Boosting Research for a Smart and Carbon Neutral Built Environment with Digital Twins (SmartWins)

Paris Fokaides
Faculty of Civil Engineering
and Architecture
Kaunas University of Technology
Kaunas, Lithuania
paris.fokaides@ktu.lt

Andrius Jurelionis
Faculty of Civil Engineering
and Architecture
Kaunas University of Technology
Kaunas, Lithuania
andrius.jurelionis@ktu.lt

Paulius Spudys
Faculty of Civil Engineering
and Architecture
Kaunas University of Technology
Kaunas, Lithuania
paulius.spudys@ktu.lt

***Abstract*—At an era when the design of the built environment is being digitised, and the evaluation of buildings is implemented with the use of Industry 4.0 tools, the assessment of the energy performance of buildings can be no exception. Practices such as transmission of information through IoT and digital twins, for the assessment and control of building units, design using Building Information Modelling (BIM), smart meters and digital logbooks are anticipated to be established for conducting the energy assessment of buildings in the near future. Also, additional layers of information related to the sustainability of the built environment have been recently developed, which can enhance the information provided to the building owners and users, regarding the environmental performance of a building.**

This study presents the overall objectives of the project "Boosting Research for a Smart and Carbon Neutral Built Environment with Digital Twins – SmartWins", which is funded under the call HORIZON-WIDERA-2021-ACCESS-03 — Twinning. SmartWins project aims to build the capacities for the Kaunas University of Technology in Lithuania, through its "Sustainable Energy in the Built Environment" Research Group (SEBERG) within the Faculty of Civil Engineering and Architecture to conduct high-quality research on the topic of next generation digital twins, applied for allowing the transition to a smart, sustainable, resilient and carbon neutral built environment. The concept of the SmartWins project is to form a network between KTU and leading institutions in the field of energy and sustainability assessment of buildings with the use of Industry 4.0 practices related research and innovation management, for know-how transfer and development of a long-term research collaboration. KTU will twin with the Politecnico di Milano University (PoliMi, Italy), the Centre for Research and Technology, Hellas (CERTH, Greece), a spin-off of the Technical University of Berlin, Contecht GmbH (CON, Germany), and Innotrope (France), aiming to increase its excellence and international reputation in the field, to both cover fundamental research aspects, as well as to further develop its skills, practices and structures to conduct top-notch research.

Keywords: Digital twins, building, BIM, Twinning, KTU.

I. Introduction

The era we are currently experiencing, can well be described as the fourth industrial revolution in many sectors, including the sector of construction. Practices such as Building Information Modelling (BIM), smart sensors, IoT and the digital twins, are developing rapidly and progressively dominating the market, utilising digital technologies to construct more efficiently with higher quality.

Recognizing the growing needs in the field of research for sustainable buildings assessment using digital tools, the University of Kaunas established in 2018 the Sustainable Energy in the Built Environment Research Group (SEBERG) [1], a research group under the Faculty of Civil Engineering and Architecture. SEBERG aims to conduct research in the fields presented in Figure 1, and be established in the Baltic region and beyond, as a reference for top-notch research for sustainable buildings, using digitized tools and methods [2]. In its short lifetime, SEBERG achieved since 2018 three Horizon grants in the field of sustainable buildings (D^2EPC GA 892984, PRECEPT GA 958284, eUMaP GA 101007641).

Fig. 1. SEBERG field of activities

SEBERG requested and achieved funding to twin with four of its partners, PoliMi, CERTH, Contecht and Innotrope under a project entitled "Boosting Research for a Smart and Carbon Neutral Built Environment with Digital Twins – SmartWins". SmartWins project aims to strengthen SEBERG capacities in the digitized assessment of buildings performance by employing digital twins practices. The proposal was evaluated under the call HORIZON-WIDERA-2021-ACCESS-03 — Twinning [3], and was considered eligible for funding. SmartWins aspires to establish a research hub in the Baltic countries for research in the field of digital twins and the sustainable built environment. This study aims to present the main concept of the SmartWins project, the research component of the initiative, as well as the critical infrastructure, which is going to be used, for this purpose. The infrastructure is located in four research entities, in Lithuania, Greece, Italy and Germany.

II. SmartWins Project Main Provisions

SmartWins concept consists in tackling the weaknesses and adapting to the threats of research for digitization of the built environment. through the measures possible in the requested Twining fundings. SmartWins will take advantage of advances in Industry 4.0 practices in the construction

sector, integrating processes compatible with the digitally structured environment. One of the major objectives of the project will be to deliver the required knowhow to KTU, to conduct fully compatible with BIM methodology energy assessment of buildings, by retrieving information from smart meters and digital twins on the actual performance of the building, enabling in this manner the energy assessment of buildings with inputs from the actual building behaviour.

