ISMC 2021
16th International Strategic Management Conference

DIGITAL TWIN AN AID TO SUSTAINABILITY: "THE SAMBA" CASE

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Abstract

Digitization today is the main option to facilitate the transition of the entire energy supply chain, facilitating the development of intelligent and sustainable energy systems on buildings, in response to the requirements of the European legislation on the "Green Deal". The purpose of this paper is to demonstrate that digital tools and techniques such as the "Digital Twin" and "Digital Revamping" seem to be the ones that, more than others at present, favor the achievement of energy efficiency objectives with greater ease, through the use of predictive models and techniques, which make it possible to make predictions on the future state of corporate assets. The building becomes "smart" thanks to artificial intelligence and 5G. Through these techniques it is possible to hypothesize scenario analyses (what-if) and evaluate the impacts and effects of any critical issues. The first part discusses the state of the art. Subsequently, the Digital Twin and the Revamping Thimble are defined as tools that promote sustainability especially in applying them to buildings. This contribution focuses on the application of Digital Twin for a real project in progress. It describes the Italian project "Smart and Advanced Multitenants Building Automation" also known as "SAMBA", a sustainable model that uses digital technologies to create "Smart Buildings" at reduced costs and zero environmental impact, starting from existing buildings, thanks to sensors, 5G technology and artificial intelligence. Finally, the conclusions are presented.

Keywords: Sustainability, digital twin, digital rewamping, energy efficiency

1. Introduction

The contents of this article describe the benefits and advantages that the use of the "Digital Twin" and "Digital Revamping" could bring to the electricity sector, in particular by improving the energy efficiency of buildings. Adapting to the pace of Digital Transformation is essential if we want to keep up with the times and not lag behind from the point of view of innovation. Today, the most advanced technologies cannot ignore an evolution that is compatible with environmental protection.

Digital twins are a hot topic, and many energy organizations are eager to find out how to make the most of their use. In fact, most companies are looking for advice on where to start. We suggest starting with the asset data one already has, putting it in a position to share, and progressing from that point. Very often good data is buried in systems inaccessible to the people who need it. One of the main benefits of digital twin technology is how it makes reliable and up-to-date information more widely available. Based on the digital twin, one of those virtual video games (SimCity) was devised, which simulates a virtual city identical to the physical city, perfectly representing many aspects and dynamics of the city, to allow rulers to verify the effects of any changes before they actually take place. In recent years there has been a lot of discussion about these new digital approaches, both in the academic world and in the business world; publications and studies are also growing in this direction and are interested in this innovative phenomenon. In recent times, in fact, various digital twin applications in the "Smart City" field have begun to see the light, with a view to improving the quality of life and city safety, under the banner of environmental sustainability. The fields of use in cities range from the simulation of people's movements and emergency evacuations, to the construction of smart buildings, infrastructures such as bridges or networks and to efficient energy management, where virtual and real merge, combining real and virtual simulations on mobility, climate, air pollution, emergency monitoring in the most critical areas etc. Through these methods, a "Digital Ecosystem" could be created that will allow companies of any size to have a concrete and sustainable approach to technology transfer. The digital twin is increasingly being explored as a means of improving the performance of physical entities through technical computational levers, themselves enabled through the virtual counterpart (Jones et al., 2020). Interest in these innovative methods is rapidly evolving to meet the different needs of the many case studies to which it can be applied. To date, there is no univocal definition of the concept, but different definitions can be found, depending on the many sectors to which they can be applied. Thanks to the digital twin "it is possible to test and understand how the systems and products that you want to create will behave in a wide variety of environments, using virtual space and simulation" (Grieves & Vickers, 2017, p. 96).

The first part of the article defines the concept of the Digital twin and its development. It is then demonstrated how it can be used in the management of a building's electrical system, to make it efficient and above all to meet the objectives of reducing harmful emissions into the environment. Today, in order to strengthen the competitiveness of the supply chain in Europe and in Italy, new strategies are needed to reduce costs and increase conversion efficiency with a crucial role for research, innovation and development, also through digitization and the use of Machine Learning techniques.

