding
- Implementing such technologies requires experience and also educating clients about potential benefits
- Lack of competence tools
- Policy formation, insufficient involvement
- High costs, different implementation methods, lack of final solutions
- Non-use.
- Unpopularity. Unclear understanding of why it is needed. Clients' desire to save as much as possible.
- Adaptation, costs, and time.
- The government's inability to standardize, set a clear strategy
- Technological challenges
- Lack of corporate knowledge and unpreparedness
- I represent a very narrow field, having little influence on the entire Smartwins project
- Lack of desire
- No unified system, too many interpretations
- Don't know

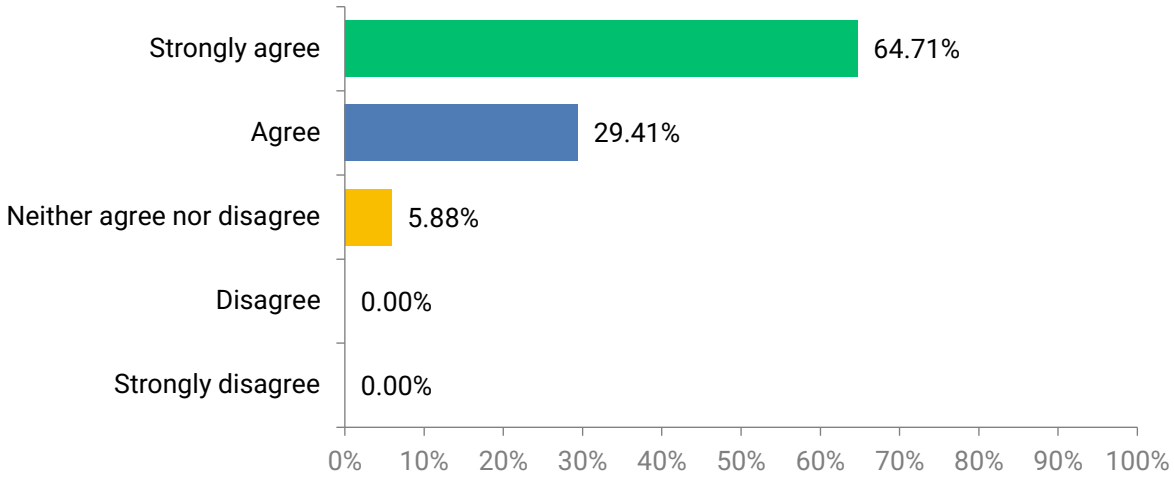
Q18: At this time, the technologies are not yet sufficiently developed for digital twins to be widely applied



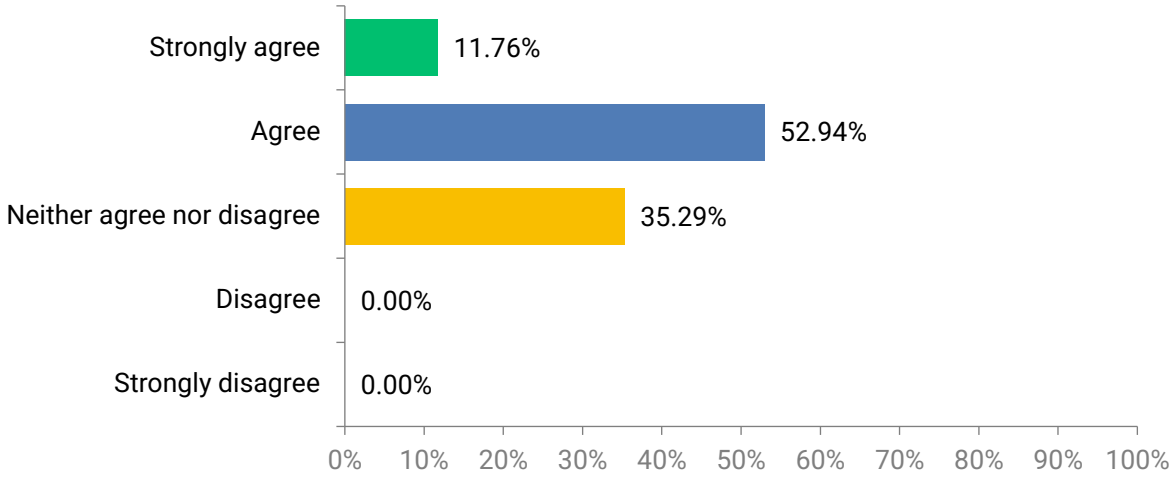
Q19: The market lacks specialists capable of working with digital twin technologies, their application is limited by a lack of knowledge



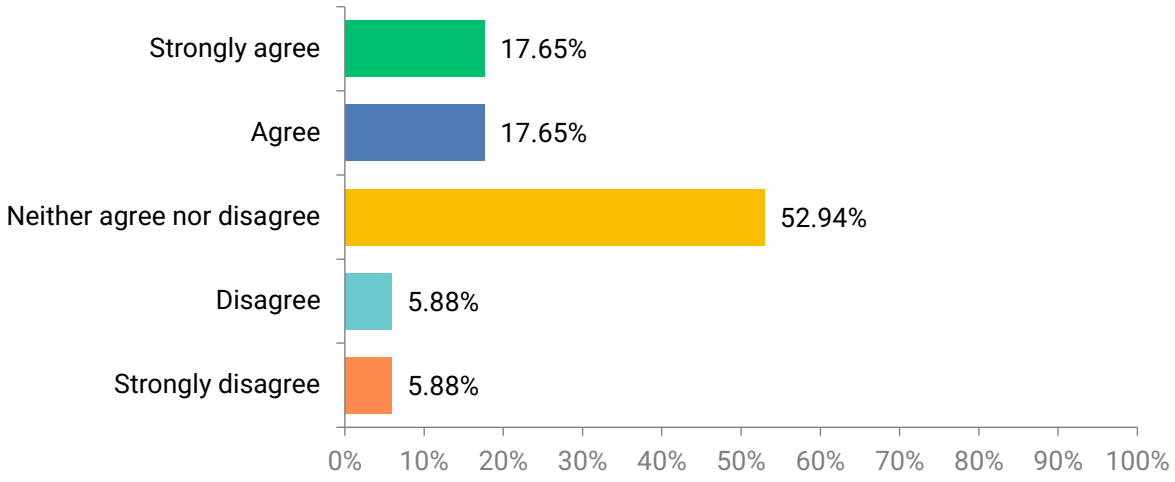

Q20: Updating the legal framework is necessary for the implementation of digital twin technologies
Strongly agree
47.06%
Agree
29.41%
Neither agree nor disagree
17.65%
Disagree
5.88%
Strongly disagree
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

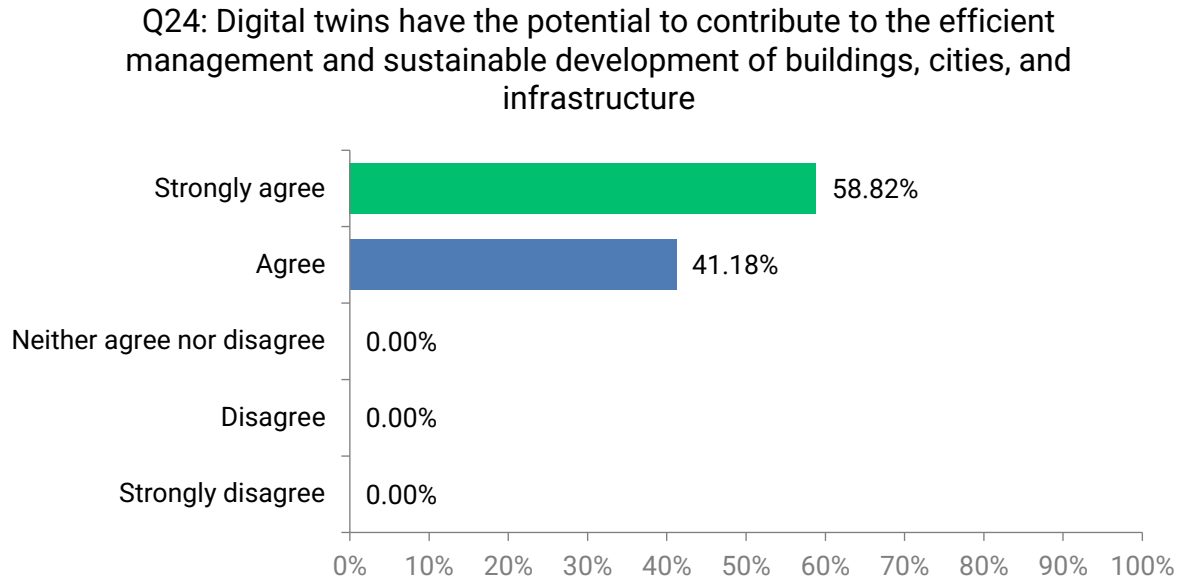

Q21: Digital twins can increase the transparency of city management
Strongly agree
64.71%
Agree
29.41%
Neither agree nor disagree
5.88%
Disagree
0.00%
Strongly disagree
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Q22: The security of digital twin data and their public accessibility can pose risks



Q23: It is challenging to ensure personal data privacy and data security when creating digital twins