Figure 2 presents an infographic with the main aspects of SmartWins project. SmartWins will handle topics of research management, linkage with business and training. The project will also entail a research component, which is described in detail in the following section.

- The research management aspect of the project will include activities of upgrade of the research management of KTU, staff exchange as well as the performance of reviews for the managerial performance of the institution. Under these activities, relevant confrerences and workshop will also be organized.
- Under the linkage with business activities, brokerage as well as citizens events will be organized. This component also includes the drafting and the delivery of a policy report, with the aim to strengthen the research capacities of the Lithuanian research community in fields of digital twins.
- For the training component of the project, new curricula relevant to the field of digital twins will be drafted. This component also includes summer and winter schools, as well as training sessions.

Fig. 2. SmartWins Concept Infographic

III. Research in SmartWins

One of the main goals of the SmartWins research assignment will be the development of an integrated methodology, making use of available and increasing number of building energy-related data from sensors, smart meters, connected devices and building systems with the help of IoT practices to assess the actual energy performance of buildings, counting also additional aspects such as indoor air quality and comfort. The SmartWins approach, in addition to its operational nature, will entail enriched information, regarding both life cycle and intelligence of the building, but also in relation to the well-being of the building users.

The research fields that will be developed within the SmartWins project are the following:

- Integral components of smart buildings digitised assessment;
- Indoor environmental quality assessment with smart sensors;
- IoT and digital twins for assessing the performance of smart buildings;
- Energy assessment of smart buildings in BIM environment.

Under the integral components of smart buildings whole life digitized assessment, the environmental life-cycle assessment and sustainability aspects of the energy assessment of buildings will be analyzed, with the aim to discuss the state-of-the-art practices in digitizing the environmental assessment of buildings. For the purpose of this task, building and construction sustainability tools and technical standards, as well as the main provisions of the Level(s) scheme will be employed. The research will focus on the definition of specific sustainability indicators of the Level (s) scheme for quantifying the environmental impact of the building during its design and construction stage, in a cradle to gate rationale. The environmental assessment of buildings will be implemented with the use of BIM documents, thus the required APIs that will extract the required building information from IFC documents will also be developed.

Indoor environment quality (IEQ) is one of the most important aspects in a building's environment which can affect the health and wellbeing of the occupants as well as lifecycle costs, and energy consumption at operational level. IEQ is determined by many factors including thermal comfort, visual comfort (lighting and daylight), air quality and ventilation, acoustic comfort, and it may be deteriorated by specific problems such as damp conditions, hidden mould and moisture and other pollution sources. Under SmartWins project, after conducting a review of all the aspects of IEQ in the built environment, research will be implemented for the identification of the sources, tools and measurement equipment to be used to measure the levels of these aspects. Further to that, a review of IEQ measurement methods and tools, as derived in the Level(s) scheme and the European standard EN 16798-1 (2019), will be implemented to identify the procedure to be followed for the IEQ analysis. Covering the main indoor climate parameters virus risk mitigation indoors and the parameters that measure the risk of

transmission, including outdoor air ventilation rates, will also be examined.

The IoT and digital twins for assessing the performance of smart buildings task, will aim to the development of the required monitoring and calculation procedures, that will enable the development of the required know-how for the operational energy assessment for all types of buildings, based on good practices and current legislations. The research will analyze the documentation of current practices for operational energy assessment of buildings with the use of smart sensors and digital twins. Input related to the frequency of energy assessment, measurement weather normalization processes, measurement devices and protocols, extracted indicators and big data management will be defined. The task will focus as well on smart sensors and digital twin practices, aiming to allow the representation of the actual energy performance of buildings within a BIM environment.

The fourth research component of the project, concerns the energy assessment of smart buildings in BIM environment. Under this research task, energy performance and non-energy aspects will be incorporated in the energy assessment procedures of buildings. The current technical documentation, derived by the EN52000 standards series, will be exploited, as well as other building energy related standards, with the scope to develop an asset-based methodology that will assess the energy performance of buildings within BIM environment. For the development of this procedure, other performance data generated over the building's life cycle will be explored as well as data related to other issues concerning consumption of non-energy resources such as water, noise and acoustic quality issues. The energy and non-energy resources assessment will be conducted in BIM environment, enabling in this manner the development of all required APIs for this purpose.

IV. SmartWins Critical Infrastructure

The SmartWins consortium members are equipped with the required critical infrastructure, which guarantees the successful implementation of the project research objectives.