The conclusions define how digital techniques can favor the improvement of the entire electrical system if fully and appropriately exploited, and what the implications of future applications may be.

2. Literature Review

At the state of the art, in the literature some scholars and researchers have dealt with the analysis and study of the phenomena covered by our article, but in a different way from each other. Studies focus more on the technical side of the phenomenon. The digital twin is made up of many software elements that are already state of the art (Pfeiffer et al., 2019). This raises the hope that in the future there will be no more isolated cost-benefit analyses for the development of isolated simulation models for specific tasks during plant operation, because all information and models are already available in the digital twin and are maintained automatically updated, so that they can be applied directly to the real twin (Labisch et al., 2019). Most modeling approaches fall into one of two categories: physics-based or data-based. Recently, a third approach is emerging for scientific applications which is a combination of these deterministic and statistical models… Addressing these challenges could enable the revolution in digital twin technologies for scientific and engineering applications (San et al., 2021). We describe the Digital Twin concept and its development, show how it applies to the entire product lifecycle in defining and understanding system behavior, and define tests to evaluate our progress. We discuss how the Digital Twin relates to systems engineering and how it can address human interactions that lead to "normal accidents" (Grieves & Vickers, 2017). An overview of the literature shows that most of the articles highlight the characteristics of the digital twin, listing gaps in research and future direction. The digital twin concept has been used in some industries where an accurate digital model of equipment can be used for predictive maintenance. Some researchers report its advantages and limitations in building construction (Khajavi et al., 2019). Others analyze it in the building field by proposing a digital twin-based intelligent building management framework to achieve a more proactive, efficient, cost-effective and environmentally friendly management control method throughout the life cycle (Nie et al., 2019). Some research describes business cases and best practices in designing IoT solutions for construction, powered by Digital Twins (Mateev, 2020).

Others describe the use of the digital twin for sustainability assessment through rating systems such as LEED, extending their use throughout the entire life cycle of an asset which includes the design phase and the use phase (Tagliabue et al.*,* 2021).

Unfortunately, the "Digital Twin" is probably a more advanced field and contains data connections between both physical and virtual entities, and it is still treated as a separate research area (Jones et al., 2020). Increasing product variety and shortening product lifecycles require a quick and cost-effective reconfiguration of existing production automation systems. To address this challenge, a solution is a digital twin, which can be used to reduce complexity and reconfiguration times by promptly detecting system design or process sequence errors with an interdominion simulation (Talkhestani et al., 2018).

In keeping with Grieves' concept, there are multiple virtual entities present in a digital twin, each with a specific purpose, e.g. planning, health monitoring, etc. Still to be presented in the literature is the way in which these different virtual entities interact, cooperate and are aggregated.

3.   Digital Twin E Digital Revamping: A Problem Statement

At the state of the art there are many definitions that have been given on the "digital twin". Its origins date back to 2003, when Michael Grieves (Chief Scientist for Advanced Manufacturing at the Florida Institute of Technology) at the University of Michigan, in a speech on Product Lifecycle Management (PLM), defined the "digital twin" as the virtual and digital equivalent of a physical product. Interest in this concept begins to mature, and in the literature there are some articles that deal with this topic under various aspects. "In the future, everything in the physical world would be replicated in the digital space through the technology of digital twins. Being a cutting-edge technology, the digital twin has received a lot of attention" (Qi et al., 2021, p. 1).

