BIM AND DIGITAL TWINS – ILHA DOS ARVOREDOS CASE

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Abstract. *The paper's main objective is to present the advancement of a GCSP project within a year, which theme is BIM and Digital Twins. This report will be focused on a case study of an island named Ilha dos Arvoredos, located in Guarujá, SP. The project's purpose is to develop a Digital Twin and resolve the islands issues related to Civil Engineering issues using BIM.*

Keywords. *IoT, Sustainability, Meteorological Station, Modeling, GCSP.*

Introduction

Since the advancement of technology throughout the world in the 1980's, most industries have innovated and adapted to new devices and methodologies. The civil engineering industry has also gone through this evolution, but in a much slower pace. The first big step was the invention of AutoCAD in 1982, which is defined as computer-aided drafting and made possible 2D and 3D modelling, which helped civil engineers to design more accurately and without the struggle of having to erase mistakes made on paper. Not only civil engineers benefited with this invention as

> Computer-aided drafting features a lot more uses than just what civil engineers use it for. Mechanical engineers can create complex parts for objects. These are mainly designed on AutoCAD and used for various uses. Mechanical engineers can actually create 2D and 3D models of objects which will be wont to accurately create the thing that was portrayed within the drawing. (SADEGHPOUR, MOSELI & ALKASS, 2006)

Even though this application was the starting point to a technological breakthrough in the AEC (architects, engineers, and constructors) industry, there are many issues due to the lack of specific components, because it only has the command of lines. This means that if you model a wall, it doesn't contain its properties. Another issue is that only one person can edit the project at a time, meaning that it could be developed in a faster rate if more people could operate at the same moment.

The solution to these issues is a methodology named BIM (Building Information Modeling) that can be defined as an "Integrated and interoperable work-flow where tasks are collapsed into a coordinated and collaborative process that maximizes computing capabilities, web communication, data aggregation (EASTMAN, 2011)". A simpler definition is that BIM is a work philosophy that integrates the AEC industry in the elaboration of an accurate virtual model.

BIM is composed of seven dimensions, which are: 3D (enhances the visualization of the project), 4D (attributes the time factor to the initial modeling), 5D (allows cost estimation and budget analysis), 6D (generated from the inclusion of sustainability components), 7D (includes operational data in the project). The development of this last dimension, can create a Digital Twin, described as, "The Digital Twin is understood as the virtual and computerized counterpart of a physical system that can be used to simulate it for different purposes, exploiting a real-time synchronization of detected data

coming from the field; such synchronization is possible thanks to the enabling technologies of Industry 4.0, and as such, DT is deeply tied to it (MACCHI, 2017)". Digital Twins are created based on a BIM and IoT (Internet of Things) integration.

Another concept that can be related to BIM and Digital Twins is Smart Cities, which can be determined as

> A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens. (GIFFINGER, 2007)

The importance of BIM and Digital Twins in Smart Cities is that this technology helps modeling buildings in a much more complex and inexpensive way. When built, it it is possible maintain and monitor the buildings, which could be hospitals, enterprises, apartments. This can be used to save energy, optimize cleaning services by using sensors to understand what time do people usually occupy which spaces.

Due to a partnership between Instituto Mauá de Tecnologia (IMT) and Instituto Nova Maré (INMAR), which is a non-profit organization focused on the development of sustainable projects in the seaside town of Guarujá, it was possible to learn about a project, maintained by this institute, named Ilha dos Arvoredos. This partnership has the purpose of using innovative civil engineering technology to resolve issues at the island. IMT is also undergoing discussions with UNAERP (Universidade de Ribeirão Preto), which is a university that also maintains this island with INMAR and is responsible for managing a Institute left by Fernando Lee named "Fundação Fernando Lee".

