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SPHERE: BIM Digital Twin Platform †

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Abstract: SPHERE (Service Platform to Host and sharE REsidential data) is a 4-year Horizon 2020 EU-funded project, carried out by 19 SMEs, RTOs and Large Enterprises across Europe. The platform aims to provide citizens, AEC stakeholders, as well as city administrations and urban developers, with an integrated ICT platform that will allow for a better assessment and development of the Design, Construction and Performance of residential buildings. SPHERE platform will facilitate improvements in the energy performance of buildings from the start of the construction process. In addition, it will also reduce time, costs, and the environmental impact of construction processes and improve the indoor environment due to a seamless integration of each meaning dimension and respective stakeholders within the platform.

Keywords: BIM; Digital Twin; AEC

1. Introduction

Citing Michael Grieves from Department of Engineering Systems in Florida Institute of Technology, Digital Twin implementation started approximately in 2010 when NASA adopted its use in their technology roadmaps [1] and proposals for sustainable space exploration [2]. The concept has been proposed for next generation fighter aircrafts and NASA vehicles [3,4], along with a description of the challenges [3] and implementation of as-builts [5]. This wide implementation in aerospace industry become a flagship to appear as a as a central concept in Internet of Things (IoT), specially related to Product Lifecycle Management in Industry 4.0. However, it is a concept primarily used for engineered products, production machines or even production lines. Using the concept by evolving BIM methodology to achieve BIM Digital Twins presents a unique important feature since they are compliant with the AEC industry.

BIM systems are based on the creation of a complete parametric model, unique and centralized for the projected building or infrastructure. The model is constituted by all the necessary elements for its construction, and each element is determined by the necessary parameters for its definition (materials, geometry, constructive systems, estimations…). With BIM systems, the representation of an element is not drawn (four lines for a pillar); the said element is projected and included in the model, estimating and sizing all its design parameters. By projecting with BIM, a "digital construction" of each element and of its relationship with the environment is made. Moreover, the model is simultaneously prepared for different specialists and contains all the necessary information for the construction of infrastructures or buildings (materials, estimations, constructive systems, measurements, etc.). This information is parameterized and subject to the traceability of the changes and is produced by its project, management and the control of the work documents. To produce this collaborative works it has to use procedures, ICT tools architectures and formats (e.g., BCF) inside what is commonly named Common Data Environments (CDE).

Nowadays trends tend to integrate 4D/5D BIM, standardized construction delivery methods, such as IPD and IDDS, as well as complementary processes/technologies such as Construction Project Management (CPMS), Computer Aided Facility Management (CAFM), Computerized Maintenance Management System (CMMS) and GIS (geographic information systems). However, there is a lot of information from the building and its subsystems which remains outside BIM methodology. For example, the integration with IoT, Building Management Systems (BMS), ERPs and Building Automation Systems (BAS) to provide tools to capture, store, and share critical building information.

SPHERE (Service Platform to Host and sharE REsidential data) is a 4-year Horizon 2020 EU-funded project, carried out by 19 SMEs, RTOs and Large Enterprises across Europe. It aims to provide citizens, AEC stakeholders as well as city administrations and urban developers with an integrated ICT platform that will allow for better assessment and development of the Design, Construction and Performance of residential buildings. The SPHERE platform will facilitate improvements in the energy performance of buildings from the start of the construction process. In addition, it will also reduce time, costs, and the environmental impact of construction processes and improve the indoor environment due to a seamless integration of each meaning dimension and respective stakeholders within the platform. The solution will integrate two planes of research, innovation and improvement: The first consisting of an integration of the processes under the Digital Twin Concept involving not only the Design and Construction of the Building but also the Manufacturing and the Operational phases. Whilst the second being the integrated platform which will be achieved through an underlying ICT Systems of Systems infrastructure based on Platform as a Service (PaaS) service to allow large scale data, information and knowledge integration and synchronization thus enabling better handling and processing.

2. Challenges

The quality of construction works also has a direct impact on the quality of life of Europeans. Not least, the energy performance of buildings and resource efficiency in manufacturing, transport and the use of products for the construction of buildings and infrastructures have an important impact on energy, climate change and the environment. Following this, decarbonizing Europe's building stock is one of the four interlinked pillars in which make up the focus of EU clean energy research and innovation to build a low-carbon, climate-resilient future. Significant actions following COP21 Paris Agreement have been increasingly aiming to develop across all sectors ground-breaking technological and non-technological solutions, capable of achieving carbon neutrality and climate resilience in the second half of this century in Europe and beyond.