According to the latest studies on the development and evolution of digital systems and the internet of things, it is understood that the emerging trend that will accompany technological innovation in the coming years is that of the "digital twin" and "digital revamping". A virtual replica of a product or process that allows us to monitor, simulate and govern reality. It is used at all stages of the process, from design to daily management, thanks to the growing number of objects connected to the network capable of transmitting data and the development of Artificial Intelligence. The benefits are huge and allow for great savings. These techniques that will frame big data, artificial intelligence, machine learning and the Internet of Things will be the masters of Industry and society 5.0, representing the new strategic, social and economic challenges, promoting and preserving the key principles of sustainability. These transformations are being put in place to innovate. Innovating means bringing a significant change in terms of progress, efficiency and productivity. As the "digital twin" is a revolutionary approach, it allows us to create virtual copies of real systems capable of replicating in full operation from life or verifying all possible alternatives. Thanks to leaner development cycles, companies reduce time by 25% with savings in the order of 10-15%. It is estimated that the market value, currently 3.8 billion dollars, will reach 35.8 billion dollars in 2025 (Bettini, 2021). The three-dimensional representation of all aspects of a product or process allows the development of both experimental activities, saving on expensive physical protocols, and predictive activities, anticipating anomalous behaviors, risks and errors. The applications are many, from automotive to management and business models, up to construction. The "digital revamping" represents that approach of integration and technological implementation, connection and new interfaces that allows a scalable functional upgrade to return "IoT ready" machinery and systems. Underlying digital revamping are features such as connectivity, performance control and improvement. Through these three pillars, the keys are obtained to open the door to innovation and sustainability. In this way, a company is able to build its own "digital ecosystem". Since "digital revamping" allows us to upgrade even old and dated systems, in order to transform them into I4.0-IIoT ready equipment and tools, it is necessary to train qualified personnel in the sector. This represents a great challenge today, because it is necessary to be able to find personnel with adequate skills, or to retrain existing workers and train them with a new set of skills. Through qualified personnel who have good skills in digital matters, by carrying out the real and sustainable technology transfer, a sustainable digital ecosystem can be created. The data collected by a survey conducted by Ucimu - Sistemi per Produrre (association of Italian manufacturers of machine tools, robots, automation and auxiliary products) show that the fleet of machine tools, robots and automation

owned by Italian manufacturers has an average age of about 13 years. Since these are technologically outdated, obsolete equipment and machines that are hardly predisposed to the digitization of the plants, it will be technically difficult to bring them to a sufficient level of modernization and it will take years to do so. Innovating the machinery of all Italian companies and making it equal to the innovations brought by the digital transformation will be very difficult.

Thanks to "digital revamping" it will be possible to implement the digitization process on dated machinery and plants, while, with the "digital twin", a real digital ecosystem will be created allowing the interaction between a real object or process and its virtual model, through the application of artificial intelligence software in asset management. These transformations will be made possible as mentioned above only if the human factor that deals with digitization has the skills and knowledge to innovate the entire process. Only with employees educated on the potential of digitizing their business will it be possible to build a sustainable and competitive digital industrial ecosystem. Following the Covid-19 pandemic and the reduced worker mobility, it was understood that with regard to the remote management of complex plants (old and new), thanks to revamping we can give new value to our assets and manage in real-time strategic data to make quick decisions.

In a short time, during the early phases of the COVID-19 pandemic outbreak, we managed to shift rapidly to use digital technologies and replace some of our daily operations with virtual modes. This shift happened so instantly and widely that it enables us to argue that the COVID-19 became a valid reason to boost some of the gradual and ongoing transitions towards faster transformations (Wang et al, 2019).

3.1. Purpose of the study: digital twin and building energy efficiency

Energy is one of the other major sectors that can be managed through the digital twin. The energy sector is in the right position to take advantage of digital technologies. Whether it is simply adding a vibration sensor to a rotating machinery, or creating a complete digital twin of an entire plant, digital twin technologies can reduce costs and simplify maintenance and operational processes. When it comes to digitization, the real estate segment would only have to gain by applying the digital twin. The building is defined as intelligent and sustainable when it is designed to efficiently guide energy trends, reducing and optimizing consumption from a green and energy-saving perspective, providing the best possible comfort to those who live there. If it is not only the management of the energy flow that is taken into consideration, but of all the ecosystems that coexist in a structure, we speak of "smart building".

An Autodesk survey on the application of Digital Twin technologies revealed that BIM users reporting a positive ROI amounted to 82% of the total, supported by 58% of customers in favor of a more collaborative and digital approach.

