DEPARTMENT OF STRUCTURAL, GEOTECHNICAL AND BUILDING ENGINEERING (DISEG)

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Integrating BIM and VR with participatory design for managing the space of O.d.C

BIM and InfraBIM for Built Heritage

Under the guidance of

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Abstract

The covid-19 pandemic hit the world and took the freedom of people by restricting the activity including AEC industry. Considering that most of the countries even with highest healthcare facilities failed to contain and sustain the situation. This made us to have a well distributed healthcare service in the entire countries including remote locations, the one type of hospitals that can provide support to national health system is Ospedale di Communita.

The Ospedale di Communita (O.d.C) or Community hospitals are primary healthcare centres mainly staffed by nurses to provide health facility to rural or to a limited zone. These hospitals provide health treatment to local population and job opportunities to local populations.

This thesis aims to develop a Methodological approach for integrating participatory design for managing the space and facilities of the Community hospital buildings with BIM and VR.

The one of the goals of thesis is to check the interoperability between Revit Architecture and Enscape3D (Virtual reality tool) for assisting the facility manager and Building engineer to considers users opinion and update the facility of the O.d.C.

This report contains Brief description of Building Information Modelling (BIM) methodology and Virtual Reality (VR) technology that was followed to model an existing building, “Astanteria Martini” for Community Hospital (O.d.C).

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List of Abbreviations

3D	Three dimension
4D	Fourth dimension with time
5D	Fifth dimension with cost
6D	Sixth dimension with sustainability
7D	Seventh dimension with Facility management
AEC	Architecture Engineering and Construction
BIM	Building information modelling
O.d.C	Ospedale di Communita
FM	Facility Management
HMD	Head mounted Display
VR	Virtual Reality
AR	Augmented Reality
VAR	Virtual Augmented Reality
XR	Extended Reality
MR	Mixed Reality
LOD	Level of Development
LOI	Level of information
IFC	Industry Foundation Class
MEP	Mechanical Electrical and Plumbing
NHS	National Health Service
PNRR	Piano Nazionale di Ripresa e Resilienza

Acknowledgment

I would like to thank my supervisor professor. Anna Osello for helping me to complete the thesis. I thank all the coordinating staff, who helped me to conduct experiment with virtual reality tools in the Drawing to Future Laboratory. Professor. Matteo del Guidice gave me the required knowledge to conduct this thesis. I also thank Politecnico di Torino for providing great platform to meet new people and challenger. I would also thank my colleagues for helping me to understand new topics during this Master of Science Course.

A special thanks is reserved to my mother and relatives for helping me to study abroad far from home by sacrificing their efforts for my achievements. Finally, thanks to everyone whom I met in my life.

1. Introduction

Even the countries with highest level of healthcare facilities struggled because of Covid 19. This situation enabled us to think to increase the number of bed places available in the hospitals that are flexible and cost effective.

1.1. Opedale di Communita / Community hospitals

The O.d.C or community hospital are healthcare facilities acting as intermediate healthcare facilities between House caring and Hospitals. The O.d.Cs are explained in detail in the following paragraphs.

1.1.1. What is O.d.C?

O.d.C stands for Ospedale di Communita or Community hospitals. These are primary healthcare centres that provide healthcare facility to local population. Here are some available international definitions for community hospitals.

1. "Community hospitals are local hospitals, units or centers whose role is to provide accessible health and associated services to meet the needs of a clinically defined and local population " **(McCor mack, 1983).**
2. In which clinical responsibility is generally entrusted to general practitioners supported by a nursing team, often also multi-professional (given the presence of health and social workers - OSS, physiotherapists, and other health professionals) **(Ritchie et al., 1998; Winpenny et al. al., 2016).**
3. Which provides, depending on the contexts and the evolutionary process that characterized its birth and development, a more or less articulated set of health services, generally attributable to the field of intermediate care **(Ashworth et al., 1996; CHA, 2008; Pitchford et al., 2017).**

The above definitions describes that these centers provide health and associated services to locally concentrated population also important to mention that these

hospitals also try to use local population for nursing hence jobs to same population. These facilities are provided with limited number of beds and acts as supporting healthcare centers for the locality. The number of beds in these types of hospitals is less on average from references literature indicates 100 beds for a population of 100,000. The population refers to the maximum number for a community hospital. The community hospitals behave like a bridge between primary and secondary health services.

These definition of community hospitals shows that there no specific definition, but the definition is based on the services that these hospitals offer. Hence the topic of O.d.C is diverse, to understand this I found a graphical representation of O.d.C in one of the scientific papers and is shown in below figure.

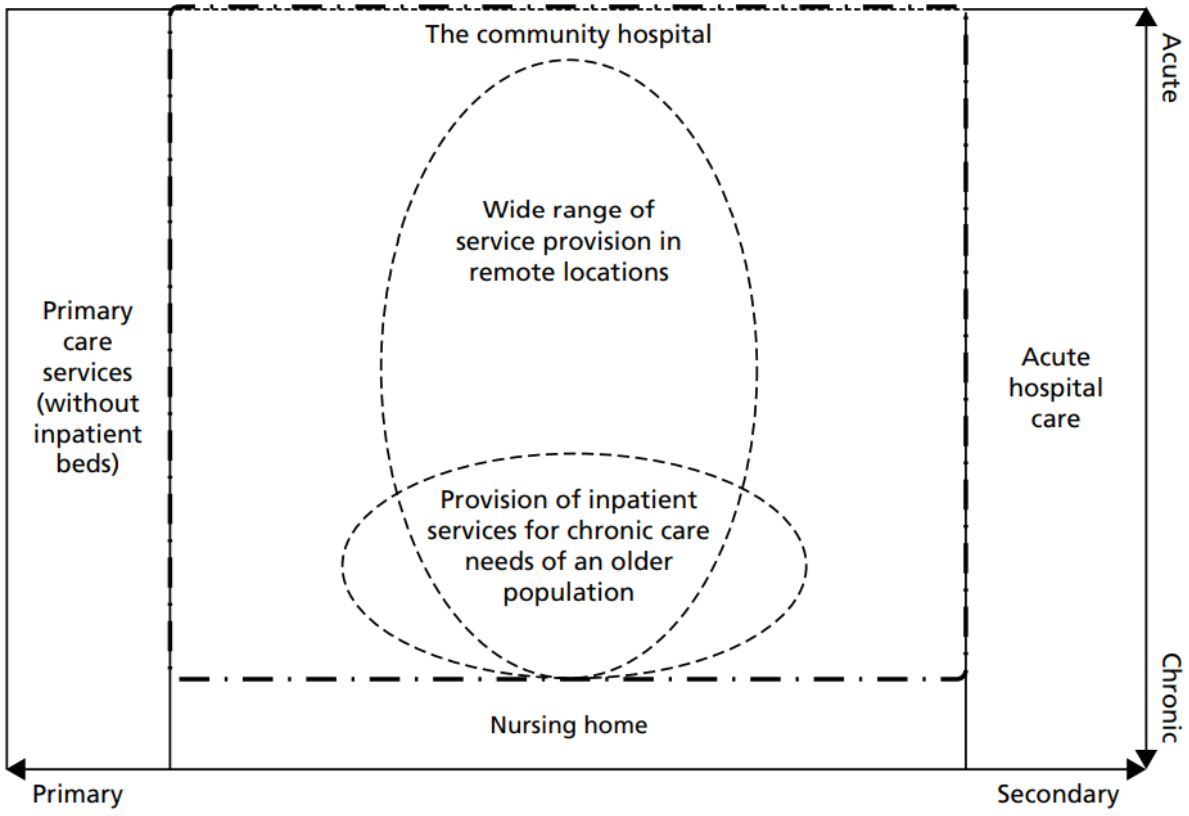

Figure 1 Graphical definition of O.d.C from – NHS (National Institution for health research

The figure says that the Community hospitals or O.d.Cs lies between the Primary care services (without in patients beds) or residential health care centers and Acute Hospital care or fully functioning or High level healthcare center which are called secondary health care centers. The dashed square between these services indicates the flexibility between the services provided form primary to secondary including home nursing. The Community hospitals can provide health care services from acute to chronic care. The services provided by these hospitals are wind or broad range in remote location and allowing inpatient services for chronic care needed by older population. This service also includes nursing.