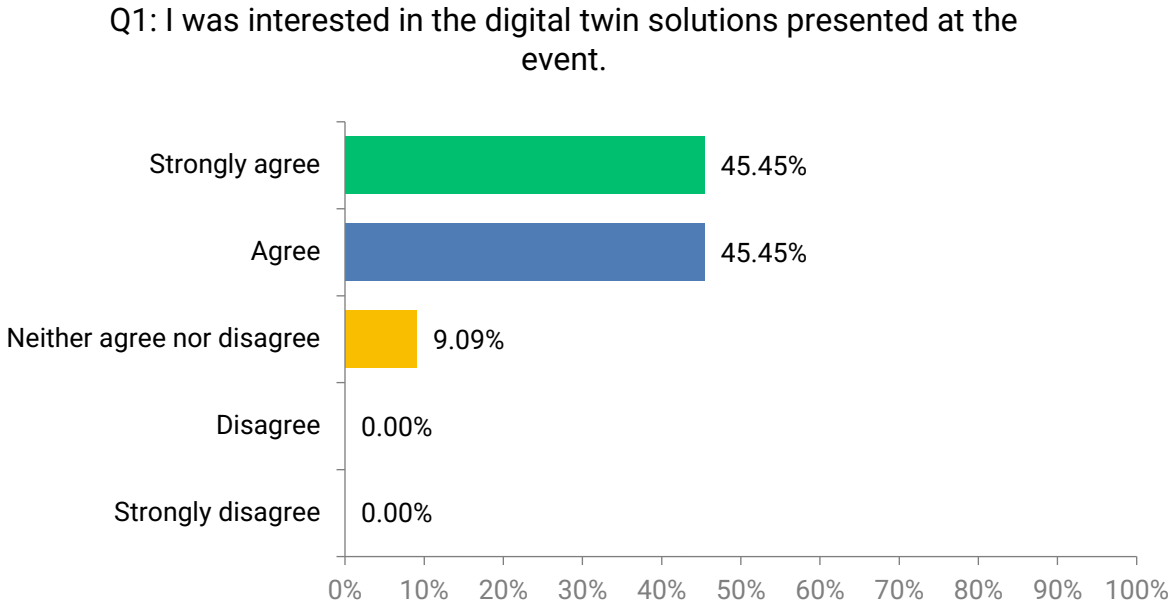


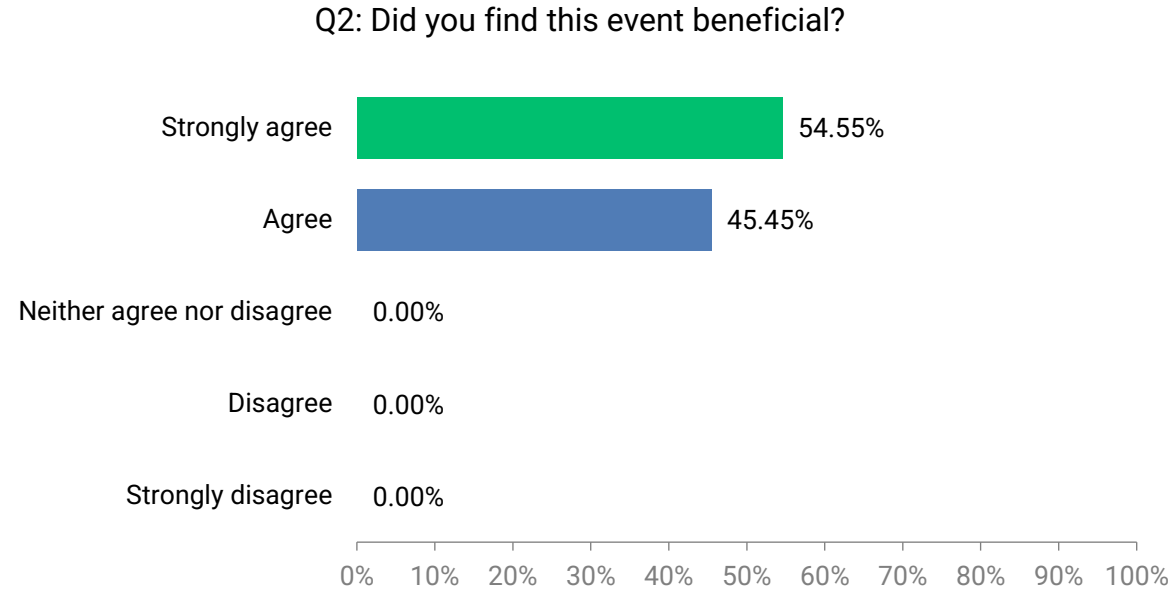
Q25: Identify the areas where the application of digital twin technologies would bring maximum benefit

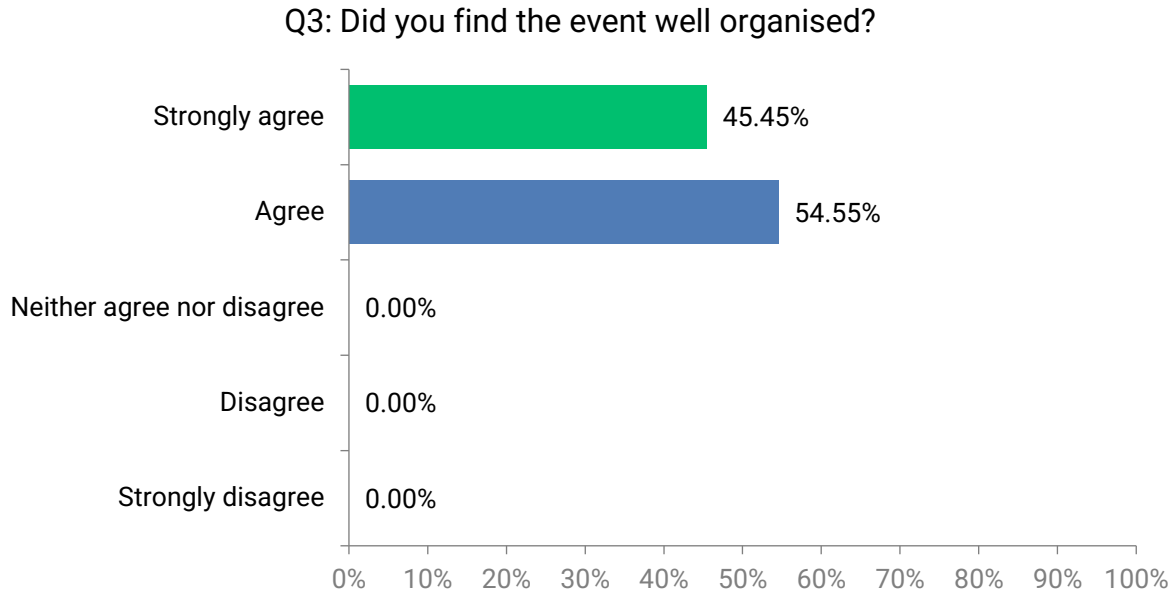
- Territory planning, construction, property management, environmental protection, management of built environments, heritage preservation.
- Private sector, business sector (offices, shopping centers, etc.). WOULD NOT APPLY TO: critical infrastructure, due to the potential for significant security compromise.
- Building maintenance
- Design, construction, use
- Asset accounting
- Real estate development, operation of engineering communications, urban planning
- Don't know
- City management
- Infrastructure planning, efficient resource management.
- Planning, property management and operation, public safety, and others.
- Infrastructure

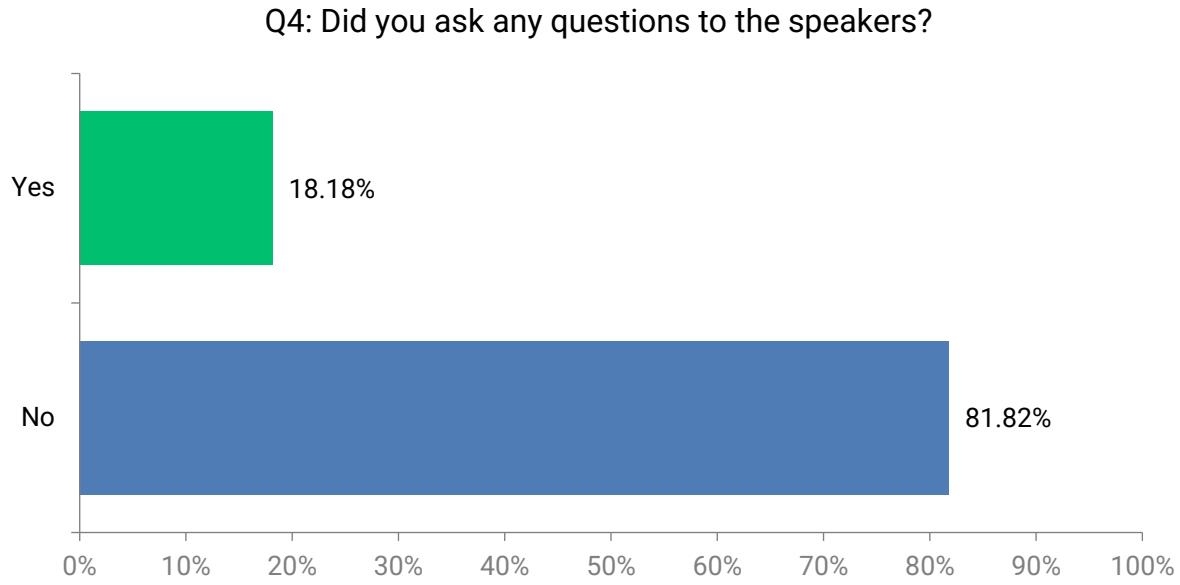
- For more efficient city management, renovation, and maintenance
- In urban planning and city planning
- Construction and urbanism
- Practically in all
- In the planning of cities and their infrastructure
- Construction

Annex 2. Survey on the 1st citizens' event "SmartWins with digital twins"

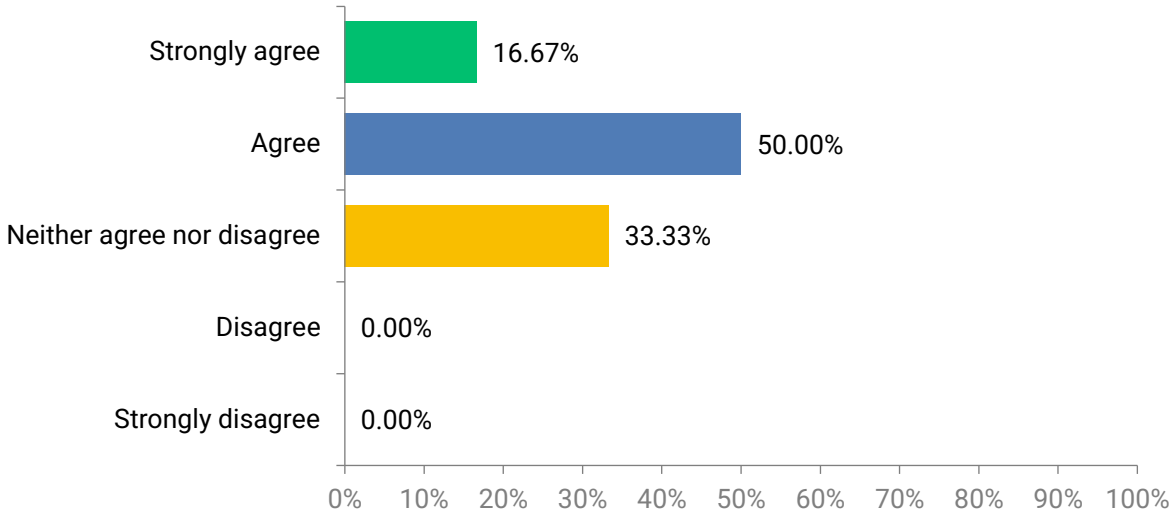




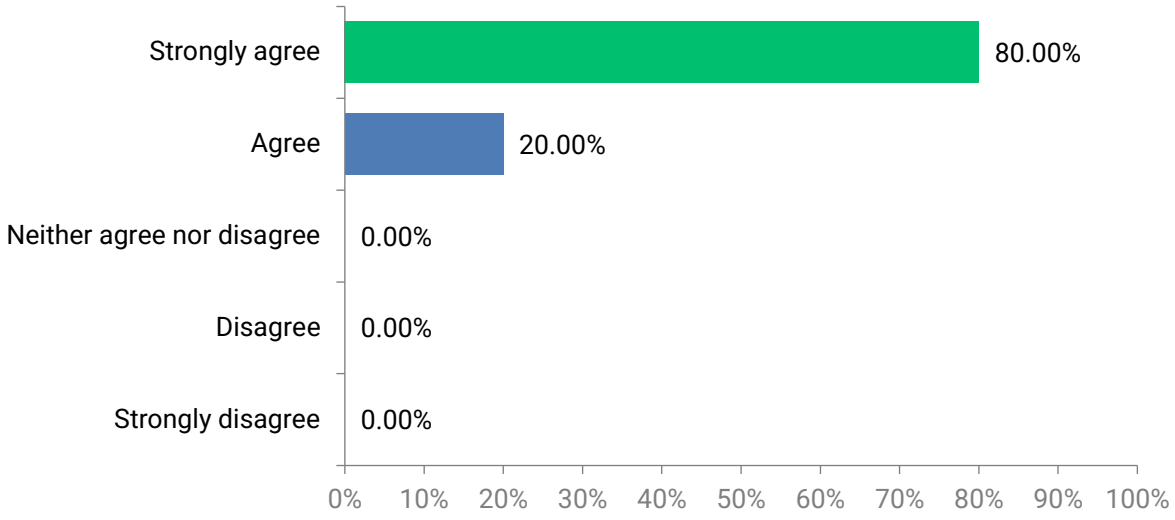

Q3: Did you find the event well organised?
Strongly agree
45.45%
Agree
54.55%
Neither agree nor disagree
0.00%
Disagree
0.00%
Strongly disagree
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q4: Did you ask any questions to the speakers?
Yes
18.18%
No
81.82%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

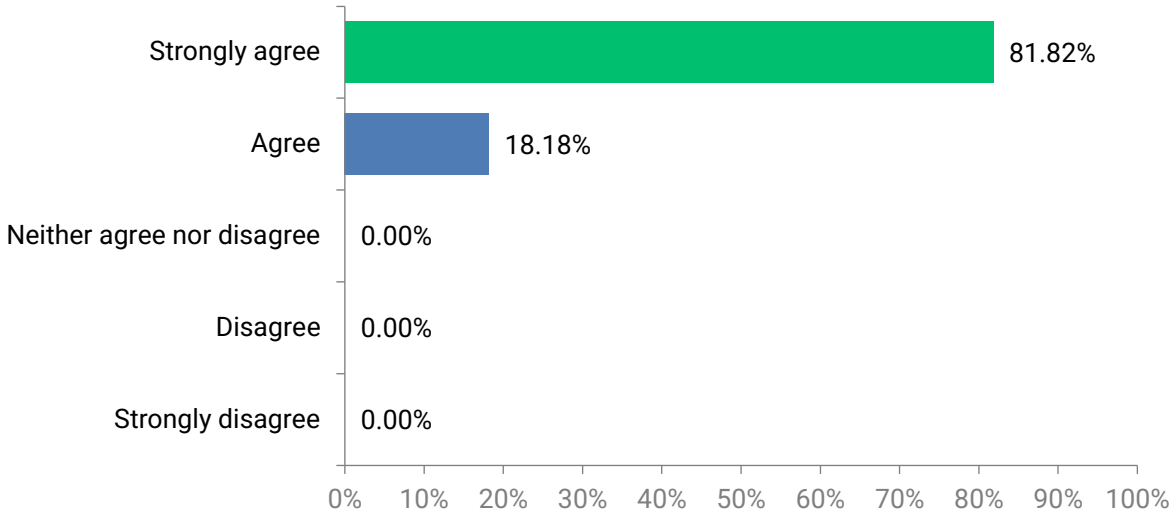
Q5: If yes, were you satisfied with the answers to your questions?