Therefore, a sustainable construction sector plays a crucial role for reaching the EU's long term 80–95% greenhouse gas emission reduction objective. According to the Roadmap for moving to a competitive low carbon economy in 2050 [6], the cost-efficient contribution of the buildings sector would require a 40 to 50% reduction in 2030 and around a 90% reduction in 2050. The needed investments would contribute substantially to the competitiveness of the European construction sector. The sector has also an important role to play in adaptation to climate change and resilience to natural and man-made disasters by promoting long term disaster proofed investments [7].

The poor energy performance that buildings exhibit may be due to the characteristics of the building materials used but also to the use of traditional or unsuitable construction processes. In order to build a low-carbon, climate-resilient future, decarbonising Europe's building stock is key: the construction industry is responsible for approximately 40% of final energy consumption and generates 36% of greenhouse gases in Europe. A more sustainable construction sector requires a closer integration of ICT-based tools to impact the processes of the overall building lifecycle, integrate the whole value chain, reduce costs and increase energy efficiency.

SPHERE will achieve this through a unique, synchronized Building-centred Digital Twin environment based on Platform as a Service (PaaS). This will allow for the vertical integration of the processes' involving its design, manufacturing, construction and operation. During any phase of the building's lifecycle, different stakeholders will be able to interact with this Digital Twin model, based on the building's information and a scalable set of different software tools such as energy

demand/performance simulation tools, Decision Support and Coaching Systems, BEMs or IoT enabled Predictive Maintenance Algorithms. With this, SPHERE aims to provide a platform and a methodology that is useful during each phase of the whole building's lifespan, where any action can be analyzed in a virtual environment from a multi-dimensional point of view, both prior to physical implementation and consequent expenses, including whilst the building is in use and operation.

The need for more suitable construction and renovation processes, to provide cost reductions, increases in energy efficiency, and reductions in the carbon emissions of buildings, will be tackled by SPHERE through the integration of the value chain, from initial brief by the owner, to design to operation and end of life. SPHERE will be built as an interoperable and flexible ICT platform based which will integrate all relevant data of the designed, As Built, and the Real Building during its life, thus creating a Digital Twin which will evolve jointly with the real asset. To achieve this, SPHERE integrates three planes of research, innovation and improvement:

- A Building-centred Digital Twin Environment, involving not only the design and construction of the Building but including also the manufacturing and the operational phases. This system of systems will be capable of aggregate all data relevant to the asset through all the Lifecycle Phases of the residential building, hence improving the productivity by more time-efficient, economic and environmental decision taking. And enable by performance-based procurement manufactures to offer early in the design process prefabricated HVAC, roof and façade modular systems integrating the value chain and reducing costs and construction time.
- A highly interactive collaborative Digital Twin Environment, where collaborative practices are facilitated based on an Integrated Design and Delivery Solutions (IDDS) framework. The environment will facilitate collaboration between all parties involved in a building's life cycle, by enabling involvement across all stages of the project cycle, integrated data and knowledge sharing capabilities, and facilitation of smart blockchain based contracting between all parties. As such, SPHERE is a first platform that allows for cost reduction and performance improvement using IDDS practices.
- The seamless and efficient updating and synchronization of SPHERE's Digital Twin platform based on emerging Digital Twin standards. This will enable future standardization of Building BIM-based models that can fully communicate with other software tools as well as other building digital twins (e.g.,: residential complex) in order to search for common goals. With this, SPHERE aims to provide a platform and digital twin methodology that is useful right from planning/design phase to demolition, going through a long lifecycle, where the analysis of any refurbishment and/or expansion actions can be analyzed in a virtual environment from a multi-dimensional point of view, prior to physical implementation and consequent expenses.

3. Impact

The benefits of introducing BIM processes in the construction sector are well documented [8–10] and include: 61% reduced errors and omissions, over 35% reduced rework, 20–30% reduced construction costs, 20% reduced project duration, 17% faster approval cycles due to fewer claims/litigations, etc. Above all, the advantage of BIM lies in the avoidance of the poor communication/silo effect [11] among construction stakeholders.