1.1.2. History of O.d.C

The Community Hospitals (O.d.C) were introduced in mid-nineteenth century in England, and they were called as “Cottage Hospitals or General practitioner Hospitals” with services provided to local population and local doctors and managing staffs. The preliminary objective of the was to provide health services to rural populations, far from main urban regions also from main well-established hospitals. Later they were added to National Health Service (NHS). Later the O.d.Cs were established in countries with low population density such as Australia, Canada, and New Zealand, where O.d.C were generally refers to infra-structure which offers wide range of health services including emergency ward. The O.d.Cs in Canada showed that the emergency urgency departments and basic laboratory services, had limited access to specialist and medical services. Only 17% of the structure was used for integrated intensive care unit **(Fleet et al., 2013).**

The O.d.Cs in European level is based on England’s version but the Service delivery system is more concentrated on limited types of services, But also the individually each country has its own importance and level of health services that it provides. In general, the service is dedicated to care services for sub-acute and post-acute patients, intermediate care, rehabilitation services and, in some cases also palliative care and pain therapy **(Winpenny et al., 2016).** the "European" model seems more oriented towards chronic patients and mainly the elderly, who due to clinical complexity and / or relative to their home context cannot be adequately treated at home **(Dobrzanska et al., 2006; Owen, 2010).** O.d.Cs in international level also includes some outpatients service for example,

Chemotherapy cycles and follow-up for cancer patients **(Neame,2008),** therapies and assistance to people with eating disorders **(Simpson, 2005),** diagnostics in the gynecological field **(Penfold, 2013).**

Hence, Based these examples the O.d.Cs can have wide range of services but the services to be provided must be selected based on the requirements of the local population. The typical types of health professionals like Physiotherapists, occupational therapists, OSS, dieticians, and rehabilitation technicians and nursing staffs can be provided. In New Zealand the surgical team visits the community hospitals twice a week and give consultation for people of remote place and are unable to reach high specialist hospitals. In Australia, the health specialist (teleophthalmology) consults patients remotely using digital health, telemedicine and telemonitoring tools.

1.1.3. Italian National legislation for O.d.C

The O.d.C in Italy were started recently. The permanent Conference for relations between the State, the regions and Autonomous Provinces of Trento and Bolzano held on 20 February 2020 established agreement on minimum structural, technological, and organizational, requirements for O.d.C based on provisions of previous agreement established in the same conference held on July 2014 (art.5, paragraph 17) for the new “Pact for health for the years 2014-2016”.

The agreement is based on indications that are already contained in decree of the ministry of health of 2 April 2015, n, 70, art 10.1. In this the O.d.C represents an intermediate structure between integrated home assistance (l’assistenza domiciliare integrate, ADI) and Hospitals with services that are different from non-hospital residential structures for self-insufficient chronically ill, disable and terminally ill patients as defined by the DPCM of 12 January 2017 (art, 29-35). Its more similar to most of the European countries were O.d.Cs are for chronical, elderly and patients whose family is unable to take care. The patients in these types of hospitals require low-intensity clinical health interventions and continuous nursing surveillance but these patients are intended to be hospitalized for short-term.

The following are the recognized regulations for O.d.Cs

The management of activities in such hospitals are responsibility of district/territorial or local healthcare organizations.

1. The O.d.Cs can have individual headquarters or can be established within public health facilities, residential facilities or acute care hospitals but the remaining services or attributes under territorial assistance.
2. The number of beds in O.d.Cs is between 15-20 for each 50,000 population (equal to 0.4 beds per 1000 inhabitants) and can be extended with two modules up to 15-20 seats each.
3. A one module having 20 beds must have 9 nurses, 6 OSS and 4 hourly doctors. The technologies like defibrillator, portable electrocardiograph/telemedicine, saturated meter, spirometer, blood gas analyzer, device for POC examinations, Ultrasound and others can be identified and defined based on the requirements.
4. The patients coming from home or other Healthcare facilities are undergone through multidimensional assessment at the access point and the nursing facility is provided within 24hrs from the time of appointment.

1.1.4. Types of patients in O.d.C

a) Pazienti fragili e/o cronici, provenienti dal domicilio, per la presenza di riacutizzazione di condizione clinica preesistente, insorgenza di un quadro imprevisto, in cui il ricovero in ospedale risulti inappropriato;
b) Pazienti, prevalentemente affetti da multimorbidità, provenienti da struttura ospedaliera, per acuti o riabilitativa, clinicamente dimissibili per conclusione del percorso diagnostico terapeutico ospedaliero, ma con condizioni richiedenti assistenza infermieristica continuativa;
c) Pazienti che necessitano di assistenza nella somministrazione di farmaci o nella gestione di presidi e dispositivi, oppure che necessitano di interventi di affiancamento, educazione ed addestramento del paziente e del caregiver prima del ritorno al domicilio;

d) Pazienti che necessitano di supporto riabilitativo-rieducativo, il quale può sostanziarsi in: valutazioni finalizzate a proporre strategie utili al mantenimento delle funzioni e delle capacità residue (es. proposte di fornitura di ausili); counselling e educazione terapeutica al paziente con disabilità motoria, cognitiva e funzionale; interventi fisioterapici nell'ambito di Percorsi/ PDTA/Protocolli già attivati nel reparto di provenienza e finalizzati al rientro a domicilio

Table 1: Types of patients for community hospitals – from Report Agenas, 2021

The above table gives the information about the types of patients to whom the Ospedale di Communita (O.d.C) are established. But below this paragraph we have translated version of the information in English.

a) Fragile and chronic patients, coming from home, due to the presence of an exacerbation of pre-existing clinical condition, onset of an unexpected situation, in which hospitalization is inappropriate.
b) Patients, mainly suffering from multimorbidity, coming from hospital, acute or rehabilitative, clinically discharged due to the conclusion of the hospital diagnostic therapeutic path, but with conditions requiring continuous nursing assistance.
c) Patients who need assistance in the administration of drugs or in the management of aids and devices, or who require support, education and training of the patient and caregiver before returning home.
d) Patients who need rehabilitation-rehabilitation support, which can consist of: evaluations aimed at proposing strategies useful for maintaining functions and residual capacities (eg proposals for the supply of aids); counseling and therapeutic education for patients with motor, cognitive and functional disabilities; physiotherapy interventions in the context of Paths /PDTA / Protocols already activated in the ward of origin and aimed at returning home.

1.2. Building Information Modelling (BIM)

The Building Information Modelling or simply known as BIM is a Methodological approach to the design and development of the building. The BIM is more than just modelling, it is a process that starts from the start of the project until Termination. We can identify important stages of BIM process, Planning, Modelling, Structural Design, Cost estimation, Construction, Operation or maintenance, and Termination. But the methodology can be decided by BIM project manager based the requirement of the clients. The BIM can be considered as Digitalization of building lifecycle.

But the case study used in the project is an easing building hence the building life cycle is modified accordingly.

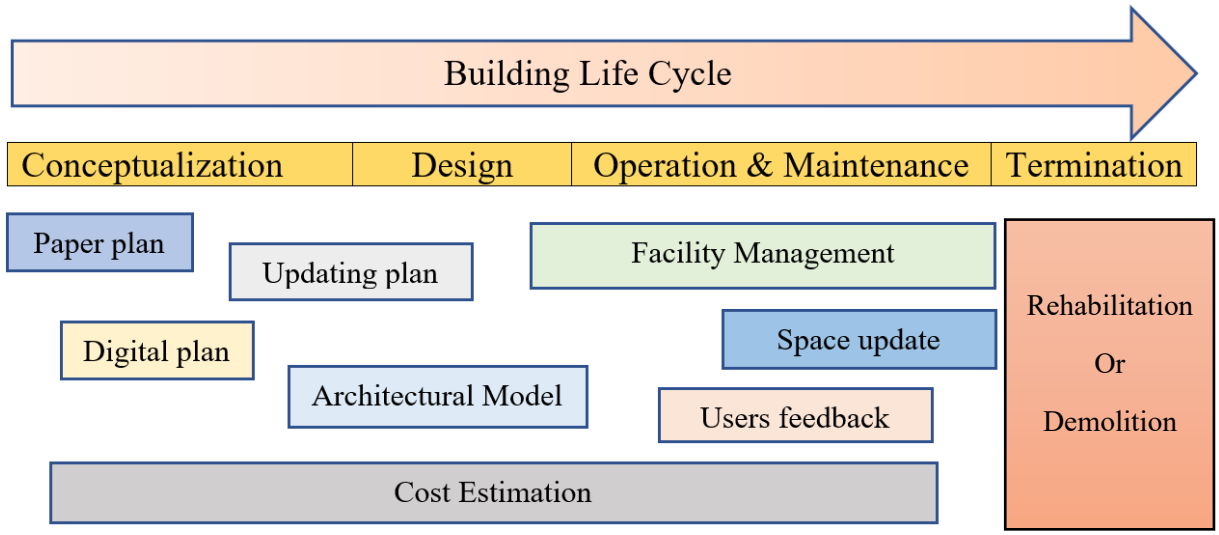

Figure 2 Building Life cycle for existing building

The main and important use of BIM is to collect, store and improvise the building information from planning until termination of the project.