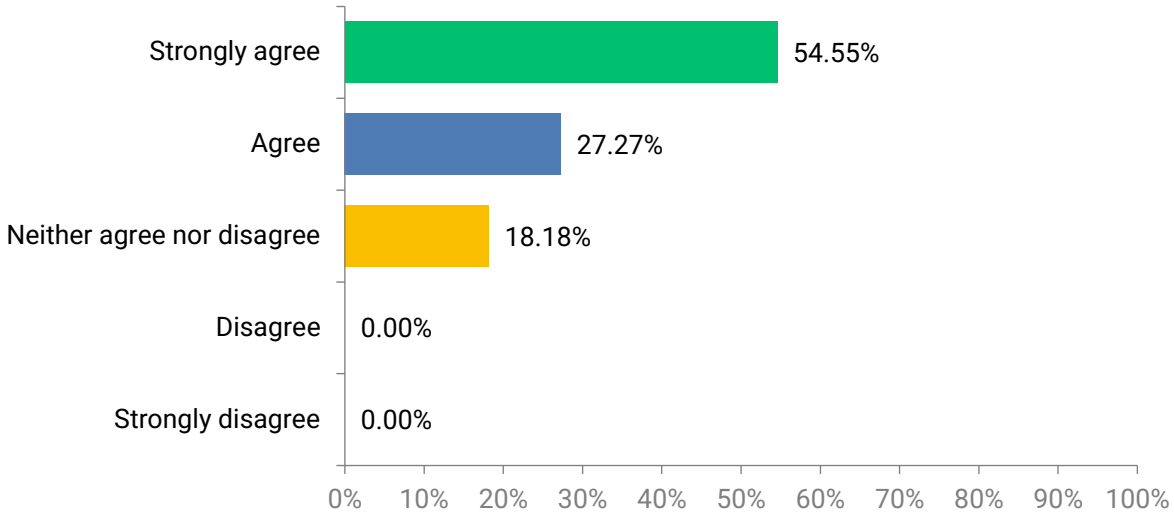
Q6: Were the speakers' interactions with you pleasant?

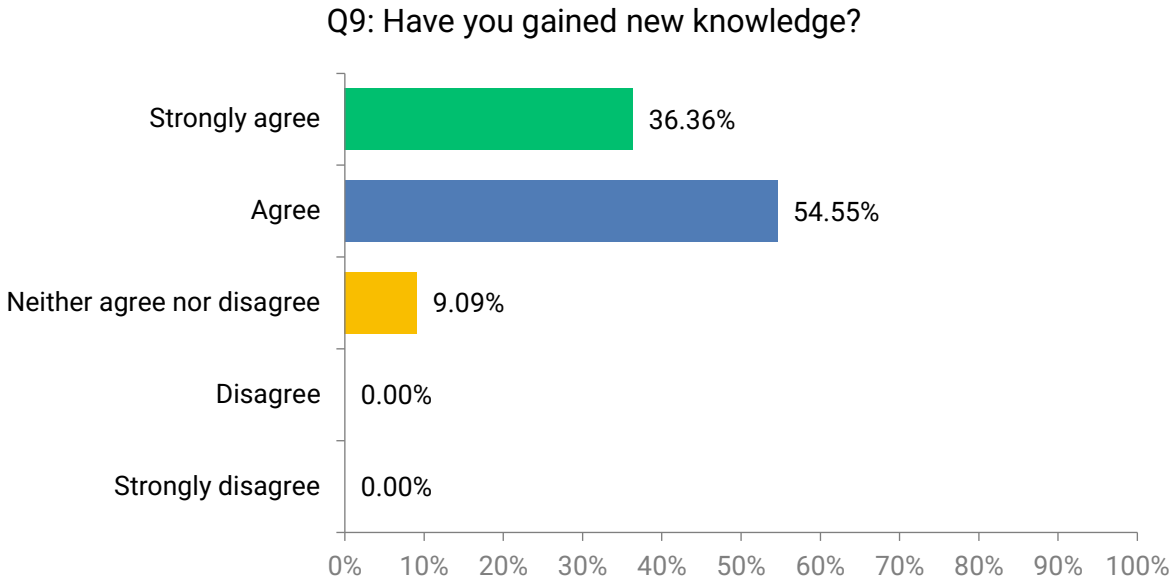


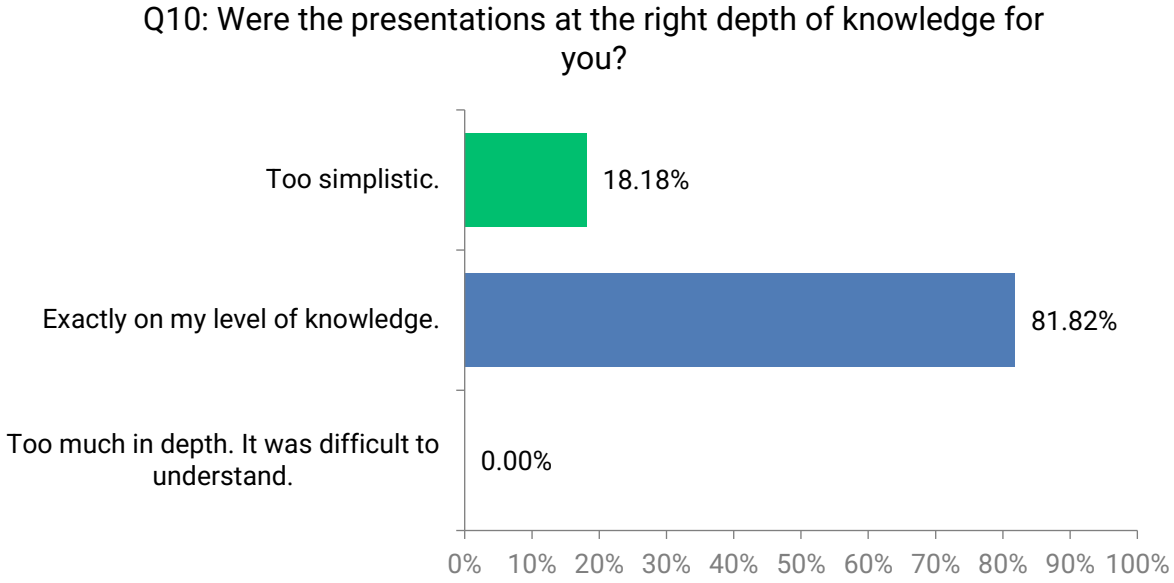
Q7: Were the speakers' interactions with others pleasant?



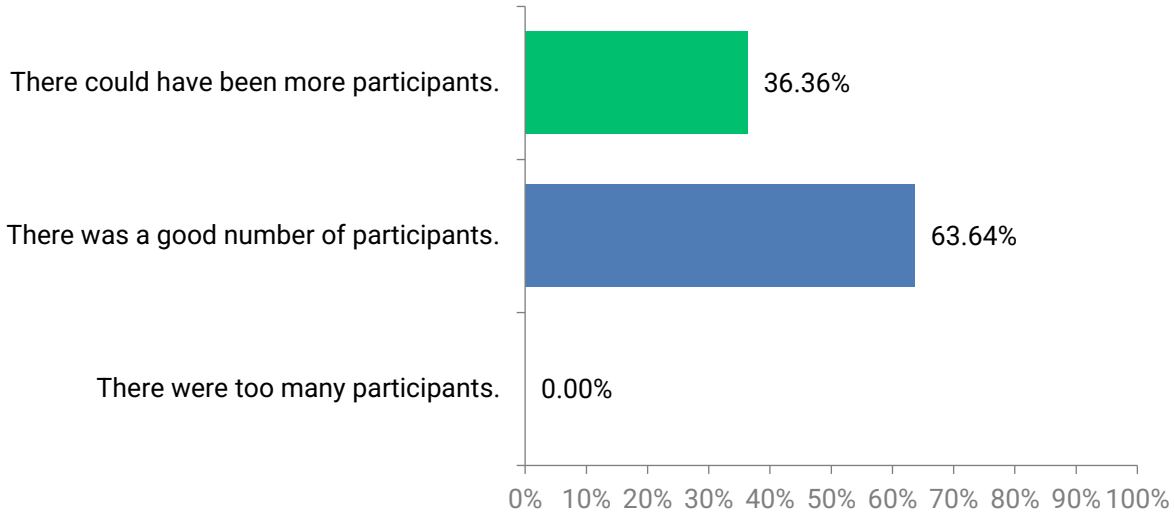
Q8: Did you feel involved in the activities of this event?



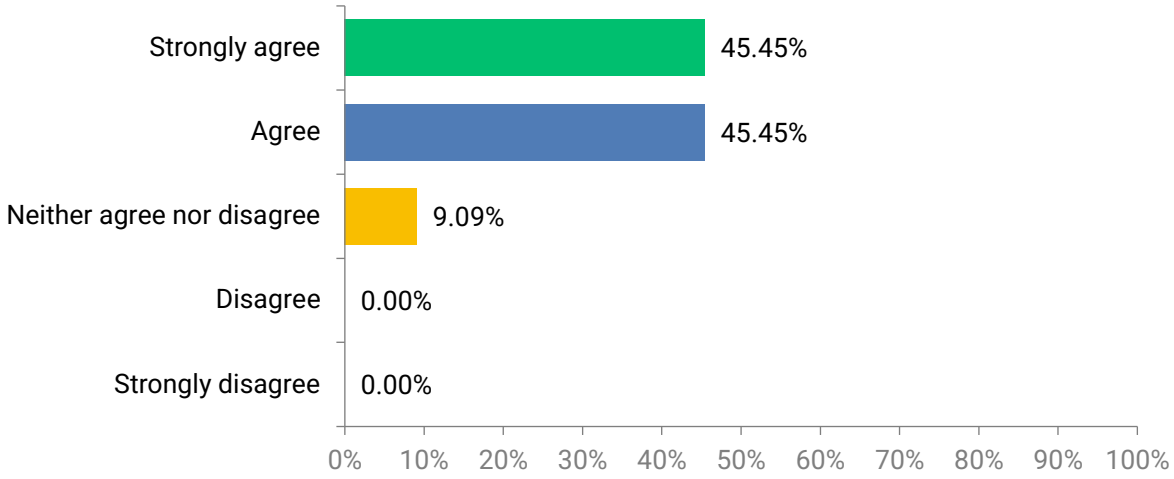

Q9: Have you gained new knowledge?
Strongly agree
36.36%
Agree
54.55%
Neither agree nor disagree
9.09%
Disagree
0.00%
Strongly disagree
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