The lean paradigm that revolutionized the automotive manufacturing industry is finally making its way to the construction sector (some early adopters/case studies in early 2000). Case studies show that lean construction can achieve time savings of at least 15% [12] and in the best cases to date, up to 30% [13]. These savings are mainly due to the mitigation of risks (e.g., uncoordinated communication, lack of visibility) so simply 'things can't go wrong'. Modular prefabricated Construction in the early design stage further reduces construction time.

Block-chain technology and smart contracts, optimize project workflows and improve collaborative working, and increase transparency over the whole construction process pushing project member to perform better given the increase accountability (all transaction can be traced to a point in time and a user). In summary, faster (almost real-time), more secure and more data-drive decision making, less mistakes, less delays (up to 30% performance lost in delays [14]).

Thanks to these technologies, SPHERE will impact in the daily work, facilitating activities, improving interconnectivity and reducing complexity, with these representative features:

No documents, only data in context—easy access to the information needed

- Able to work in any selected CAD/BIM tool, however connected to the team
- Built on open standards: OpenBIM, IFC, BCF, COINS, CObie
- Kanban-based workflows & zero-email communication
- Contextualized 3D/IFC-viewers, for easy project navigation
- Reduction in queries response time by using Relational Graph Databases

In summary (Figure 1), twinning this virtual information model with the reality helps significantly in decision-making during each phase of the whole building's lifespan, increases collaboration and reduces inefficiencies, while improving the energy efficiency and reducing time and costs. In numbers, it should help achieve 15% reduction in residential buildings' energy demand during the operational phase, 25% reduction in construction time and 25% reduction in CO_2 and other GHG emissions in buildings' construction and operational phases.

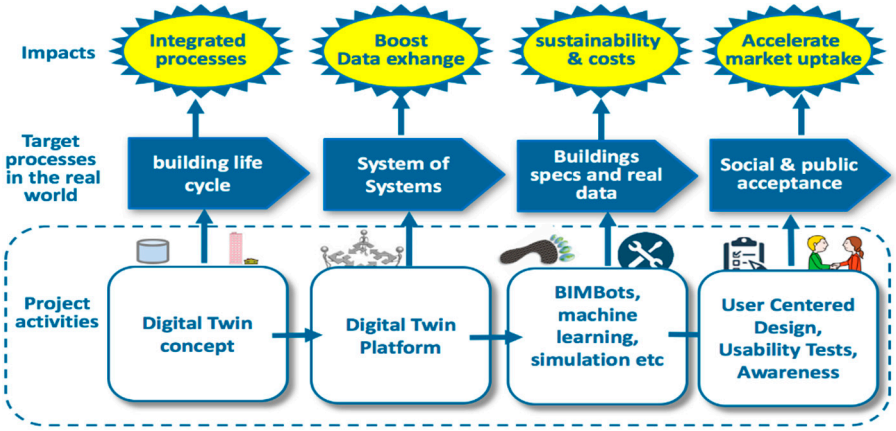

Figure 1. activities and impacts.

4. Conclusions

This paper introduced SPHERE: BIM Digital Twin. A project and a platform with the ultimate goal of the improvement and optimization of buildings' energy design, construction, performance, and management, reducing construction costs and their environmental impact while increasing overall energy performance. The SPHERE project will integrate three planes of research, innovation and improvement: (i) integration of the processes under the Digital Twin Concept, involving not only the Design and Construction of the Building but also the Manufacturing and the Operational phases; (ii) a methodology where collaborative practices are facilitated based on an Integrated Design and Delivery Solutions (IDDS) framework, and (iii) an integrated platform that will be achieved through an underlying ICT Systems of Systems infrastructure based on Platform as a Service (PaaS) service to allow large scale data, information and knowledge integration and synchronization thus allowing a better handling and processing, e.g., BIMBots, machine learning, simulation etc.

As previously proven in other fields, twinning this virtual information model with the reality helps significantly in decision-making during each phase of the whole building's lifespan (manufacturing, design, construction, maintenance, operation, retrofitting and even demolition). The SPHERE platform will enable the interaction of many different stakeholders during any phase of the asset with a building Digital Twin model of information of the building and a scalable set of different software tools, such as energy demand/performance simulation tools, Decision Support and Coaching Systems, BEMs or IoT enabled Predictive Maintenance Algorithms.

SPHERE has the potential to achieve significant reduction in residential buildings' energy demand during both, the construction and operational phases and should reduce rework and approval cycles while increasing the transparency and collaborative working.

Supplementary Materials: Please visit the SPHERE website at http://sphere-project.eu/.

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