The practical benefits that can be obtained in the implementation of a Digital Twin are many, we summarize some of them below: database of all information in a single centralized environment, centralization of all actions in a single activity control dashboard and IoT systems, with dashboards summarizing the values and parameters for monitoring the health of the building, predicting behavior and applying error and malfunction prevention strategies, optimizing performance and safety; efficiency of the management and maintenance phases: maximization of ROI and reduction of time and costs. The operation phase corresponds to 80% of the entire cost of the building calculated over its useful life.

Tracking of actions and related responsibilities, with a view to transparency and continuous updating of activities, digitization of documentation, reducing the risk associated with the use of paper supports (errors in archiving, difficulties in sharing data, etc.)

As digital twins will replace human labor in the near future, the disadvantages of digital twins are obvious. First of all, the question arises about our security. Digital clones will use all possible resources to reintegrate information about us. These are algorithms that collect data from social media accounts, and from our personal correspondence, and from all documents and files that, in one way or another, concern us. Of course, this can only be alarming: as we have already discovered, "digital twins" are able to constantly update and improve. Therefore, one of the priority tasks should be the creation of a legal basis for determining the "admissibility limits" of artificial intelligence.

3.2. Digital twin as a method for developing the energy efficiency of buildings: proposed application to Bim

The applicability of the digital twin to "Building Information Modeling" therefore allows a number of advantages. If applied to buildings, it provides the skills and tools to conceive, design, build and manage buildings and infrastructures following a system that is as efficient as possible. If BIM shapes the building as it should be, the digital twin is able to guide the building now and into the future, improving the performance of the smart building, and optimizing time and costs, satisfying the needs of customers in the best possible way, allowing to increase performance on services and models. The digital twin is an ideal tool for smart building, to implement energy management and efficiency and best meets the need for comfort and well-being of those who live and inhabit the building. Among the benefits of this application, in addition to the reduction of costs, greater efficiency and resilience are estimated, as well as a broader perspective regarding the dialogue between parts of a project. With regard to the efficiency of buildings, in particular, the digital twin makes it possible to evaluate: energy needs, the quality of the internal environment, CO_2 emissions, the necessary energy saving measures and their timing. So with the Digital Twin it is possible to create digital twins of buildings to: make real-time analysis of the current state, provide for future maintenance and management interventions, such as energy efficiency or transformation into a smart building (Eden Group, 2021). Today it has become a phenomenon in growing use at the Smart City level and it is not an absolute novelty, as from 2018 an example of a "virtual version" can be found in the city of Singapore. It is as if we had a digitized copy of a smart city, in a completely virtual scale model, which helps people with reduced mobility, through simulation, to eliminate architectural barriers. Specifically, the digital twin model was used for the first time in the construction of buildings and other types of infrastructures with BIM programs to monitor all the components of a building with the aim of anticipating potential material defects. Later it was realized that the model could be applied to other services such as sewerage, energy, urban mobility, population growth, participatory policies of a city or education. The applications are truly vast: they range from the aerospace sector (where it was used for the first time) to the industrial context to the management of a building or a city. While BIM is a system that allows us to collect all information on the design and management of the building, "if you add simulation capacity to BIM, through the connection to real sensors, you would have the digital twin of a building" (Universita di Verona, 2020).

It is like having a bridge that connects a physical and real object to a virtual alter ego, collecting and sending information. The digital twin represents the evolution of BIM and of all the systems of representation of the building in a geometric and virtual way, because in addition to understanding the part relating to the design, it allows us to count on all the data and information in real time taken from the building-plant. It is as if we simultaneously had information on the past, present and future of the building with the aim of constantly monitoring the evolution of the building. In the case of the building, the data at present are those generated and communicated thanks to the Internet of Things, which has provided machines and systems with the ability to communicate with each other and with the supervision and control systems. Through the digital twin it is possible to understand the state of an asset, simulating possible situations, monitoring its operation and solving any problems.