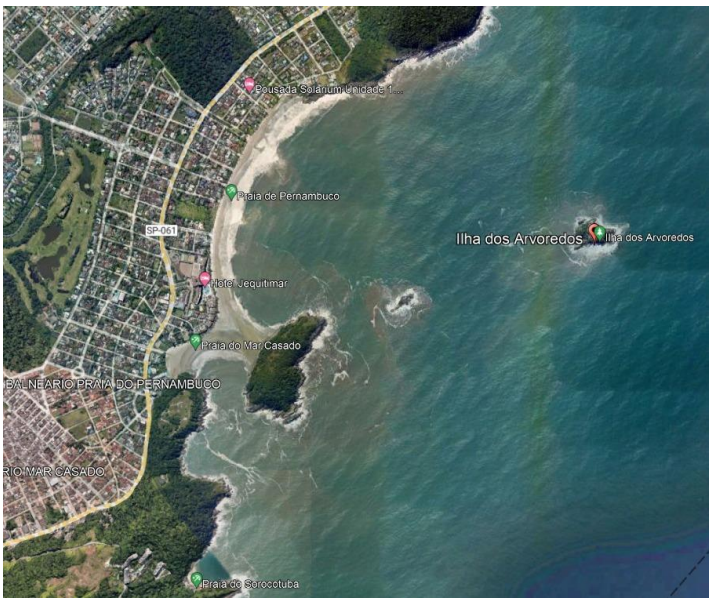
Objectives

The objective of this study is to develop a Digital Twin of Ilha dos Arvoredos, the resolution of problems at the island which require the use of BIM and the implementation of a meteorological station to capture data, such as, humidity, temperature, wind speed and wind direction.

Development

Ilha dos Arvoredos is a skerry with an area of 36000 m² and 28 meters in height at 1,6 km off Pernambuco Beach, in the town of Guarujá, located 62 km south of São Paulo. This island is fully dedicated to the educational and research fields.

Fig. 1 - Ilha dos Arvoredos location



Reference: Ilha dos Arvoredos, *Google Maps* 2022.

The engineering projects at the island started with Fernando Lee, who was a Brazilian engineer, with American nationality, which motto was "Research for the benefit of humanity". Lee dedicated 42 years of his life doing research to prove that human and nature can live in harmony. During this time, he made several projects in Ilha dos Arvoredos, one achievement was the installation of the first solar panels in Brazil. After his passing, the island continued having research purposes.

After visiting the island, one problem encountered early on was to figure out how to measure the height of the waves that hit the coast of the Island, because the waves must be below 0,9 meters for the staff to allow visitors.

> In Brazil, the most used equipment for this measurement is the analogue tide gauge, equipped with a buoy and a counterweight, with a paper register. However, its accuracy is too small for a correct use in more accurate studies, its operation requires special care, especially when changing tide charts and the availability of data still must go through a digitalization process, which increases not only the time and effort involved, but also the possibility of introducing systematic or random errors. (CANDELLA, 2008)

To understand and resolve this issue with an innovative approach, it was crucial to read a Final Paper, from CASTRO, L.G.S. (2016) based on a device that helped measuring the height of waves through surfers in which the sensor was placed on the surfboard. An enlightening excerpt about the device was “It is possible to capture measurements from 20 cm to 10 m. It also has an important and essential characteristic that is the possibility of submerging the sensor up to 1 m for 30 min”. But there were many steps that had to be adapted if this model was to be implemented on the island because it was made to stay mounted on a surfboard, so there was a demand to research a new way of measuring, which is still being studied.

An advancement achieved was building a meteorological station, led by GCSP professor, ASSIS. W, who presented the station and allowed testing all of its components. This station helped with having a better control and measurement for the

weather in the island. All its components were working, so the conclusion was that it would be perfect to use at Ilha dos Arvoredos. However, after further research, it didn't seem feasible because it couldn't be connected via Bluetooth. After some trials, it was found that there was another meteorological station at IMT, used in a project of the Research Center, which captures data such as humidity, temperature, wind speed and wind direction. It also has Bluetooth and connects to their server (LoRaWAN) and could be used in this project. So, we decided to ask IMT to purchase this meteorological station. LoRa (*Long Range*) is a communication technology of radio frequency and radio link, is an interesting approach because it reaches a radius of up to 15 km, so, the data captured from the sensors of the meteorological station could be received at UNAERP or at the INMAR headquarters, instead of being done at the island. For this methodology to function, it would be necessary to install internet at the island because a gateway is required for the communication between devices. Another advantage for using this methodology is that IMT has researchers specialized in using this technology, who could help if there are any possible issues.