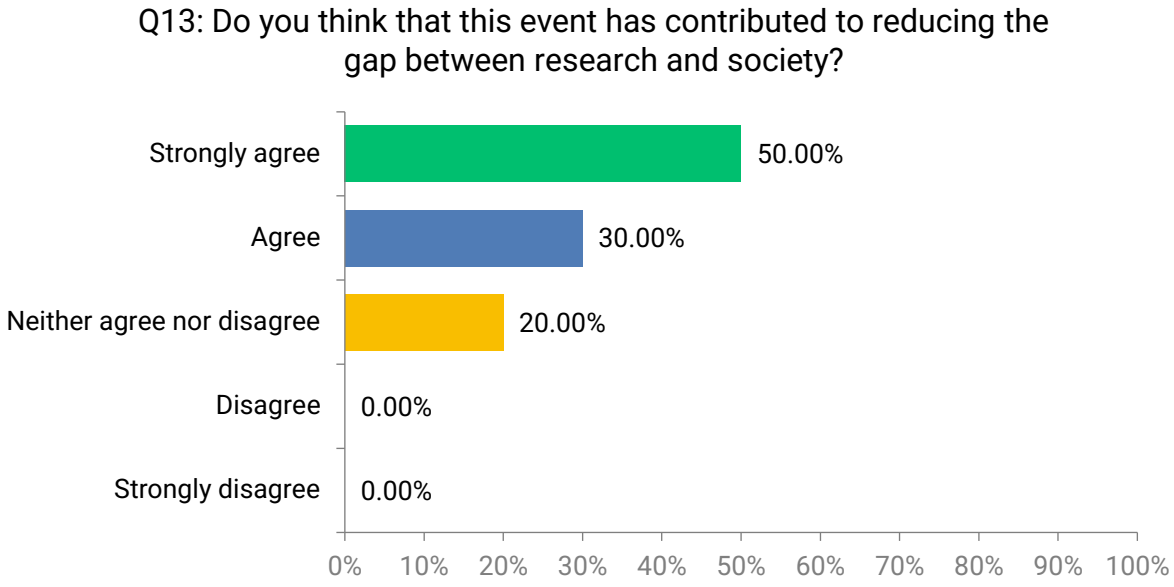

Q10: Were the presentations at the right depth of knowledge for you?
Too simplistic.
18.18%
Exactly on my level of knowledge.
81.82%
Too much in depth. It was difficult to understand.
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Q11: Was the number of participants good?

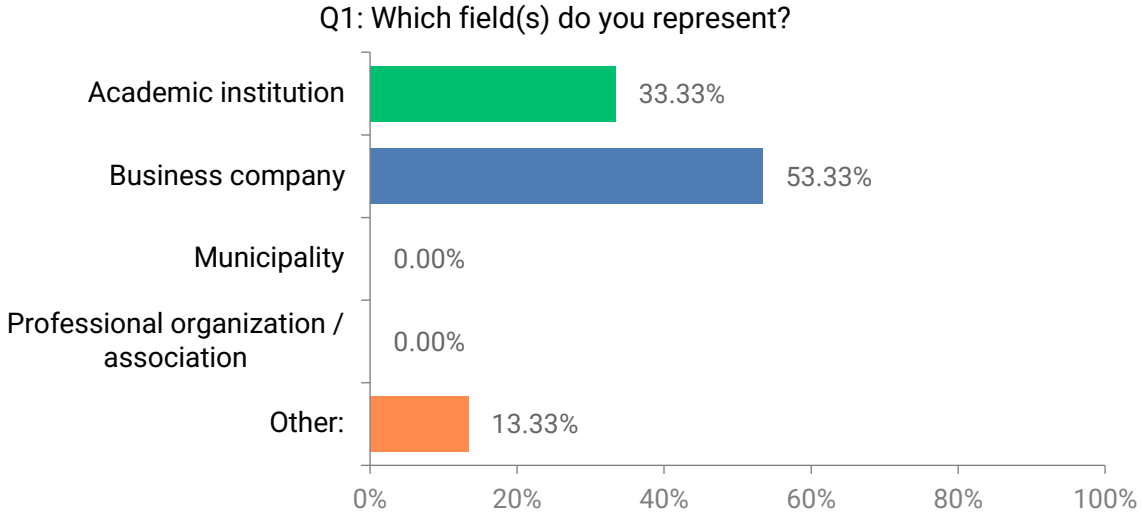


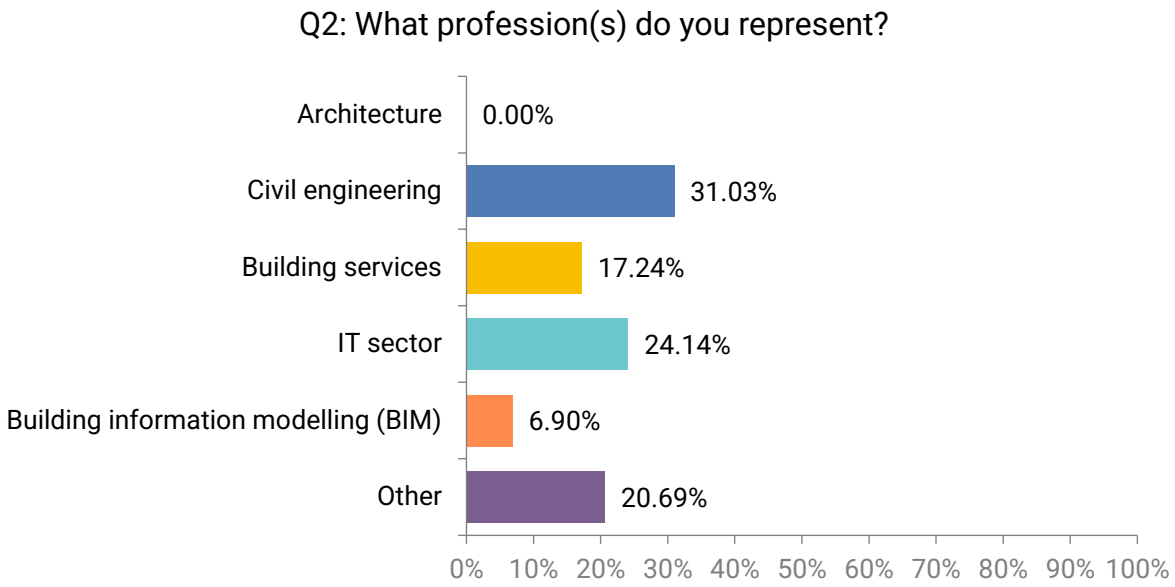
Q12: Would you recommend SmartWins events to your colleagues/friends?



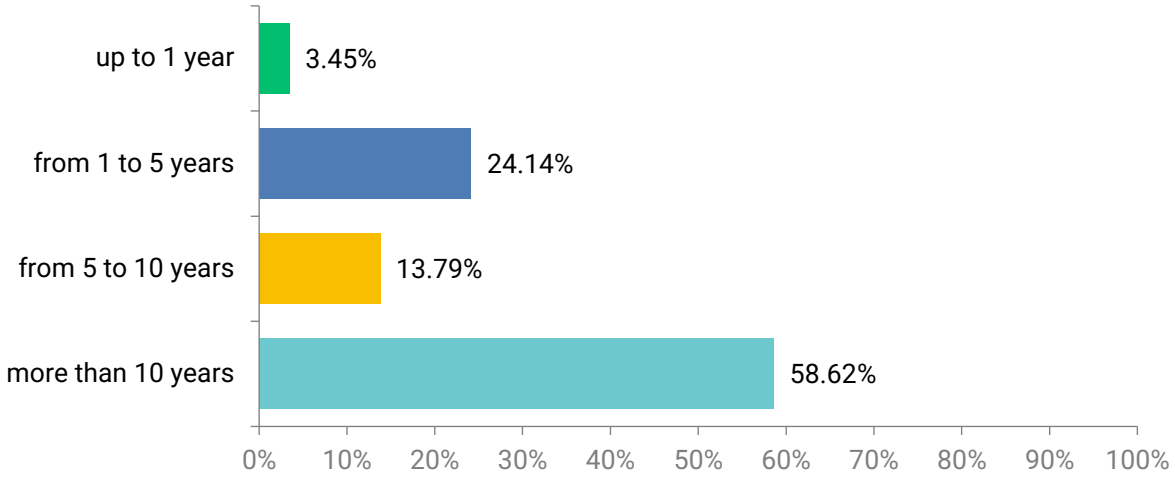

Q13: Do you think that this event has contributed to reducing the gap between research and society?
Strongly agree
50.00%
Agree
30.00%
Neither agree nor disagree
20.00%
Disagree
0.00%
Strongly disagree
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Annex 3. 2nd citizens' event questionnaire on current knowledge of participants on Digital Twins.

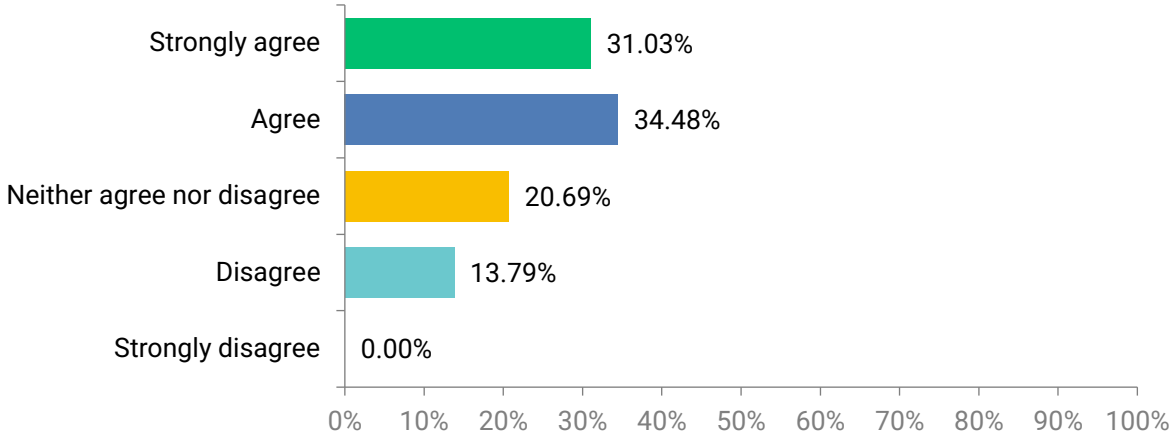




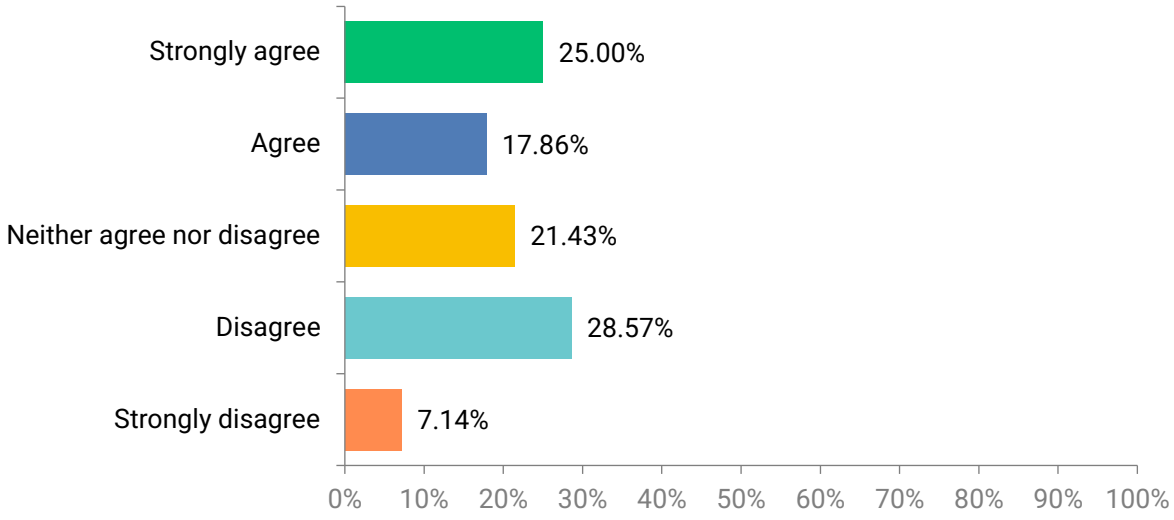
Q3: How many years of experience do you have in your main profession?