1.2.1 BIM Methodology

The Typical BIM methodology is the inter-operable process between the stakeholders who participate in the building lifecycle from design until termination. BIM methodology can be modified according to the requirements of the project. The methodology is interoperable between stakeholders of different roles. Here the Project is handled by Project Manager or BIM manager, The Design process includes development of plans to be executed and Architectural design, design for structural stability, usually design process includes more than one stakeholder like Architects, Structural Designer, Interior designer and building engineer, rehabilitation engineer. The cost will be estimated based on the design. The BIM facility Manager adopts the design and manages the operation and maintenance of the building based on user feedback system that will be explained in this report later. The rehabilitation is conducted after or during the operation phase. These stages of the building are assisted by BIM based software. The described methodology is shown in the figure below,

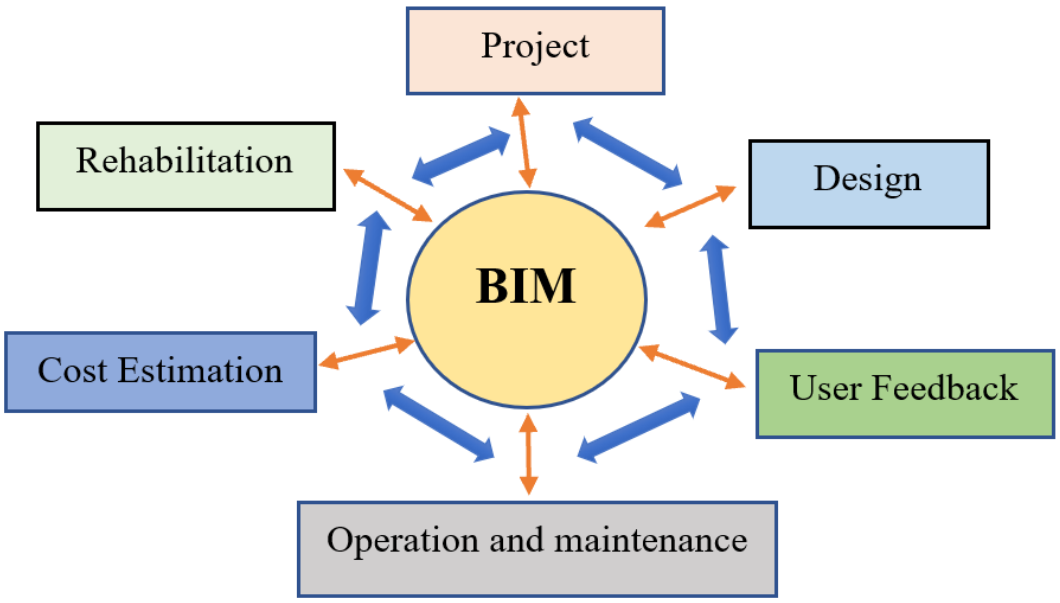

Figure 3 BIM Methodology

1.2.2 Level of Development (LOD)

As described earlier, the BIM is a methodological approach, and we need to define the project with high information. The Level of development (LOD) defined based on the level of information that embedded in the model or included in the design process. The Level of development also enhances the knowledge of design process within the stakeholders of the project. The Level of Development is not level of detail because the Level of detail is just the detailing of the 3d model whereas Level of Development is information that are embedded in the model. The figure below illustrates the meaning of LOD in simple way.

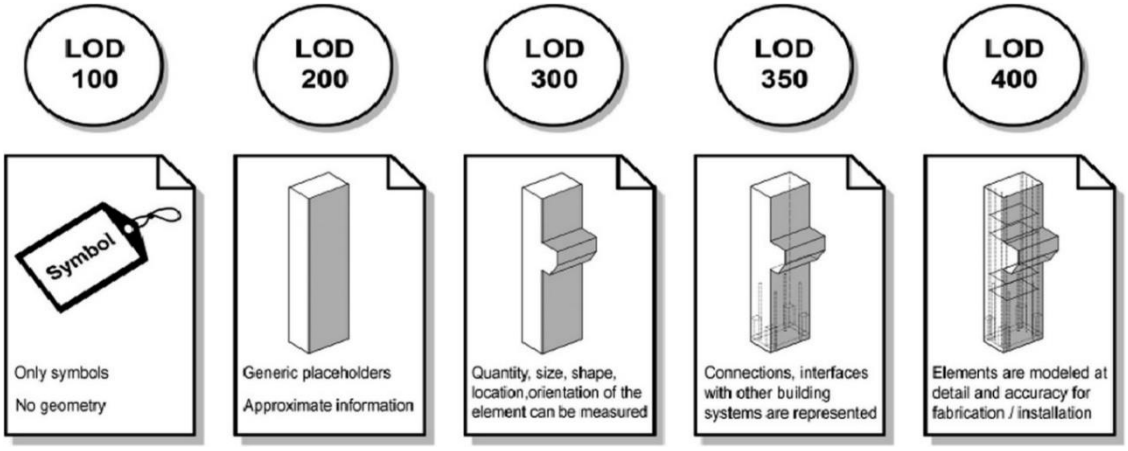

Figure 4 Level of Development in BIM -(Mekawy & Petzold, 2018, Figure 2)

The LOD 100 is just a symbolic representation of the Element. LOD 200 is approximated information about the element also a geometrical outline of the element. The LOD 300 is little closer to shape and size of the element with orientation. LOD 350 has connections, interfaces and with some more information about the building. The last LOD 400 contains every possible information of the element with installation or fabrication details.

1.2.3. BIM Dimensions

The building information modelling is expressed based on level of development, level of information and level of details. The BIM dimensions define the level to which the project is targeted. It depends on the type of project and user

requirements. 3D BIM is Geometric representation of building in space within physical aspects. The 4D BIM is achieved by adding time parameter of construction sequence into the project development phase. 5D is Cost Analysis and monitoring, 6D is when Sustainable development is considered during the design, and 7D which is under development, this is design of building maintenance phase, Still the BIM dimensions are under research stage. We are seeing some researchers adding "n" number before "D" and making new dimensions by considering safety and more parameters.

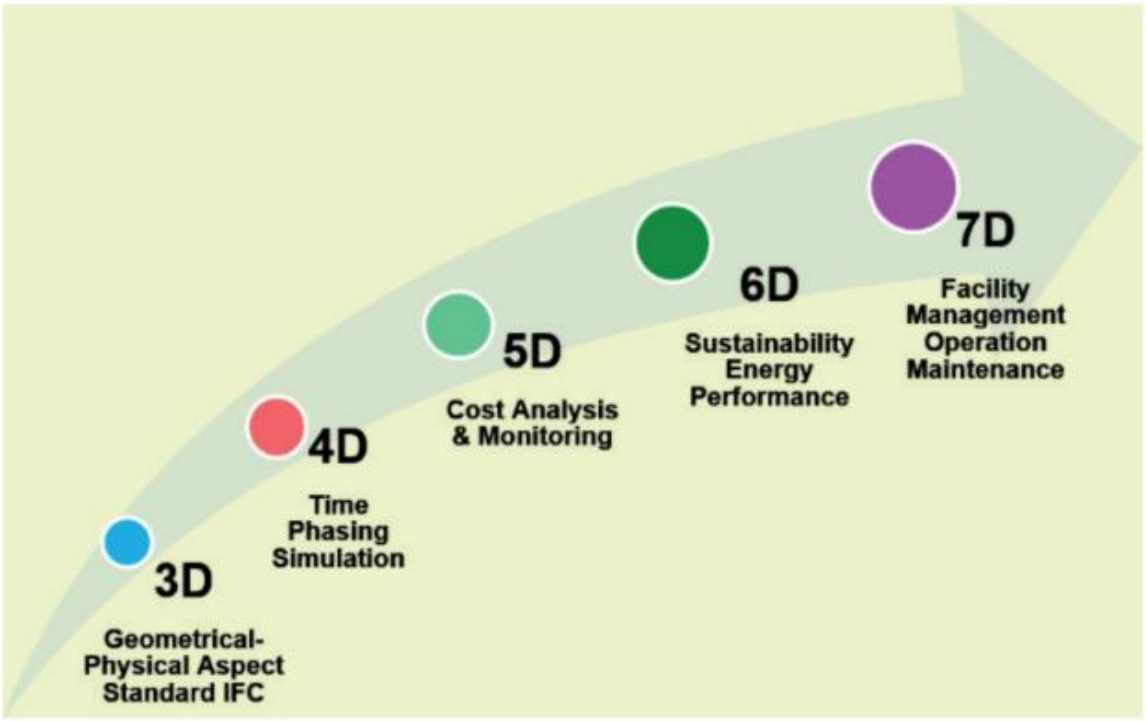

Figure 5 BIM dimensions, (Kontothanasis et al., 2019, Figure 1)

1.3. Virtual Reality

The Virtual reality is the reality that is created using computer. The 3D model that is modelled during the BIM process is visualized using appropriate

virtual reality software. The Virtual reality has high virtual content, low real content, and low interactivity. It has been in use since 1990 and after 2005, the study shows the implementation of virtual reality in wide range of fields like, engineering, medicine, mental health, design, architecture, and construction, education and training, the arts, entertainment, business, communication, marketing, military and travel.