An accomplishment involving Digital Twins, was the participation in the Autodesk Forge Hackathon, there were five categories in this competition, the one that correlated the best with the project was "I feel the need, the need for Digital Twin" in which the objective was to create the most innovative and Twin. Since there are sensors present at the IMT library, it was decided to create a Digital Twin of that location. At first, the team would only be formed by two members of Civil Engineering but, after facing difficulties while programming and integrating the BIM model with the sensors located inside the library, it was decided to team up with two Computer Engineering students, who are specialized in programming. It was a worthwhile experience as our team reached second place in the competition. This experience helped to understand how the integration of sensors and a BIM model is attained, and how is the step-to-step process so it can be applied at Ilha dos Arvoredos. The first step is to model the buildings present at the island using an application named Revit. The second step is to install the meteorological station and test its sensors. The third step is to integrate the Revit model with the sensors using Autodesk Forge, it is the most complicated part, but when finished, the result will be a Digital Twin.

Results and Discussion

The projects done this year have been accomplished due to a group work with BONELLI and GRESPAN, who are also a part of the GCSP program at IMT. The following items are going to contemplate the advancement achieved in the year of 2022 at Ilha dos Arvoredos.

Fig. 2 – (a) Photograph of Ilha dos Arvoredos; (b) Model of the topography of the Island using Revit

(a) (b)

Reference: (a) Available at: https://portalguaruja.tur.br/atracoes/ilha-dos-arvoredos/; (b) GRESPAN, *Revit* 2021.

It was necessary to model the topography of the island, to be able of building a digital replica of the physical space. There is also a feature in the application that links the latitude and longitude of the location, which creates a georeferencing model.

Fig. 3 – (a) Photograph of Fernando Lee's house; (b) Model of Fernando Lee's house

(a) (b)

Reference: (a) LYRA, 2022; (b) GRESPAN, *SketchUP* 2022.

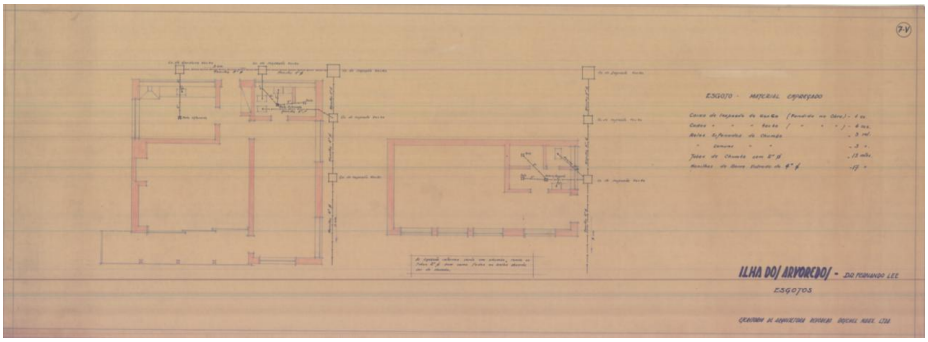
The picture on the left, is portraying the current state of Fernando Lee's house. The first floor's rooms are only used as storage space and the rest of the floor doesn't contain anything specific. The second floor is Fernando Lee's museum, in which many of his favorite objects and also pictures of him at the island are displayed. The image on the right, is a virtual representation made of his house, using an application named SketchUp.

Fig. 4 - Model of a visitor's restroom

Reference: GRESPAN, *SketchUP* 2022.

One major issue in the island is the lack of a restroom for visitors. The only restroom in the island is located inside Fernando Lee's house and it hasn't gone through maintenance since it was built, so it isn't in great conditions for visitors. The solution was to create a restroom with inexpensive materials, so this project could have a better chance of being accepted.

Fig. 5 – Fernando Lee's house sewage plant



Reference: LEE, sewage plant [sine nomine]

The problem faced with the installation of restrooms at the island is that there is only one sewage plant of the whole island, which is of Fernando Lee's house. After analysing this plant, the conclusion is that it isn't possible to locate where is the sewer of the island. This is very dangerous because being a sustainable island, having a sustainable sewer is important, so the next step of this process is to locate where is the sewer talking to the staff at INMAR, if it doesn't have a sustainable approach, it has to be changed.