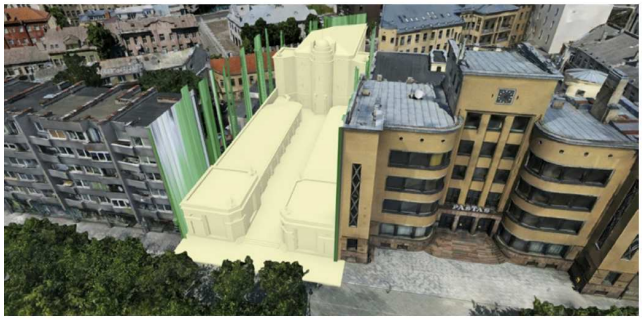

Fig. 3. Examples of KTU digital models: the historic central of the Jewish Bank

KTU will exploit the facilities of the **Center of Smart Cities and Infrastructure** [4], developed under the Faculty of Civil Engineering and Architecture in 2018, consisting of wide variety of BIM / GIS related software tools and packages (Open Cities Planner, Revit, Dynamo, IDA-ICE, ArcGIS, Context Capture, Open Building Designer, Tekla Structures, Solibri Model Checker, Navisworks etc.) for the creation, integration, parametrisation, analysis of digital data related to buildings and infrastructure. The digital construction modelling laboratory at KTU (Centre for Smart Cities and Infrastructure) will be intended for the various activities related to thematic of building information modelling (BIM), GIS, smart cities and Internet of Things. The centre possesses the required infrastructure to properly develop models of digital twins, that allow the assessment of properties related to the smartness performance of the units.

KTU will also employ its **Energy and indoor climate laboratory**, which is equipped with state-of-the-art infrastructure for conducting research in the field of HVAC monitoring and control as well as on indoor environmental conditions assessment. This lab hosts a full-scale indoor environment chamber, mainly used for research on indoor air quality, thermal comfort and occupant productivity, as well as an air handling unit consisting of fans, filters, rotary heat exchanger in combination with a water-borne air heater and cooler, and water-borne cooling system.

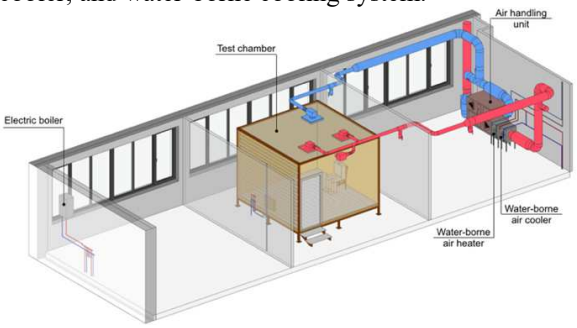

Fig. 4. KTU's full-scale indoor environment chamber and air handling unit

The **Centre for Research & Technology, Hellas – CERTH will deploy its nZEB Smart Home, CERTH's IoT Platform and the CERTH's IoT Energy Platform** as demonstrators and for research within SmartWins project. CERTH nZEB Smart Home [5] is an active liaison between research and the markets, acting as a driving force for empowering market-oriented stakeholders with innovative digital solutions. It aims to become a cornerstone DIH for R&D and commercialization of novel solutions in line with the National & EU digitization objectives.

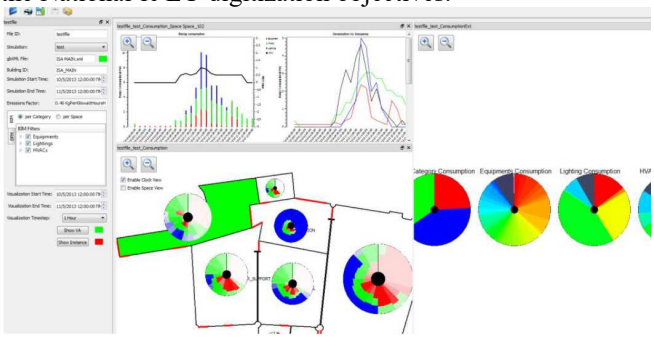

Fig. 5. CERTH Visual Analytics Tool

CERTH's innovative IoT framework is designed to collect, process, analyse, compare & present information collected at different architectural nodes of an end-to-end ecosystem. It develops and exploits wireless and wired local or international communication, voice, data, image, IoT etc. On the same page, **CERTH's IoT Energy Platform** will be deployed to provide as a good practice in monitoring and controlling smart sensors, accounting for interoperability and robust real- time communication. CERTH will also integrate into the research conducted and in practices to demonstrate

its **web-based visual analytics toolkit**, supporting different visualizations for analytic tools output representation.