There are three main visual display options which are called the immersion levels the levels are as follows (Hassanein, 2020):

- **Non-immersive VR platform:** The non-immersive Virtual reality is visualizing the created Virtual content on Desktop screen and the viewing is controlled by keyboard and mouse attached to the computer. The associated cost of this VR is the lowest among. The example is Autodesk Navisworks model.
- **Semi-immersive VR platform:** This VR technology uses desktop screen to project the virtual content, but the user uses 3D stereoscopic Glass to see the content. Still the movement of the objects are controlled by keyboard and mouse connected to Computer.
- **Full-immersive VR platform:** This Virtual reality system projects complete 360 visuals around the user. The User uses Head mounted display to view the content. Still, this requires the computer with powerful hardware. This is the expensive VR technology and offers fully immersive experience.

Figure 6 VR Immersive Levels (Ghani et al., 2019, Figure 1)

2. Literature Review - Findings

The Introduction contains the information that are extracted from scientific papers. The experience of reading all these papers enhanced my knowledge about community hospitals around the world, Building information modelling and virtual reality. I found that each researching team has done very impressive work in their research. The important findings of these research are mentioned in below table.

Title- Research paper	Publication year	Findings	Authors
3D-Modelling and virtual reality applied to complex architecture – an application to hospital design	2019	1. BIM Methodology 2. Coordination between design and construction	P.Chias, TAbad, M.de.Miguel G.Garcia-Rosales, E.Echeveria.
A BIM based space-oriented solution for hospital facilities management	2020	1. Space oriented solution as interface to transfer data from BIM manager to Facility manager	Ya Wen, Llewellyn C.M. Tang and Daniel C.W. Ho
An Integrated BIM framework to support facility management in healthcare environment	2012	1. Relationship between FM and clinical staff 2. Method to manage healthcare facility data	Lucas, Jason David
From BIM to VR integrating immersive visualizations in the current design process	2014	1. Immersive visualization for design 2. Realtime visualization	Mikael Johansson Mattias Roupé Mikael Viklund Tallgren

From BIM to extended reality in AEC	2020	1. XR and tools for construction management 2. Cloud based data management	Sepehr Alizadehsalehia, Ahmad Hadavib , Joseph Chuenhuei Huangc
BIM based modelling and management of design option at early phase	2018	1. Manage design options with graph data models	Hannah Mattern, Markus Konig
A conceptual idea of participatory design with BIM	2019	1. Involving the users in design phase 2. Remove limitations of participatory design	Emrah Türkyılmaz, Muhammet Berkay Kizilkan
Virtual reality as a tool for participatory architectural design	2019	1. User review and design updating method	Emre Dedekargınoğlu Meltem Yılmaz
A mixed reality approach to 3D interactive prototyping for participatory design of ambient intelligence	2016	1. Mixed reality with participatory design for ambient intelligence	Yang Yu
The integration of BIM in facility management using AR/VR	2021	1. BIM to FM integration 2. 7D BIM with VR/AR tools	Ahmed Ghoneim
Participatory design through BIM	2019	1. Increase quality of design with participatory design	Turkyilmaz, Emrah Kizilkan, Berkay

Table 2 Literature Review and findings.

I found a situation where; I could combine the space management and participatory design together. The space and facility management are one of the important stages for the building, I will be developing a possible methodology for integrating the participatory design (involving user of the building) for space and facility management. Every user has their individual choices when it comes to managing the space of their staying.

3. Case Study – Thesis development

The case study used for this thesis is an existing building located at the intersection of Via Francesco Cigna and via Cuneo with an airy park at the back. The building is known as Astanteria Martini the owner of the land is Professor Enrico Martini. The building was designed in 1920 by Carlo Sgarbi, the design drawing showed that the faced has three floors above the ground, of which the last (2nd floor) was used as dormitory and lateral wings had two floors. The hospital was inaugurated by Enrico martini on May 5th, 1923, with the name Astanteria Municipale Martini. The Main aim was to provide emergency aid in the northern region and hospitalizing the seriously ill of both sexes in the beds set by the Town Hall. The structure was expanded by th engineer Francesco manca in 1929 with the construction of a chapel on the second floor and new pavilions used as infirmaries along the Cigna and Dogliani streets.

The building was transferred to municipality in 1937 and became the part of Ospedale Maggiore San Giovanni Battista. But in 1954 the building was sold to Giovanni Bosco Hospital, and new Astateria martini was inaugurated in 1961. The hospital was closed in 1997 and the wards were transferred to Giovanni Bosco Hospital and the building has been unused since 2003.

The important history also includes damaging of the building by bombing during an air raid on July 13, 1943. The explosive caused dame to the roof and walls collapsed with serious damage to the windows. The building was refurbished in 1943 and the historical architecture was restored.

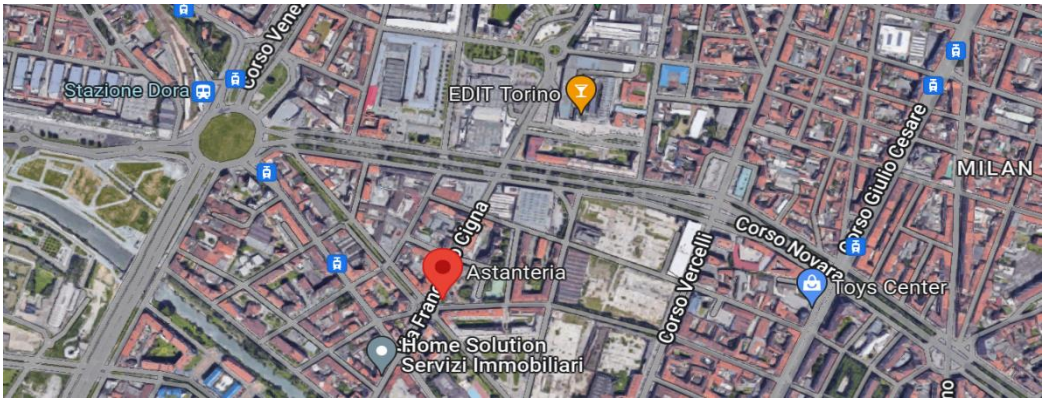

Figure 7 Location of Astanteria martini, via Francesco Cigna 74, Torino. (From google.com)

Figure 8 Current Astanteria martini, from Google maps

Figure 9 Astateria Martini, Torino. Site visit

3.1. Tools

The space management is one of the important design steps for a hospital and facility manager. To develop a simple setup that can be used for space management I choose Revit and Enscspe3D. As the abstract suggest that one of the aims is also to check the interoperability between Revit and Enscape3D. The software used for this thesis are AutoCAD, Revit Architecture, and Enscape3D. The hardware used is Oculus Rift S.

3.1.1.AutoCAD

AutoCAD is a digital software developed by Autodesk enabling design team to be creative with automation, collaboration, and machine learning capabilities. Importantly the AEC industry rely on AutoCAD for designing, automated task (including measurement and blocks creation), and finally creating a custom workspace. With the help of AutoCAD, we can create the plans and sections of the project.

Figure 10 AutoCAD logo, 1000marche.net

3.1.2.Revit Architecture

Autodesk Revit 2021 version is used for modelling the 3D model of the Astanteria martini.The Revit Architecture is a Building information modelling (BIM) software produced by Autodesk. This software helps architecture, engineering, and construction (AEC) teams to create or design high-quality buildings and infrastructure. The architect or engineer can create model of any shape. This software allows different file formats (ifc, fbx, dwg, etc.) to link into the project. The Revit comes with loadable components as family (like doors, windows,

furniture, and staircase) thus allowing the designer to enhance design process. Revit also helps is cost estimation by developing a table of components.