Conclusion

Based on the advancements made in the year of 2022, it is possible to infer that there was a massive development of studies surrounding BIM and Digital Twins since the start of the year, with the creation of models of the topography from the island, from

Fernando Lee's house, and from a visitor's restroom. Also, the study and testing of meteorological stations with the help of colleagues and professors from IMT, which helped to understand more about sensors, their different types and how they are connected.

If the purchase of the meteorological station is approved, it will be necessary to re-visit the island and begin the process of its implementation and monitoring. It will also be necessary to have a meeting with UNAERP and INMAR to align the information gathered throughout the year and have an insight on their plans surrounding the island. Another step to be achieved is to model the buildings present at the island in the topography model, to create an actual digital replica of the island.

After understanding more about Ilha dos Arvoredos and their engineering projects, many research topics which could be studied at the island in the future were brought up, such as: Use of salt water in the sewage system, biodigesters, reuse of photovoltaic panels as an energy source, construction pathologies at the island, low-cost lightning protection study for deployment on the island, user safety on tourist visits, breakwater study.

References

MACCHI, Marco. A review of the roles of Digital Twins in CPS-based production, Procedia Manufacturing, 27th International Conference on Flexible Automation and Intelligent Manufacturing, June 2017. Available at: https://www.sciencedirect.com/science/article/pii/S2351978917304067. Access on: November 12 of 2022.

EASTMAN, C.; TEICHOLZ, P.; SACKS, R.; LISTON, K. BIM Handbook: a guide to building information modeling for owners, managers, designers, engineers, and contractors, Second Edition. New Jersey: John Wiley & sons, 2011.

CARNEIRO, Rubens et al. Revitlização e inovação do acervo da memória e pesquisas de Fernando Eduardo Lee na Ilha dos Arvoredos, [sin nomine]. Available at: https://www.unaerp.br/documentos/2182-revitalizacao-e-inovacao-do-acervo-da-memoria-e-pesquisas-de-fernando-eduardo-lee-na-ilha-dos-arvoredos/file. Access on: October 9 of 2022.

GRIEVES, Michael. Digital Twin: Manufacturing Excellence through Virtual Factory Replication, March 2015. Available at: https://www.researchgate.net/publication/275211047_Digital_Twin_Manufacturing_Excellence_through_Virtual_Factory_Replication , March, 2015. Access on: June 26 of 2022.

WANG W. et al. BIM Information Integration Based VR Modeling in Digital Twins in Industry 5.0. ScienceDirect, 2022. Available at: https://www.sciencedirect.com/science/article/abs/pii/S2452414X2200022X. Access on: April 9 of 2022.

DE PAULA, Jeziel. Uma Ilha, um homem e um sonho: meio ambiente, humanidade e tecnologias na obra de Fernando Lee, 2008. Available at: https://www.unaerp.br/documentos/1632-uma-ilha-um-homem-e-um-sonho-1/file. Access on: October 10 of 2022.

GIFFINGER, Rudolph et al. Smart Cities: Ranking of European Medium-sized Cities Vienna: Centre of Regional Science, 2007. Available at: http://www.smart-cities.eu/download/smart_cities_final_report.pdf. Access on: August 22 of 2022.

GIFFINGER, Rudolph et al. Smart Cities Ranking: An Effective Instrument for the Positioning of Cities?, ACE Architecture," City and Environment, 2010. Available at: https://core.ac.uk/download/pdf/301204045.pdf. Access on: August 22 of 2022.

CANDELLA, Rogério. Estação Maregráfica e Monitoramento do Nível do Mar, 2008. Available at: http://www.redebim.dphdm.mar.mil.br/vinculos/000009/000009aa.pdf. Access on: June 2 of 2022.

SMITH, Dwayne. Importance of AutoCAD in civil engineering, March 2020. Available at: https://medium.com/@smithdwayne352/importance-of-autocad-in-civil-engineering-334b0cf62d05. Access on: October 12 of 2022.