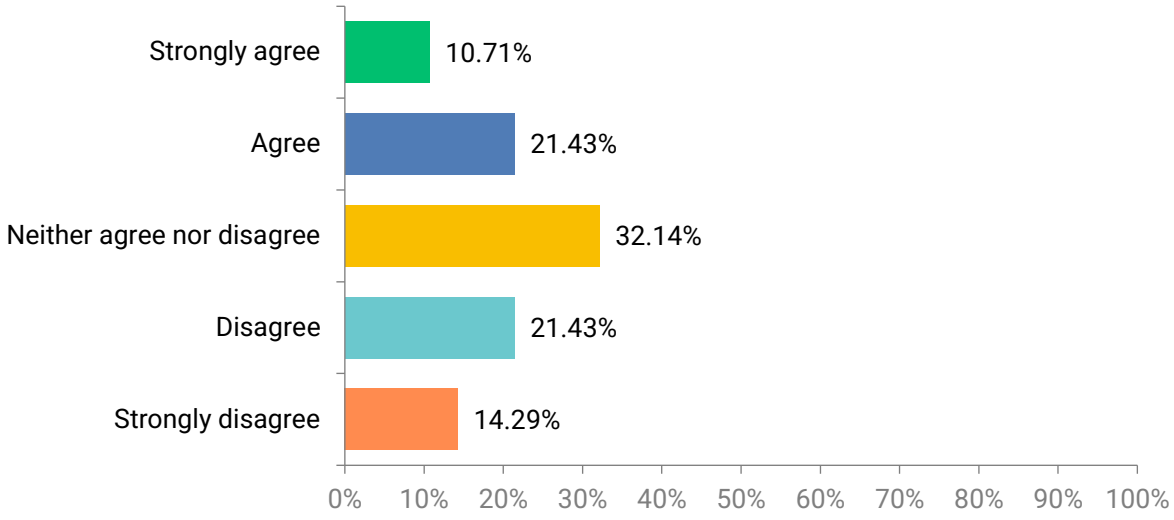
Q4: I work using BIM (Building Information Management) methodology (digital design, data exchange, data transfer for operation).

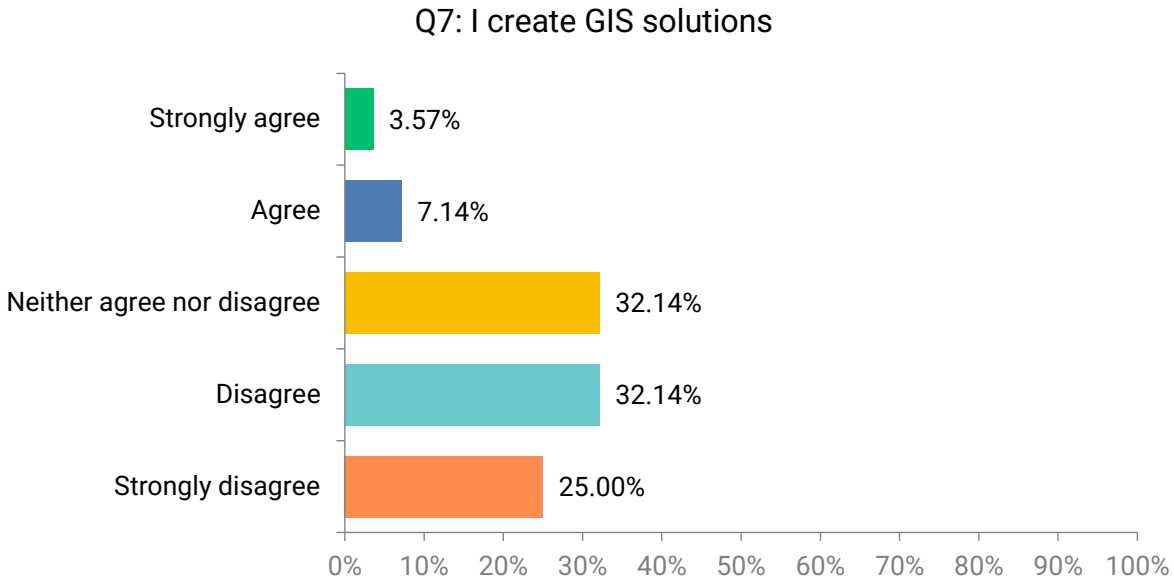


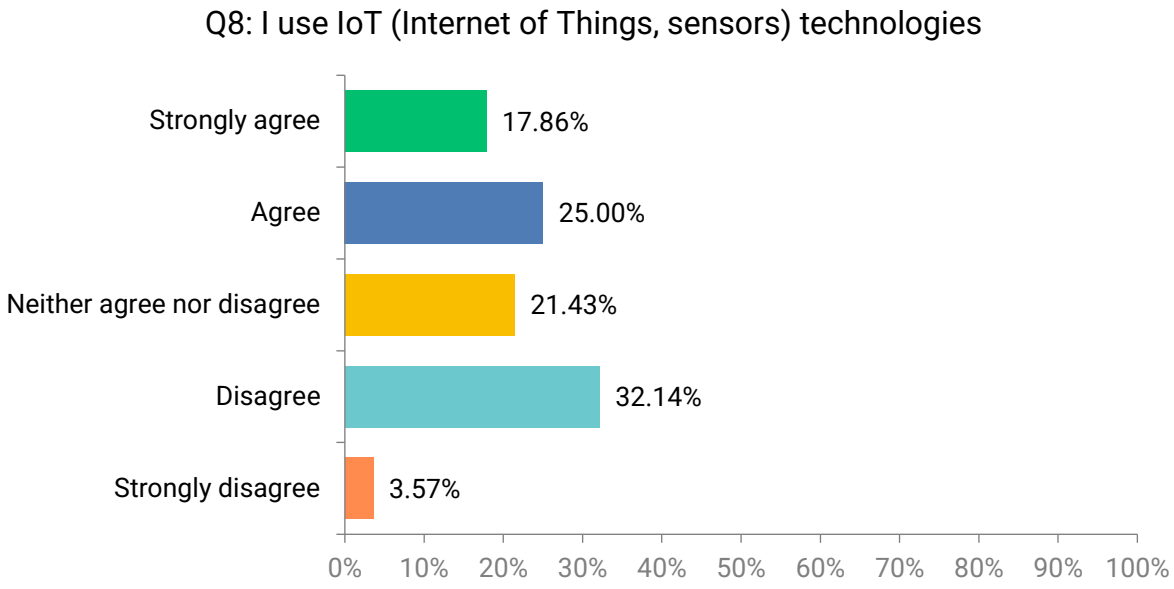
Q5: I create BIM solutions (BIM tools, components)

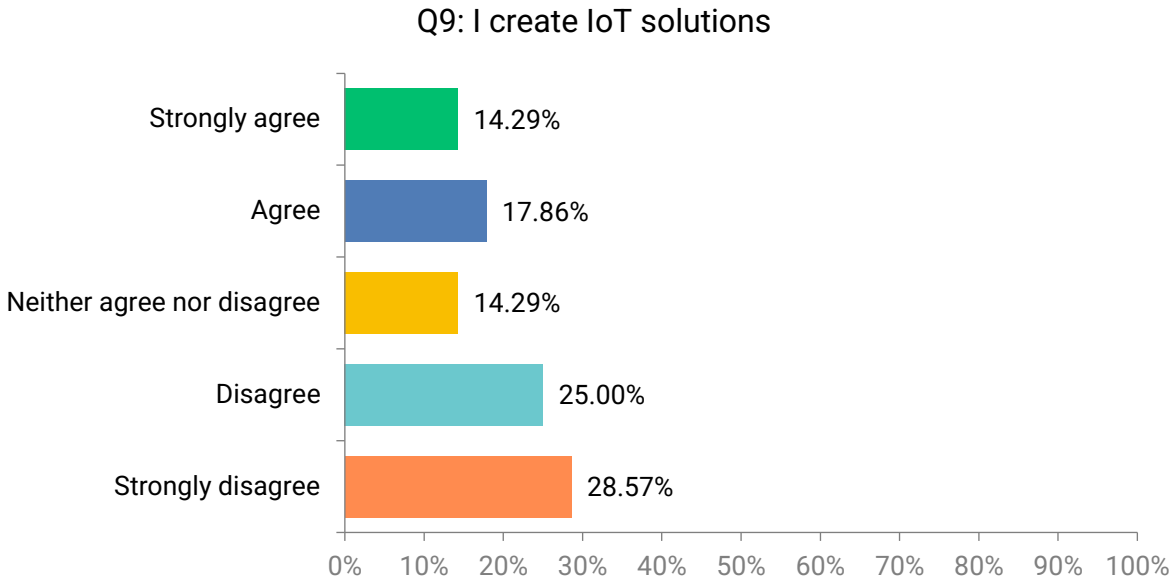


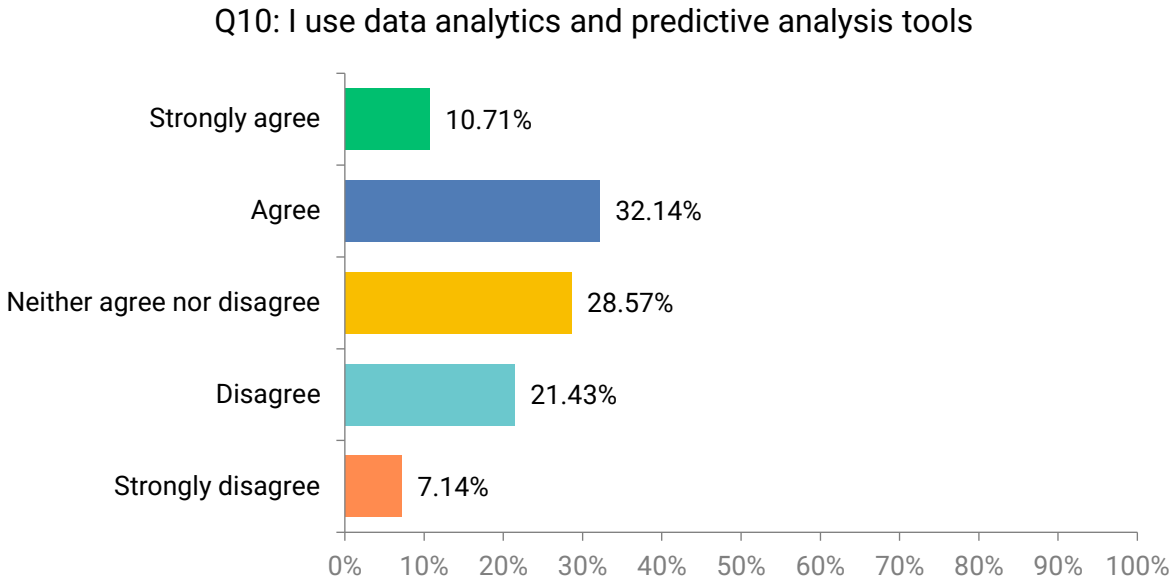
Q6: I use GIS (Geographic Information Systems) technology