Figure 11 Revit Architecture. logolynx.com

3.1.3.Enscape3D

Enscape is more than 3D rendering software for CAD and BIM software. The design process is enhanced by immersive visualization. It supports wide verity of software like Revit, SketchUP, ArchiCAD, etc. The Enscape is a one press simple to start visualizing in immersive visualization. It allows the designer to import pre-installed families from Asset library. It allows real time visualization during the design step. But the properties of the components installed are not visualized in real time.

Figure 12 Enscape logo. enscape3d.com

3.1.4.Oculus Rift S

Oculus Rift S is one of the PC powered Virtual reality Gaming Head Mounted Devices. I chose to use this because its simple and convenient to use with the desktop. It can render high quality image faster. To play this just requires oculus software, but once the software is installed, I can just plug and play. The interaction with model is done through right and left joystick. The price of this device is 400 to 600 USD.

Figure 13 Oculus Rift S from amazon.it

3.2. BIM Workflow

The BIM workflow followed to develop a virtual reality model of Astateria martini is described here. The floor plans were collected from office of Archivio Storico dell Citta di Torino at Via Barbaroux 32. The file formats that was available was Pdf and JPG. These floor plans were then exported into AutoCAD and by performing tracing, the digital drawings of floor plans were generated.

After this step, the digital floor plans were imported into the Revit Architecture using link. In the Revit 3D modal of Astanteria martini was created. To create virtual modal of the building Enscape which works as plugin was used. The interoperability between Revit and Enscape is explained later. But the model was visualized using Oculus Rift S. This workflow was followed to develop the model and understand the different purposes of the software and hardware. The workflow has been demonstrated in the below figure (13).

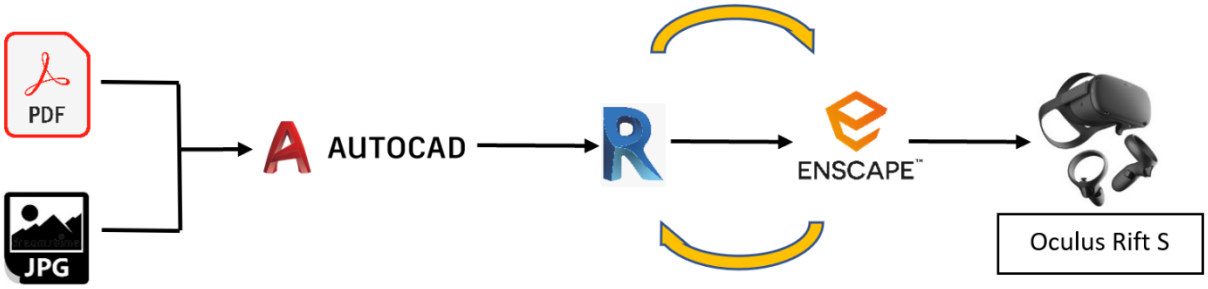

Figure 14 BIM workflow of Tools used.

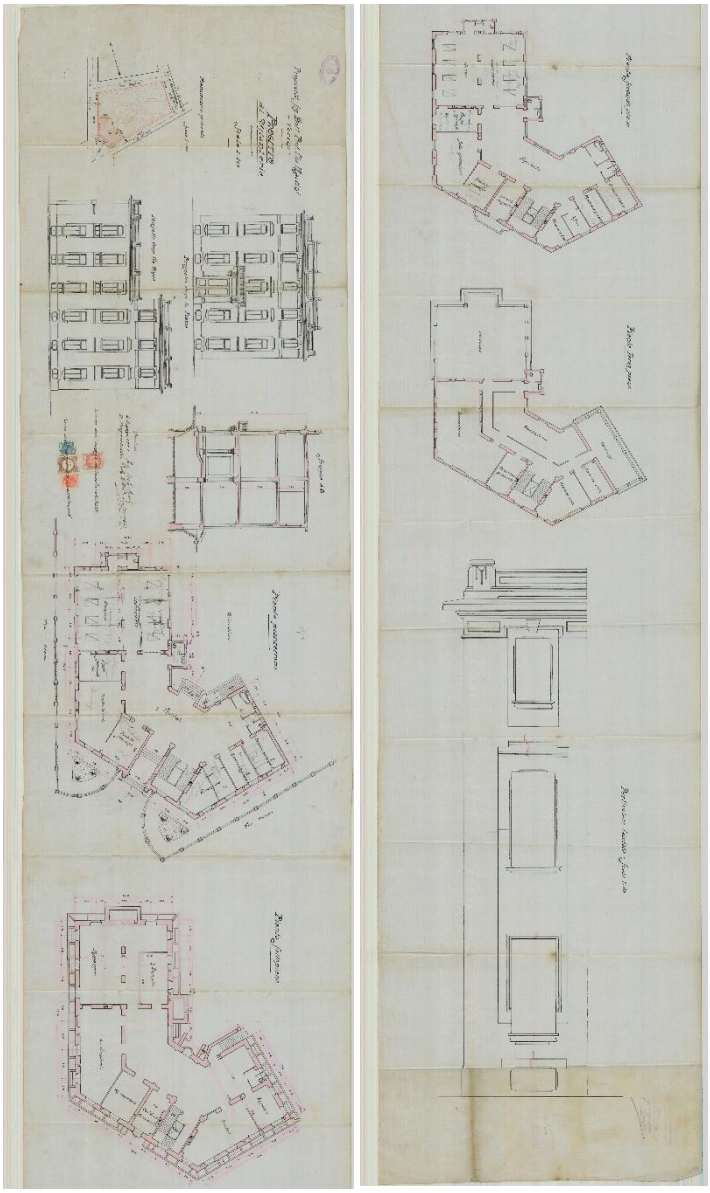

Figure 15 JPD file of Astanteria martini floor plans.

3.2.1.AutoCAD Drawings

The floor plans were traced in AutoCAD software. These floor plans had limited specification to satisfy the conditions of an O.d.C. Hence the floor plans were updated according to the requirements.

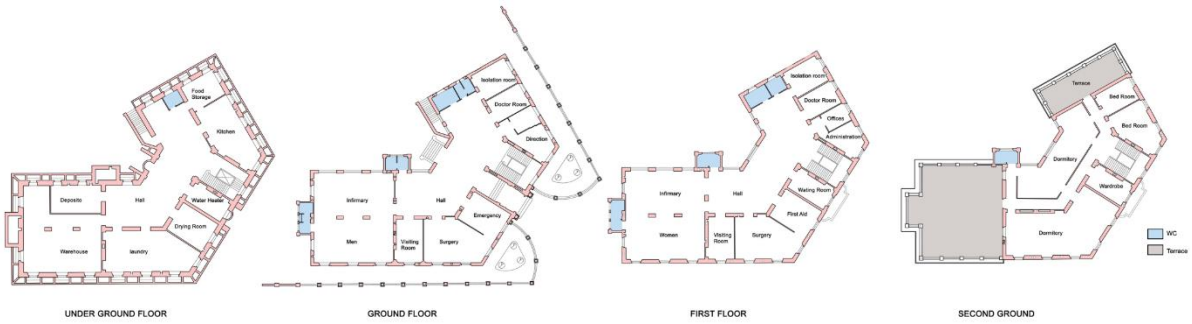

Figure 16 Digitally traced floor plans of Astanteria martini.

The Figure 15 is the digitally traced floor plans on AutoCAD software. The Figure 16 below (next page) shows the updated plans of Astanteria martini for O.d.C. The basement or underground floor is reserved for storage of maintenance equipment and medical equipment, the ground floor is organized for incoming patients and waiting hall for family and parents or visitors, this place also includes reception. At this time, we had a thought of increasing the green space between the O.d.C and flexible or detachable container rooms. The container blocks are added to increase the number of beds on the O.d.C and are explained later.

The first and second floor is extremely reserved for patients' room with 2 beds in each room The floor plan had only one elevator and we added another as visible in second floor plan

.

Figure 17 Updated floor plans of Astanteria martini for O.d.C.

3.2.2.Modelling in Revit

The AutoCAD files were imported into Revit using link CAD. In the initial stage the model with walls was created, then the family components like doors and windows were added. After this step the model with green space, roof top winter garden and container rooms were created in Revit Architecture.

Figure 18 Model development of Astanteria martini. Revit Architecture.