There are many problems that could be solved: for example, if solar panels or an innovative waste collection system were installed in our city, it could be useful, without affecting budgets and citizens, to plan changes and anticipate the problems that may arise in the city and thus improve the lives of those who live there. The primary purpose of the digital twin, through a simple and immediate user interface, is to allow the user to move freely in the virtual space, interacting with elements and information that mirror the real behavior of the building, from the point of view of environmental comfort, sustainability, energy saving, structural safety. At present, many projects have started in Italy that are working on developing the digital twin in buildings to make them efficient and sustainable. For example, let us examine the Smart and Advanced Multitenants Building Automation project, also known as "SAMBA", a project funded under the POR FESR 2014-2020 of the Lombardy Region, which aims to develop an innovative and particularly relevant application, a technological solution that fits between history-tradition on the one hand and digital innovation on the other, a control platform for existing buildings that can be transformed into smart buildings with potentially enormous beneficial impacts (Eucentre, n.d.). In compliance with the project objectives, aimed at issues such as environmental comfort, energy saving, increased productivity and safety.

4.   Research Method: Illustration of the "Samba" Project

Within the "SAMBA" project - "Smart and Advanced Multitenants Buildings Automation" - "Harpaceas[1]" is working on the creation of the digital twin of "CoFabb".

CoFabb is the pilot structure - almost 5000 square meters - on which "SAMBA" is working with the aim of transforming the building into a smart building. CoFabb's digital twin is a faithful virtual reproduction of the physical spaces of the building and allows us to navigate inside remotely as if you were really on site. The "SAMBA" project aims to develop digital technologies to create Smart Buildings starting from existing buildings, underlining the importance of digital, artificial intelligence and machine learning in the energy efficiency of existing buildings. The tools used by "SAMBA", within the experimentation underway at "CoFabb", will allow to improve the comfort of the building's users,

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[1] Company founded in 1990 in Milan by a group of engineers who operate and are the protagonists of the digital transformation of the construction sector and the adoption of BIM as a method for the innovation of the service chain for the implementation of BIM.

minimizing costs and waste. This is a sustainable model that can also be replicated in other types of buildings such as condominiums, schools, libraries, museums and hospitals.

The project will be tested in a building in Sesto San Giovanni which houses over 4000 square meters of different types of activities, companies, laboratories, bars and canteens, a gym and common areas. The building therefore becomes an ecosystem of devices and systems connected to each other, through non-invasive technologies: an economic solution with low impact and maximum performance in terms of performance, for which the building will be able to activate its own utilities (lights, heating, cooling, security, accesses) in a predictive way and ensure living and working comfort.

Buildings and equipment that consume less energy (less kilowatt hours) because they are more efficient impose lower power loads (lower kilowatts of demand) on the system, and over 20 years of efficiency program data document this effect. Since most of the technologies promoted by energy efficiency programs (e.g. lighting, air conditioning) operate during peak demand hours, typically hot summer afternoons in most of the United States, they contribute to the reduction of the System peak (York & Kushler, 2005).

The Sesto San Giovanni building, therefore, represents a prototype on which to test the control platform. Subsequently, the project team, in all its components, will be able to propose itself as a reality able to develop custom proposals based on the possible requests of diversified users. It involves developing a graphical interface that allows us to remotely control the functions of the building, based on the data collected by the sensors. The challenge of the project is the integration of different types of sensors, which detect temperature, humidity, human presence, vibrations. This is a diversity of sources that must be integrated in order to obtain a view of all the factors. "SAMBA is an innovative project also because it intends to integrate the various systems of the building by ergonomizing the control in a user friendly interface that takes into account flexibility, connectivity and control in a logic of open innovation and incremental approach (by implementing third-party technologies and solutions parts at any time) and above all with zero environmental impact. Within the "SAMBA" project it was decided to exploit a series of technological solutions for the virtualization of the building and specifically for the creation of a special Digital Twin, designed to allow a new concept user experience, ensuring users can interact with the building that houses them and above all with the real-time data and information that orbit around it.