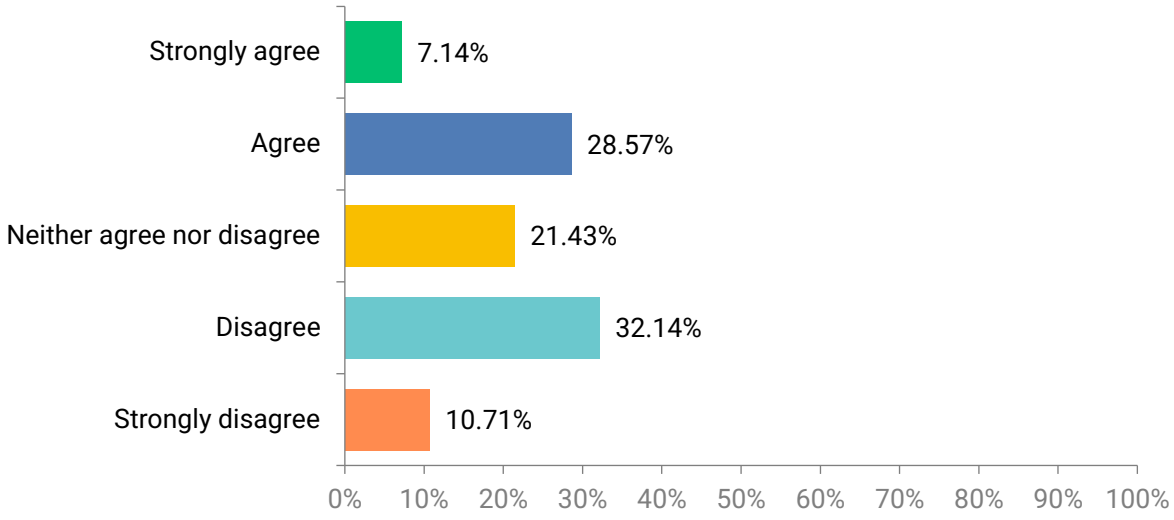

Q7: I create GIS solutions
Strongly agree
3.57%
Agree
7.14%
Neither agree nor disagree
32.14%
Disagree
32.14%
Strongly disagree
25.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q8: I use IoT (Internet of Things, sensors) technologies
Strongly agree
17.86%
Agree
25.00%
Neither agree nor disagree
21.43%
Disagree
32.14%
Strongly disagree
3.57%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

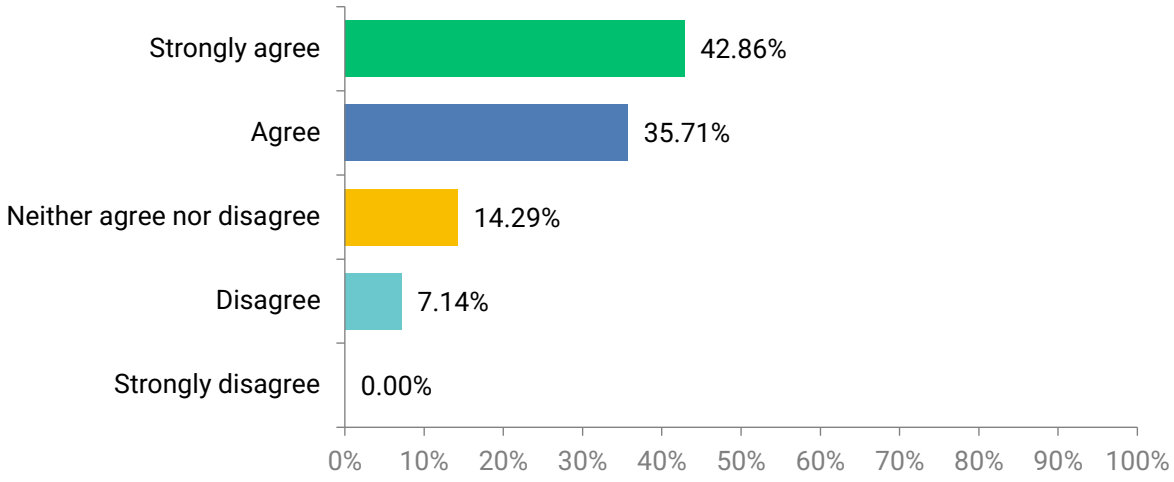

Q9: I create IoT solutions
Strongly agree
14.29%
Agree
17.86%
Neither agree nor disagree
14.29%
Disagree
25.00%
Strongly disagree
28.57%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q10: I use data analytics and predictive analysis tools
Strongly agree
10.71%
Agree
32.14%
Neither agree nor disagree
28.57%
Disagree
21.43%
Strongly disagree
7.14%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

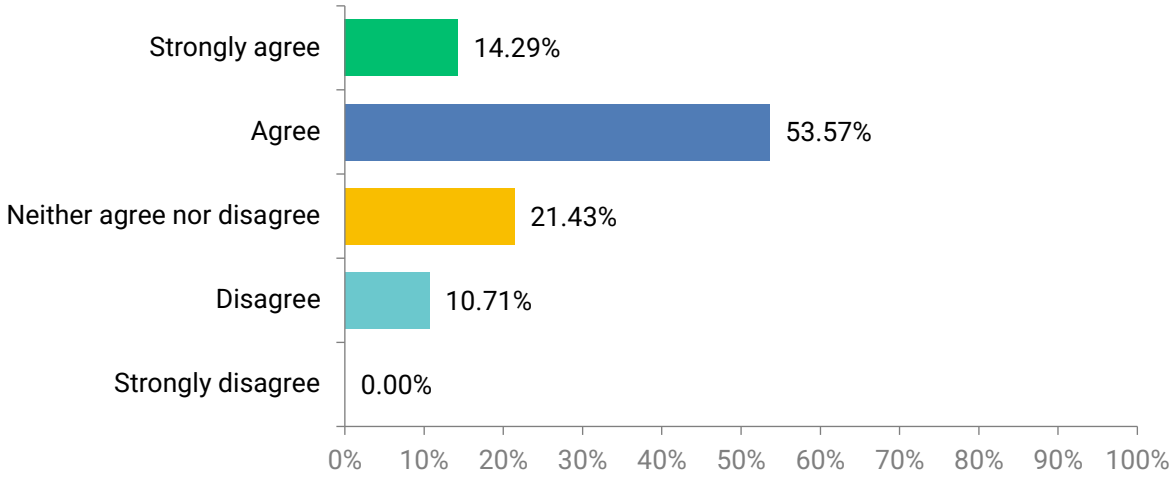
Q11: I create data analytics and predictive analysis tools



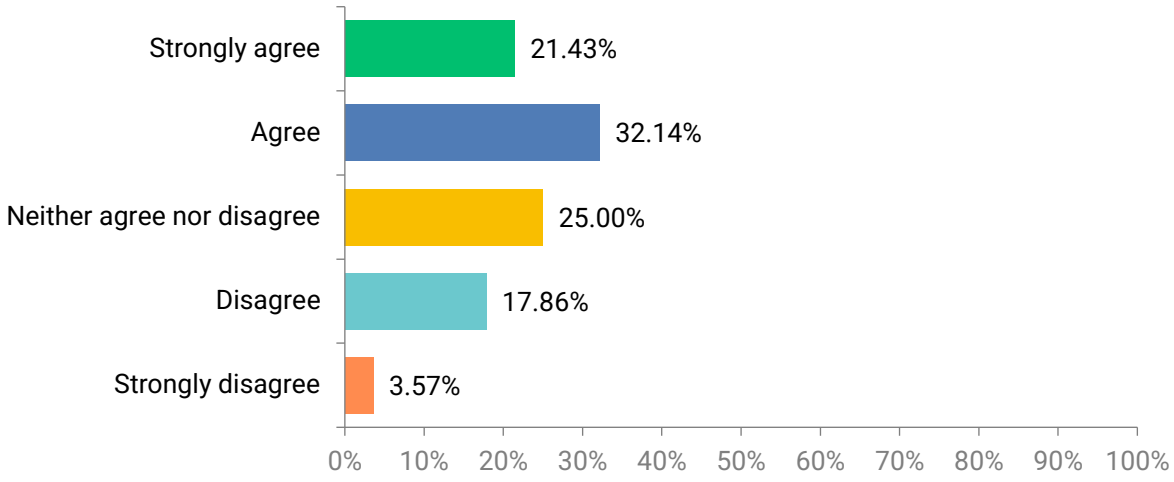
Q12: BIM technologies are widely applied in my environment (organization, sector)

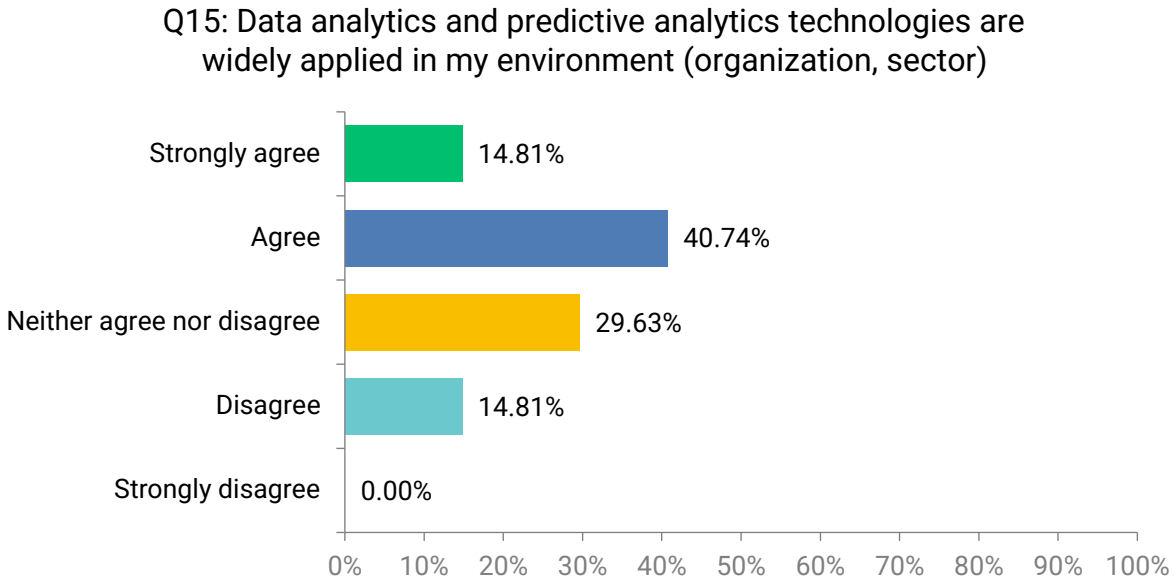


Q13: GIS technologies are widely applied in my environment (organization, sector)



Q14: IoT technologies are widely applied in my environment (organization, sector)





Q16: What benefits do you see in the application of digital twin technologies in your represented sector?