3.2.2.1. Roof top winter garden.

The roof top winter garden is designed at the roof of the Astanteria martini. This garden is considered to enhance the life of living in the hospital. The separate garden will be used as place, where patients can spend their time enjoying the scenario and relax by doing exercises or yoga. This will improve the recovery of illness of patients.

Figure 19 Roof top winter garden.

Figure 20 Possible usage of roof garden.

3.2.2.2. Container rooms for additional beds

The space behind the Astanteria martini is designed with more green space and container blocks which can be expanded. These container blocks are prefabricated specifically for health care purpose and can accommodate 2 beds in each block. The dimension of this block is 6m x 3.7m x 2.6m as length, width, and height. But width has a one restriction which is transportation. The maximum width that can be transported on road in Italy is 2.5m. for this the container blocks are made compressible into the width of 2.4m during the transportation and can be expanded to 3.7m during installation.

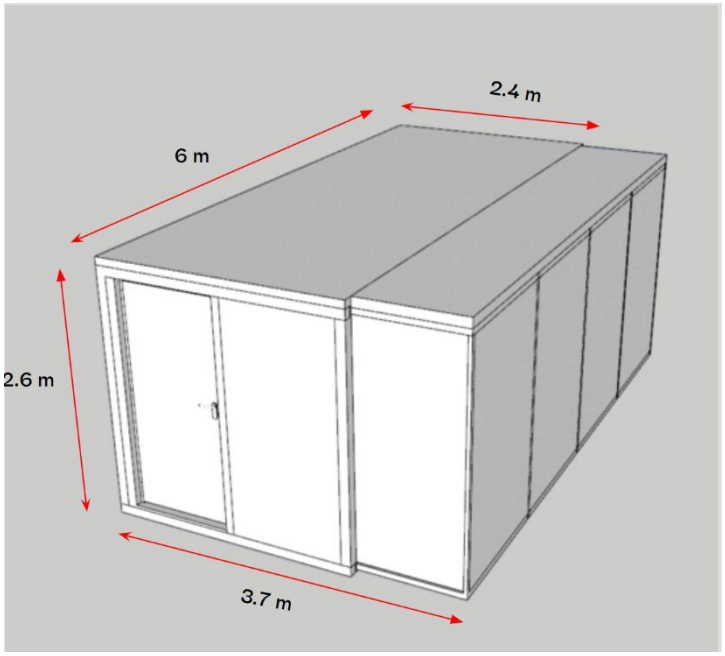

Figure 21 Size of container blocks.

The purpose of these blocks is to expand the capacity of hospitals during at the time of pandemic situation or also to assist the big specialty hospitals during the need of more beds. The container blocks are made of steel material. These steel container blocks are arranged in horizontal and vertical to form a structure and are supported by steel beams and columns.

Figure 22 Arrangement of container blocks.

3.2.3. Enscape3D Plug-in and import

Enscape operates with Revit as plug-in. This ribbon contains Start to launch into render able visualization model. But in addition to this we have wide range of asset libraries through which many assets like plants, people, furniture, and vehicles. Enscape also contains material library to create realistic texture of material of elements.

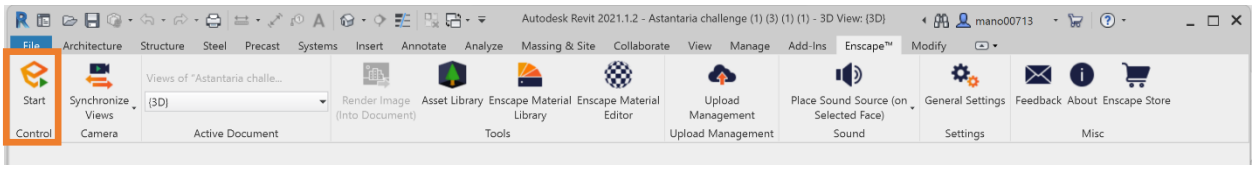

Figure 23 Enscape plug-in ribbon.

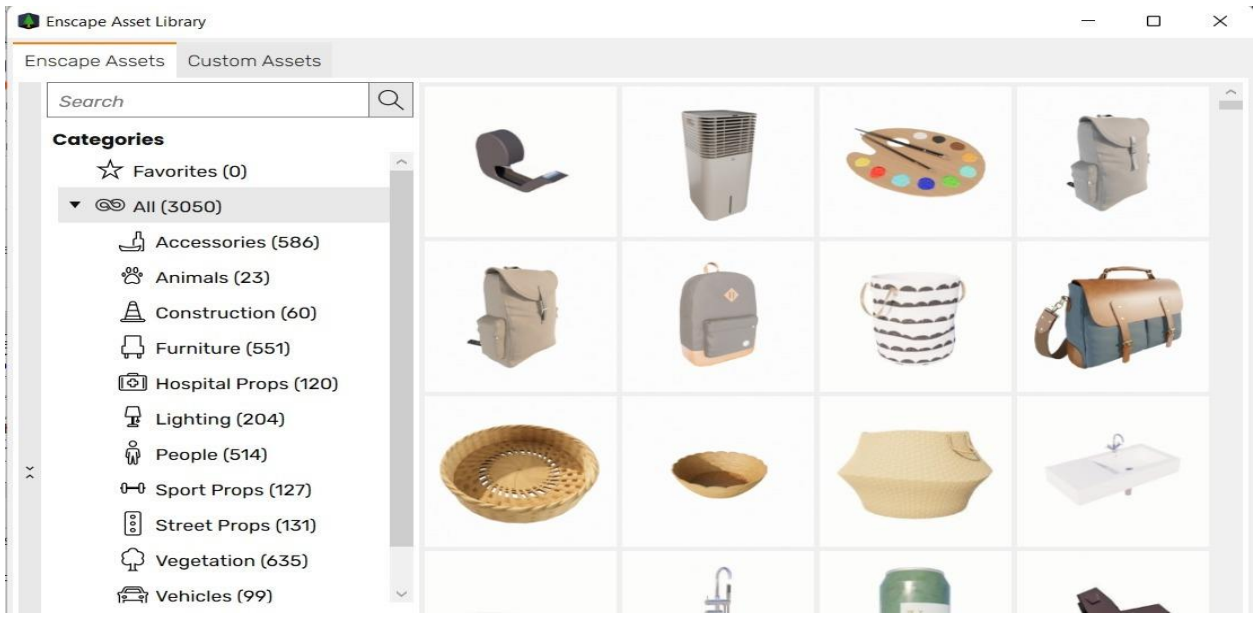

Figure 24 Enscape Asset Library

Once the Start is done, the model will be launched on to Enscape. Currently, it is possible to view the properties of each element under BIM button. There are many options to view the model, but we are focused on Virtual reality visualization. To visualize using oculus rift S we need to press button with headset symbol on top right corner.

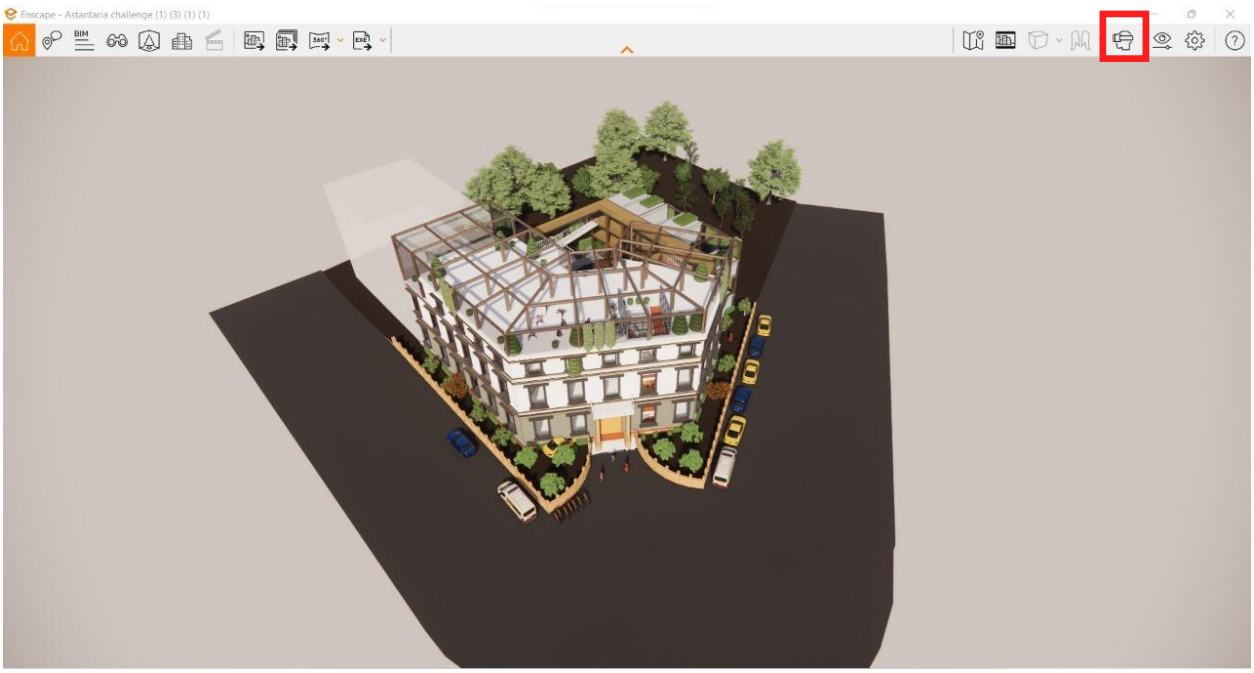

Figure 25 Astanteria martini on Enscape3D.