It is a significant innovation, because it is based on the low-cost application of digital technologies to the historic building heritage, which in Lombardy and Italy represents the majority of existing buildings, to achieve social, environmental and production objectives: an "appropriate" technological solution to the Italian and Lombard context, characterized by the necessary meeting between history and tradition on the one hand and innovation and digital on the other. Specifically, the realization of the digital twin for "SAMBA" basically translates into two main steps. The first concerns the pure three-dimensionalization of the asset, made possible through the use of an action cam (such as the GoPro with video stabilizer) functional to the video capture of the environments to be digitized. The shots are a fundamental input data that is reworked through advanced image recognition algorithms to obtain first of all a photorealistic and navigable building. The second step involves the enrichment of the aforementioned geometric model, developing a series of intelligent objects and specific features at the service of the various user levels. This in fact represents the primary purpose of the digital twin, a simple

and immediate user interface that allows the user to move freely in the virtual space, interacting with elements and information that mirror the real behavior of the building, from the point of view of the environmental comfort, sustainability, energy saving, structural safety. The ultimate purpose of the digital twin becomes to establish a link and a continuous dialogue with data (and their processing). This translates into the possibility, for various user profiles, to consult, monitor and manage the spaces associated with it, acting within specific functionalities and intelligent objects linked to the domain of interest.

Consider, for example, the issue of environmental comfort: through the digital twin it is therefore possible to have a clear view of the conditions (real-time and/or historical) of humidity, temperature and air quality at any time and in any virtual place of the template. The potential offered by such a solution can even respond to purely information or training needs. In this direction, the use of the digital twin could support various users in finding the best path to reach the desired location of the building, which is very useful especially for visitors or employees of companies made up of multiple departments distributed in very large complexes. The "SAMBA" project, in an ambitious and far-sighted way, therefore aims to create a real intelligent system, a combination of various technological components. From sensors to communication protocols, from databases to predictive models, from artificial intelligence to front-ends (including DT) available to the user and his needs. "SAMBA" is part of a digital transformation logic that sees, thanks to new technologies, the review of work processes ensuring transparency in the use of services, sharing of spaces and resources (human, material, intellectual, economic), new areas of inclusion and contributing to an improvement in the quality of working life and therefore in social sustainability.

5. Conclusion and Discussion

At the end of this article, we realized that digital twins have the potential to offer huge energy benefits. However, the challenges are: where to start, what are the next steps and how to accelerate digitization. The current political strategies, especially European ones, are pushing the productive fabric towards and the implementation of circular economy models, in which the processes reduce, up to cancellation, the environmental impact, and the sustainability products their added value, eliminating waste and scraps as much as possible. An example is the Action Plan for the Circular Economy, transmitted by the European Commission, on 11 March 2020 and which is part of the European Green Deal, the European roadmap that encompasses a set of initiatives proposed by the Commission itself with the overall goal of achieving climate neutrality in Europe by 2050.

The production fabric of the future is therefore part of an intelligent and sustainable ecosystem, in which the implementation of the Digital Twin, an enabling technology that is revolutionizing the new industry model, becomes fundamental. Most companies in the energy sector have good document management systems to support regulatory processes and, often, good asset management systems to support maintenance. Much of the data, however, is inaccessible to those who need it and is often out of date as it should be. "However, research on digital twins for the built environment is still in its nascent stages and advances in underlying enabling technologies are needed and a convergent context for ongoing and future research is needed" (Deng et al., 2021, p. 58).

To comply with the Green economy model, it is necessary to protect the ecosystem by adopting an attitude that respects the environment and a sustainable use of fossil fuels, with the aim of reducing environmental impacts by enhancing natural and social capital (intense as well-being of society) as well as on the economic one. By developing projects such as "SAMBA", through the use of new ecological technologies for heating, or for electrical components and from recycled raw materials for less polluting cars, attention to sustainability is promoted and valued. Digital twins can be considered the new tool for the green and digital transition of industry, much desired by Europe, but since data is the basis of this technology, legal criticalities must be addressed and resolved in time.

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