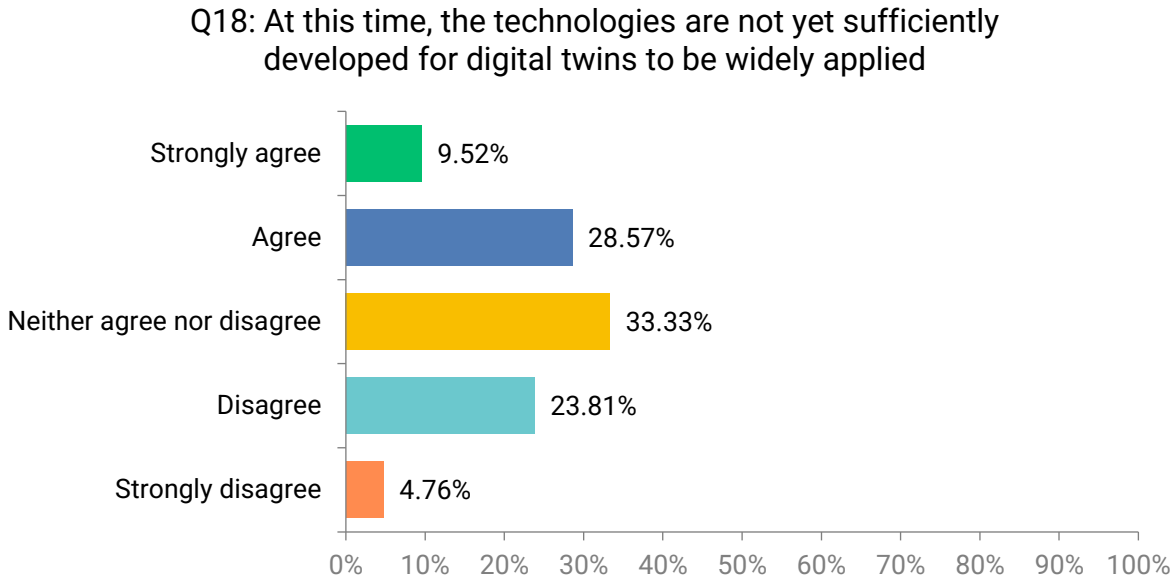
- Digital twins are particularly useful for the study process and research related to building conditions.
- Precision construction and building operation
- Data analytics
- Data analytics
- Data management and analysis
- All information presented digitally
- I believe that there will soon be many digital twins
- Helps organize the construction process, avoid mistakes, make comparisons - simulations
- Energy optimization
- Effective decision making
- Accurate data
- Many benefits, fundamental error elimination, monitoring, prediction
- Property management, integration of renewable energy sources
- Clarifies the sector
- The same.
- The same
- Efficiency

- Efficiency in building usage
- Benefits for the building operator.
- More sustainable solutions
- More transparent sector
- More transparent sector
- Faster data analysis and decision making
- Predictive building maintenance, energy cost analysis, forecasting
- Building usage and maintenance
- Efficiency of all life cycle stages
- Quality improvement, cost reduction, time savings when technologies and methodologies are mastered and widespread.
- Process efficiency
- Lower resource costs
- Efficient resource management.
- Planning stage, selection of design solutions.
- Aspects covering many areas, identifying needs and opportunities for both residents and the entire city.
- More efficient use and management
- Avoidance of design errors

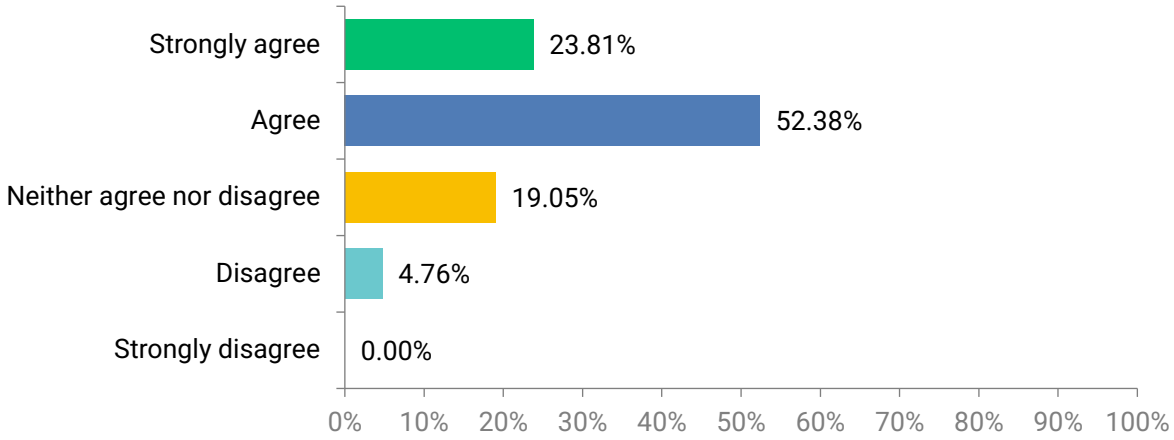
Q17: What are the main obstacles to the implementation of these technologies in your represented sector?

- Finances
- One of the obstacles - compatibility issues with certain technologies that require a lot of resources to resolve.
- Price and availability
- Price and availability
- Data collection
- Money
- User maturity and skills
- Data reliability
- Lack of data, quality
- Client needs, mandatory requirements.
- Closed software, data resolution
- Understanding of needs

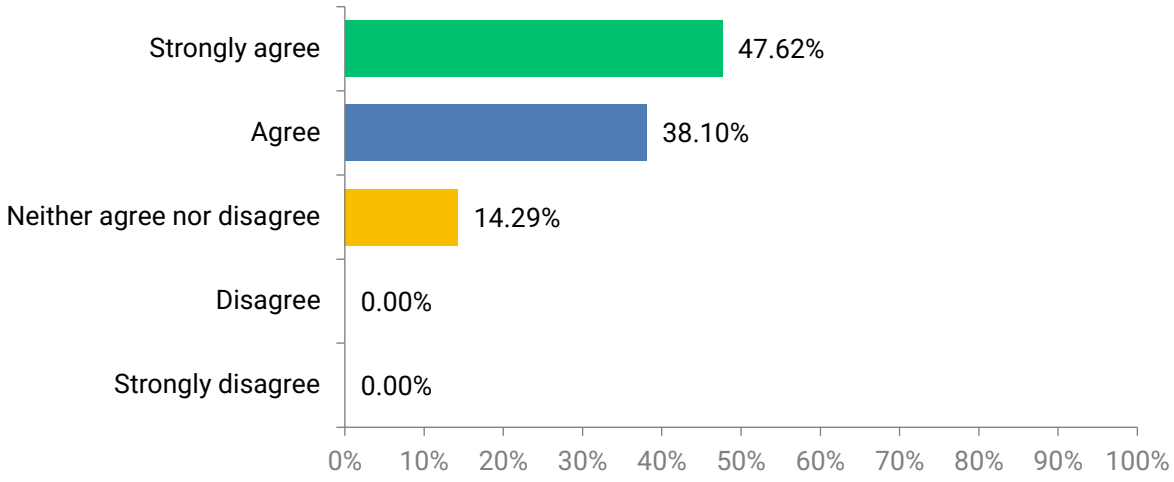
- Investments
- Slow adaptation
- Lack of clients who would use technologies for building operation
- Lack of funding
- Financing and competence
- Financing and lack of competence
- Lack of buildings with executable BIM models, too few software solutions available
- Competence, data
- People's education, too little motivation to invest faster in technology adaptation
- Lack of competence
- Lack of state strategic goals
- Lack of mandatory requirements
- Competence, client needs
- Price
- Price
- Lack of competence
- Availability

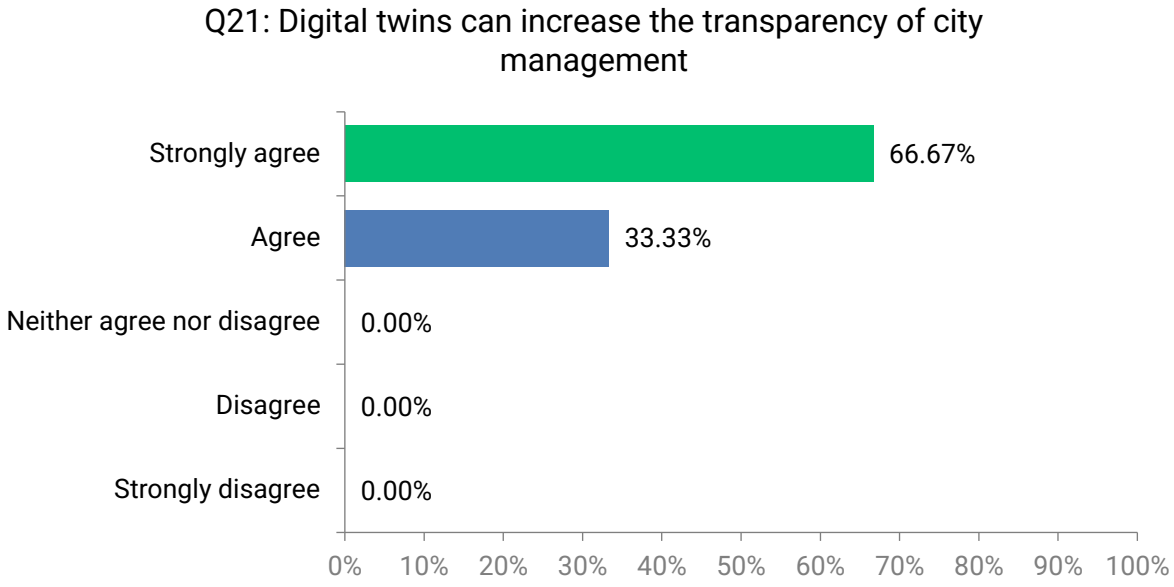


Q19: The market lacks specialists capable of working with digital twin technologies, their application is limited by a lack of knowledge

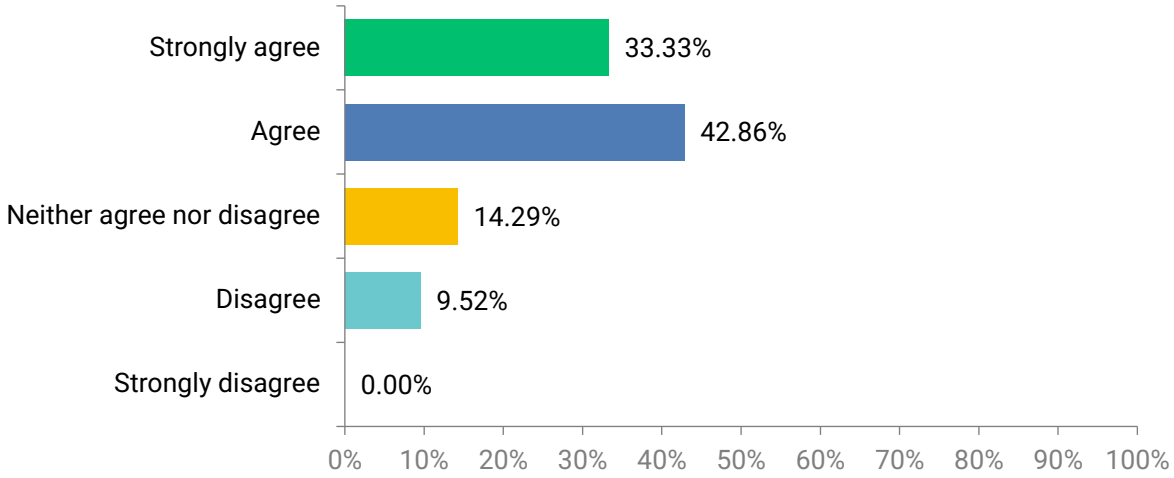


Q20: Updating the legal framework is necessary for the implementation of digital twin technologies

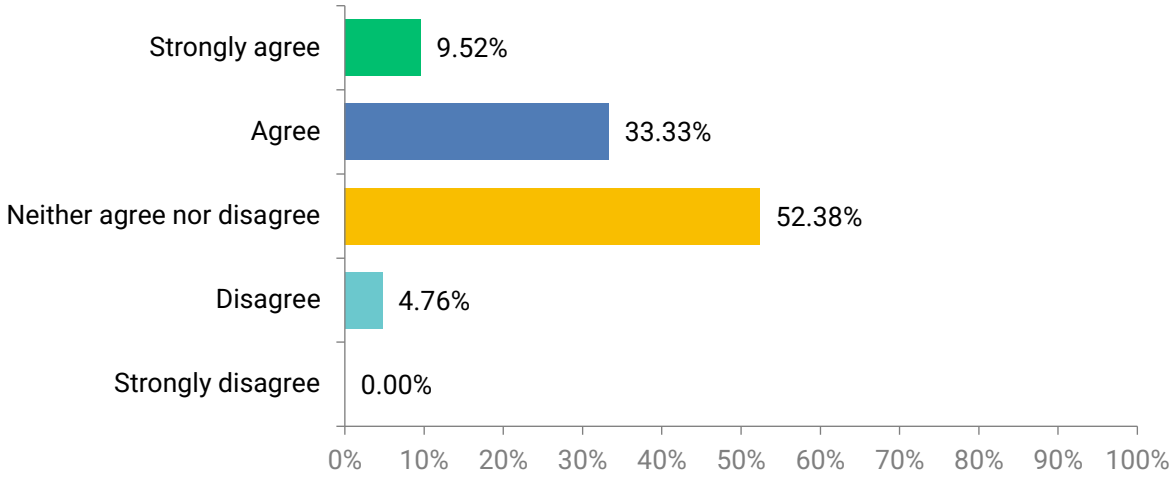



Q21: Digital twins can increase the transparency of city management
Strongly agree
66.67%
Agree
33.33%
Neither agree nor disagree
0.00%
Disagree
0.00%
Strongly disagree
0.00%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Q22: The security of digital twin data and their public accessibility can pose risks