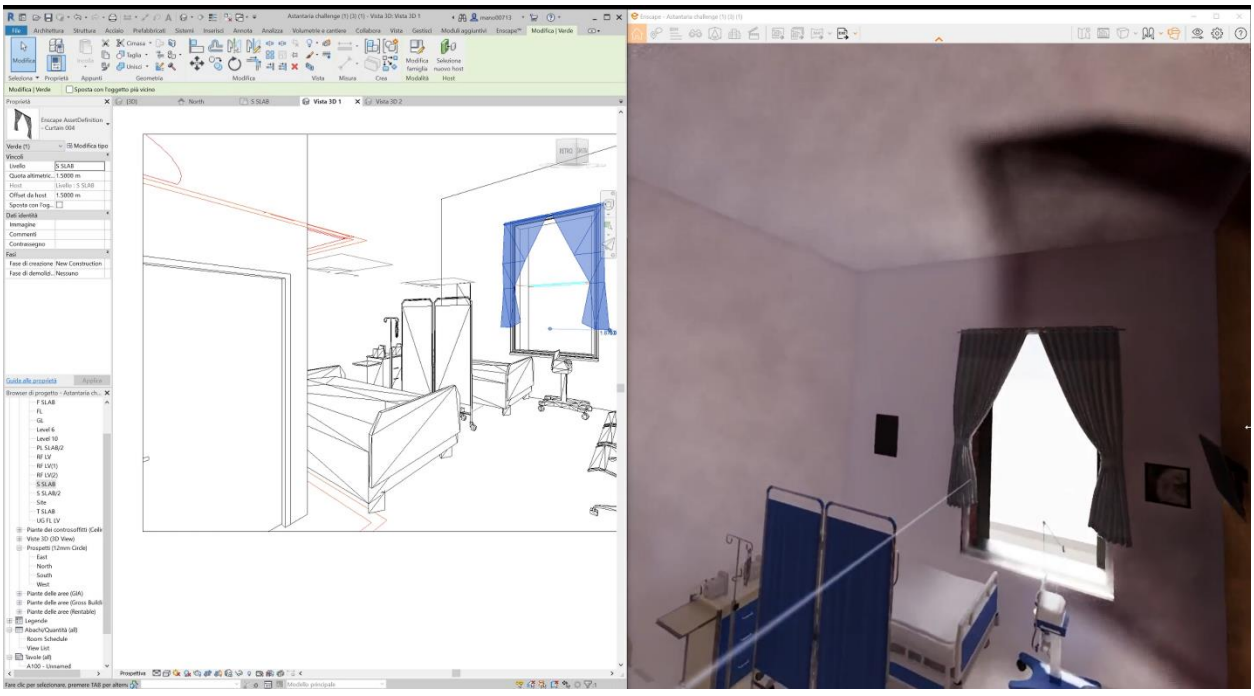

Figure 26 Realtime visualization for space management

The rays, that are visible in the virtual reality mode is the ray for moving in the project. The settings in virtual reality mode shows visualization modes (like fly-mode, walking mode) and rendering feature to render visual model using screenshot and render image.

Figure 27 Virtual reality mode settings. enscspe3d.com

Figure 28 Virtual reality usage at Politecnico di Torino

3.3. Interoperability between Revit and Enscape3D

Interoperability can be defined as back-bone of BIM methodology because BIM is not just modelling but a process involving different stakeholders of the project. The interoperability between stakeholders as managed by project manager whereas interoperability between software depends on the software company that develops, and the process defines the efficiency of the project that will be developed.

The aim intended to check interoperability between Revit and Enscape3D is to define the place of improvements for the software and to assist the facility manager to manage the space of Ospedale di Communita at Astanteria martini.

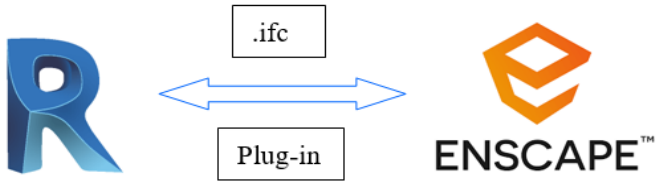

Figure 29 Interoperability between Revit and Enscape3d.

Modes / Features	3D model	Virtual reality
Real-time visualization	✓	✓
Rendering	✓	✓
Modification	✓	✗
Properties	✓	✗

Table 3 Results of Interoperability check

The interoperability between Revit Architecture and Enscape3D is positive in terms of its usage. When Enscape3D is launched with start the visualization is in 3D model and in this mode all the functions (like visualization, rendering, modifications and, Properties view) but during the virtual reality visualization the modification and properties does not work.

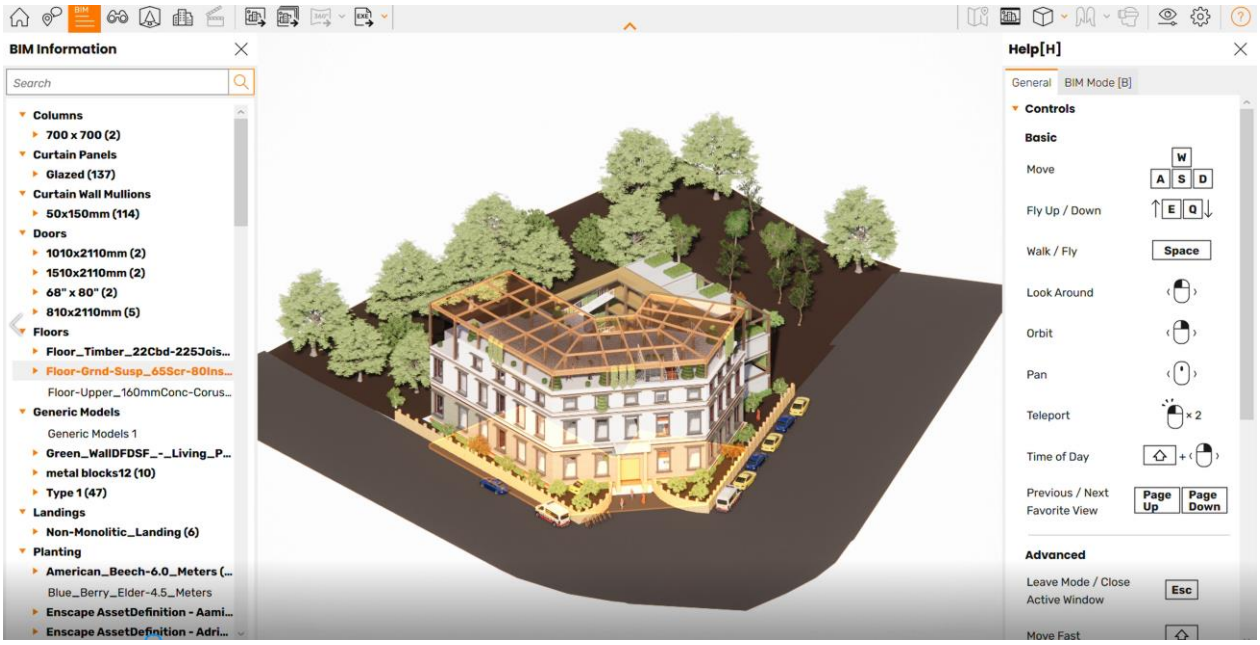

Figure 30 Properties visualization in 3d model mode.