Politecnico di Milano will employ the facilities of RELAB [6] **in SmartWins project,** an EN17025 certified lab in which research for building systems is conducted, in compliance with numerous EN standards (EN 14511, EN14825, EN16147, EN1397, EN12309, EN16583 and EN12102) and European regulations (ECO design, ECO Label and ErP directives). The RELAB Group conducts applied research on Renewable Heating and Cooling at both Building and District levels. The activities involve experimental characterization of heating and cooling systems prototypes, numerical modelling of heat and mass transfer, dynamic simulations of building energy systems and energy planning of district heating and cooling networks. The RELAB expertise in renewables and energy saving extends to Life Cycle Assessment of products (goods and services) and of organizations, aiming at supporting companies and public entities in understanding and improving their environmental sustainability profile.

Fig. 6. PoliMi RELAB Double Chamber Calibrated Calorimeter

PoliMi will also employ ETNA, an innovative in-house developed IT platform for the collection and analysis of energy data from various monitoring systems, which may interconnect to both a building management system and with smart meters deployed, allowing for the implementation of digital twins for monitoring and controlling of buildings indoor environmental conditions.

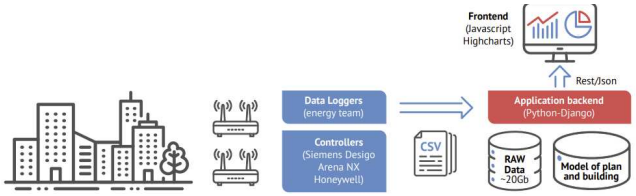

Fig. 7. PoliMi ETNA platform

Contecht, an Autodesk Forge certified integrator, will employ some of the tools it has developed over the recent years in the SmartWins project, towards **demonstrating best practices in digital twins, and particularly concerning the integration of the information provided by digital twins into BIM environment** .

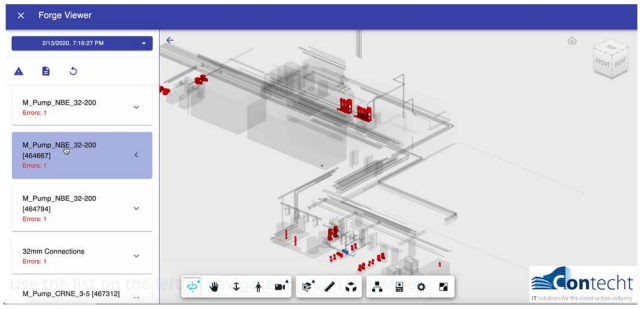

Fig. 8. Contecth 4D Planner Software

Particularly, Contecth will exploit 4D-Planner Software and Model Checker, two of its top-notch products, used for simulating sustainable buildings into a 4D environment, as well as for validating properties within various BIM models against multiple schemas, supporting in this manner KTU to enhance its background in Industry 4.0 practices related to BIM design and employment.

V. Conclusions

The purpose of this report was to demonstrate the main aspects of SmartWins, a Horizon Europe Twining project, kicking off in October 2022, which aspires to deliver a major research center for smart twins at the Faculty of Civil Engineering and Architecture of the Kaunas University of Tehcnology. In this study, the main project components were presented, which aim to increase the research capacity of the institution in the field of digital twins for sustainable buildings. These components include both liaison activities with the industry as well as training. The research management aspects were also introduced. In this report, further analysis was also conducted for the research component of the project, which is aimed to cover main aspects of digital twins for buildings. This component was described in detail, based on the activities foreseen by all involved partners. Finally, state-of-the-art critical infrastructure, in the field of digital twins and the decarbonized built environment, which are going to be exploited in the project, were also introduced. SmartWins aims to be a gamechanger in the field of digital twins and the smart built environment in the Baltic region, as well as to serve as a lighthouse for other similar research initiatives across Europe. Progress activities of this research institution will be presented in future studies, foreseen in the following months.

References

[1] Kaunas University of Technology (2022). Research Group Sustainable Energy in the Built Environment https://en.ktu.edu/research/research-at-divisions/rg_sustainable-energy-in-the-urbanized-environment/ Last accessed 03.03.2022

[2] Fokaides, P. A., Apanaviciene, R., Černeckiene, J., Jurelionis, A., Klumbyte, E., Kriauciunaite-Neklejonoviene, V., ... & Ždankus, T. (2020). Research challenges and advancements in the field of sustainable energy technologies in the built environment. Sustainability, 12(20), 8417.

[3] European Commission, (2022). Twinning TOPIC ID: HORIZON-WIDERA-2021-ACCESS-03-01 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-widera-2021-access-03-01 Last accessed 03.03.2022

[4] Center of Smart Cities and Infrastructure (2022). http://csci.ktu.edu Last accessed 03.03.2022

[5] Centre for Research & Technology, Hellas – CERTH (2022). CERTH nZEB Smart Home https://smarthome.iti.gr Last accessed 03.03.2022

[6] Politecnico di Milano will employ the facilities of RELAB https://www.relab.polimi.it/ Last accessed 03.03.2022