Q23: It is challenging to ensure personal data privacy and data security when creating digital twins

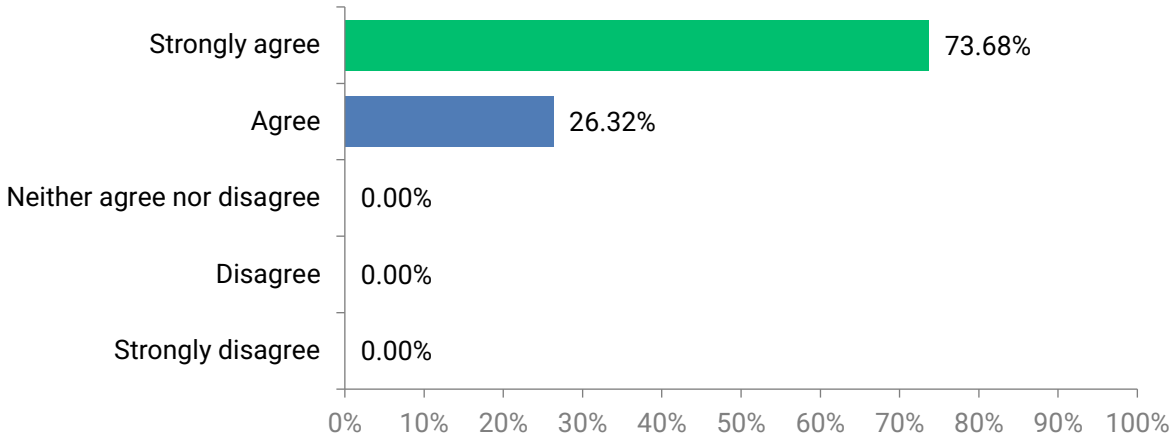


Q24: How digital twins can be applied in your environment?

- Real-time situation monitoring
- Can be applied to improve the study process and assess the state of buildings
- Precise building construction and acceptance for use
- Building management
- Building management
- Directly

- Greater opportunities to implement asset management and operational tasks
- Improves planning
- Providing maintenance services
- Creating new project concepts using information collected in existing buildings
- For simulation
- For demonstration
- For demonstration, data analytics
- Making planning decisions
- Asset management

Q25: Digital twins have the potential to contribute to the efficient management and sustainable development of buildings, cities, and infrastructure

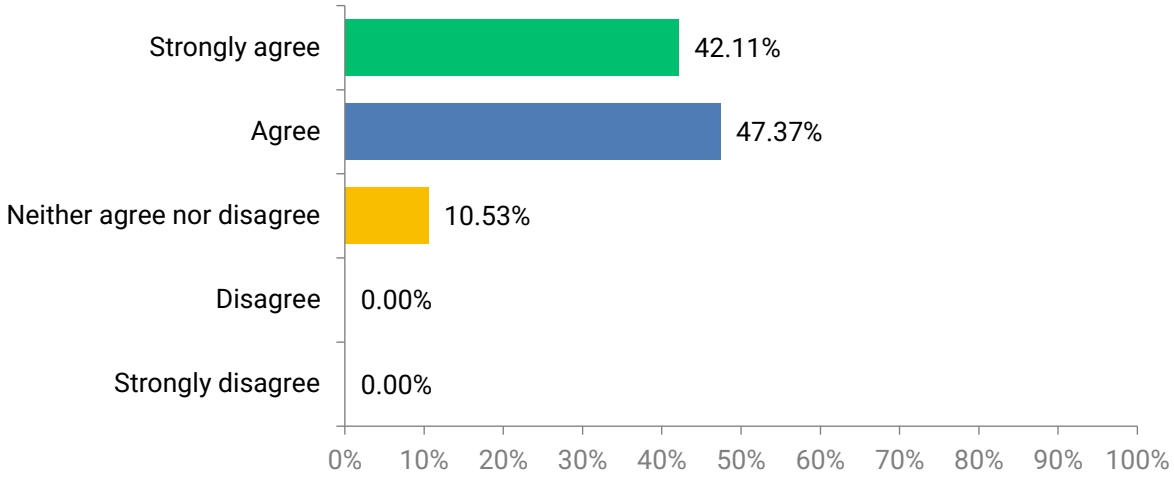


Q26: List the fields where the application of digital twin technologies would bring maximum benefits

- Security/Defence industry. Monitoring of gathering places/bunkers data
- Construction, renovation, urban planning
- Building operation
- Energy, city infrastructure
- Asset accounting, operation
- Urban planning, construction sector
- Efficient resource use
- Efficient building maintenance, efficient energy use
- Operation
- Real estate

- During the maintenance phase
- Maintenance
- Maintenance
- Application in public services

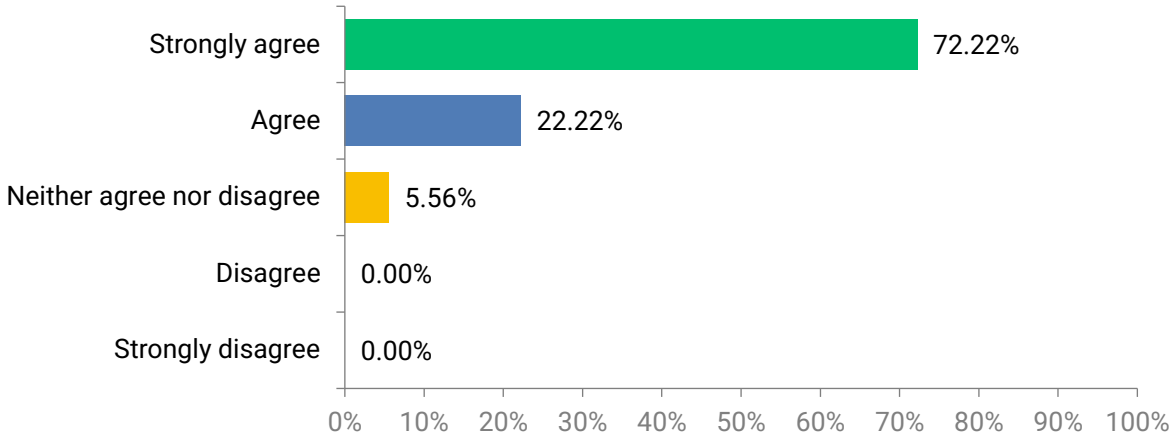
Q27: Lithuanian higher education institutions have the potential to develop digital twin technologies



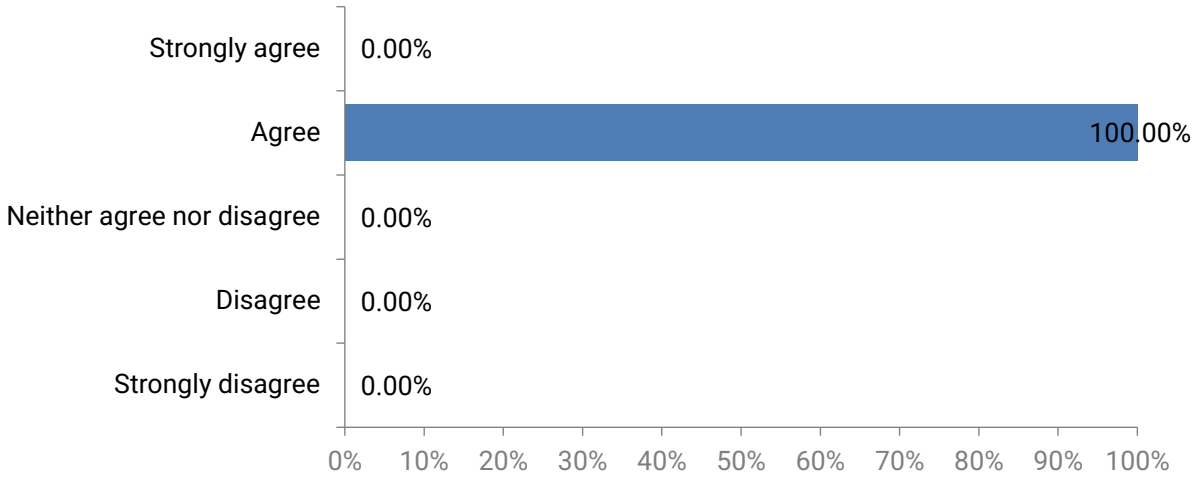
Q28: In which areas could scientific, business, and governmental institutions collaborate to achieve sustainability, citizens engagement, security, and other EU goals?

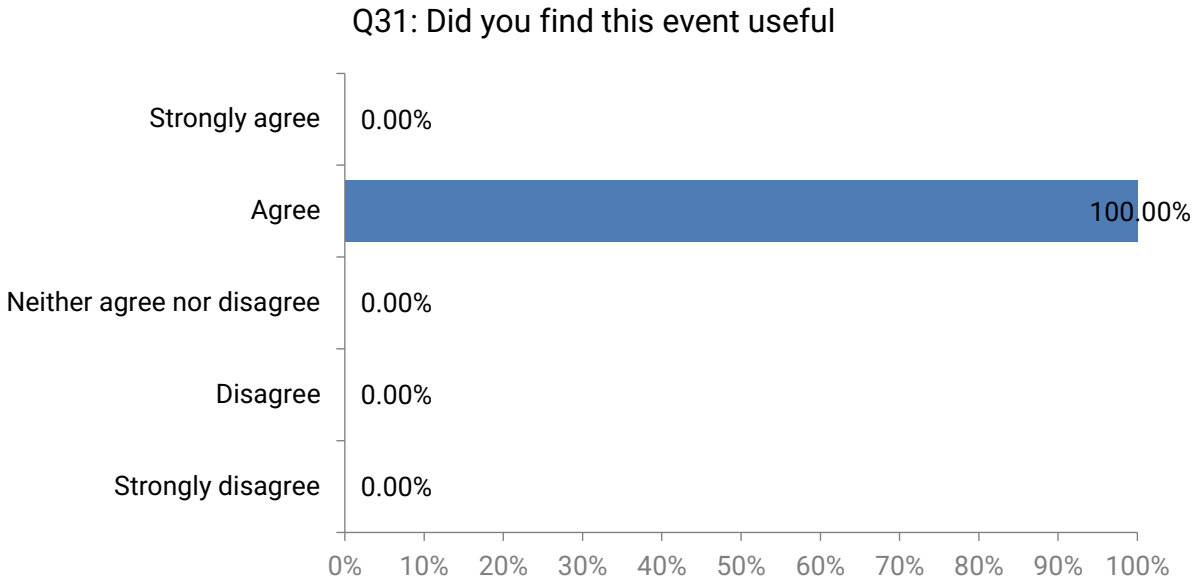
- Transparency
- Construction
- In all areas
- No opinion
- Industry, buildings, urban infrastructure
- Data collection, systematization
- Education
- Demonstrating benefits, training existing and new specialists
- Methodology development
- Methodology
- Methodology
- Digitalization of the built environment

Q29: Digital twins can contribute to Lithuania's long-term goals: strengthening the innovation economy and creating high value-added products



Q30: Do you think that this event contributed to bridging the gap between society and research?





Q32: Describe your experience in this event in one word

- Good
- Interesting
- Engaging
- Great