Positive

- The Enscape3D operates as a plug-in rather as a separate software which is very convenient for usage.
- .ifc behaves as standard file transfer format.
- Synchronize the view just by one click.
- Real-time visualization of modifications.
- Asset library to import Revit families.
- No loss in information.
- Accurate visualization of information in real-time.
- Rendering of images during usage of virtual reality.
- Can view properties of elements in used in model in normal mode.

Negative

- Lack of visualization of elements properties in virtual reality mode.
- Not possible to edit and modify the model in virtual reality mode.
- Revit must be kept opened during usage of virtual reality.

3.4. Integration of BIM and VR with participatory design

Participatory design is under use since 1990 and have been important integration because it allows collaboration between designer and users in the design process. Participatory design means involving the users of the building in design process. This thesis is aimed to involve users for space management of the O.d.C, that will be developed in Astanteria martini. The user of O.d.C are subject to change frequently because once the patients has recovered fully from the illness, he or she will be discharged from the O.d.C. to provide pleasant place during the stay the space inside the patient room is organized as per patient requirements. The doctor's and staff's room will also organized based on their requirements.

3.4.1.Workflow

The workflow for integration of BIM and VR with participatory design for space management was developed keeping in mind the users of the Ospedale di Communita. This method is applied during the operation and maintenance phase of Building lifecycle shown in figure 2. Hence this activity is managed by facility manager.

The users of O.d.C. are Patients, Doctors, and Nurse staff who can request to visit the virtual reality room (VRR is a room containing Virtual reality equipment and desktop) in the hospital. They will be taken into the virtual reality room and made to wear (Head Mounted Display) HMD. The facility manager of the building will launch the Revit Architecture and Enscape3d on a desktop with attached software of HMD (Oculus rift S). When the User can view users' room in the HMD can write the changes that they need in their room. Also, the facility manager can

modify the model under view when user is viewing the model on virtual reality HMD. The workflow is repeated for different users of the O.d.C. The hospital model is modelled and tested by building engineer before giving it to facility manager. The workflow is shown in the figure 30.

The feedback or checklist contains the modification requirements of each user. The checklist can have the organization of equipment, television height, position of wall paintings or replacing the wall paintings with their family photos. But this user's requirements must not include the requests that are not economical and executable like changing the color of the wall paint.

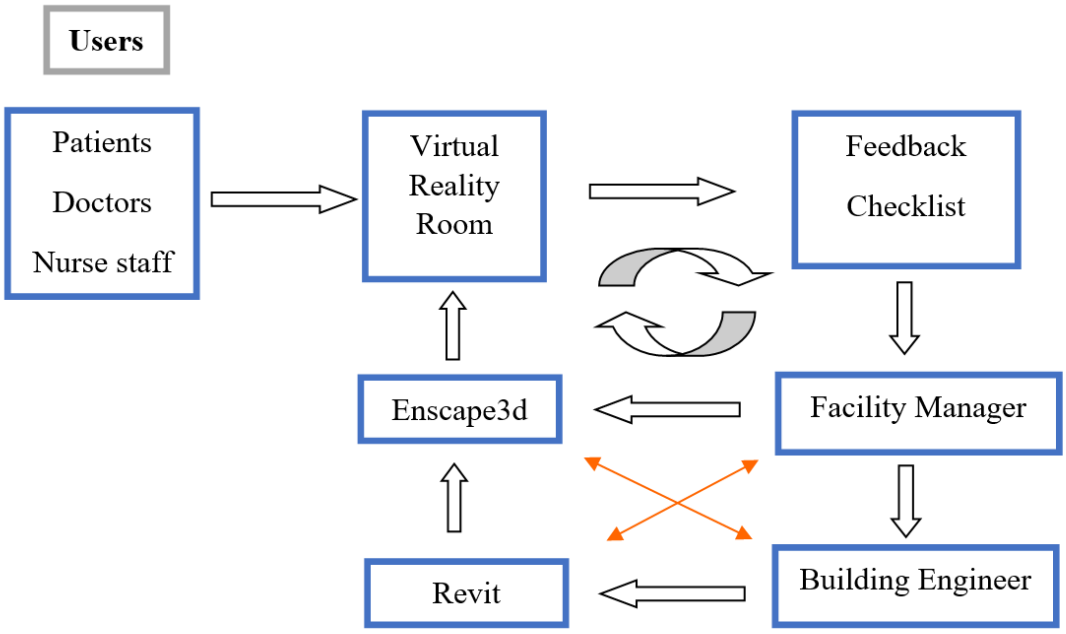

Figure 31 Workflow of Integration of BIM and VR with participatory design.

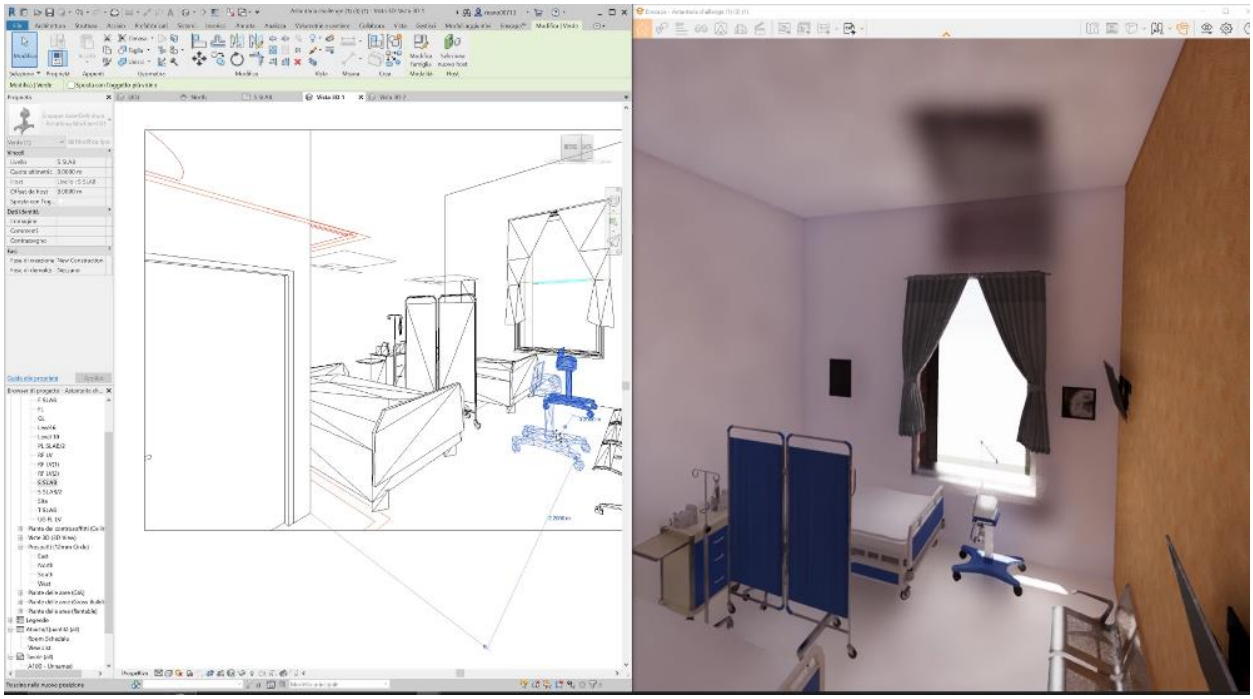

Figure 32 Side by side Visualization and modification.

The figure 31, demonstrates the real-time visualization of medical equipment's position changing. The left tab shows the modification done on Revit Architecture when Enscape3d was launched, and the position of breathing equipment was changed, this change was immediately visualized in real-time on Enscape3d in the right tab, demonstrating the interoperability of Revit and Enscape3d for space management.

Conclusion

The community hospitals are still under development in Italy. Some countries like England, Australia, India etc. have these types of hospitals to support rural population. Astanteria martini is one of the identified buildings for O.d.C. This project aims to provide intermediate health service and job opportunities to the local population.

The thesis aim is to study the Integrating BIM and VR with participatory design and is completed successfully. This integration helps the designer to provide best service to the users of Ospedale di communita or community hospitals. But it is possible to use this methodology to all types of projects from residential building to important public centers. The facility manager and building engineer can use the methodology to manage space inside the building and this integration can be applied both during the design and operation phases of the building, hence it is not restricted just in specific stage of the building information modelling of the building project.

The interoperability between BIM tools and virtual reality software is takes important operation for managing the space of the building. In this thesis, the interoperability between Revit architecture and enscape3d (shown in table 3) works efficiently. The enscape3d is simple software with important features like easy operation and real-time visualization of the model but needs few updates to make it more usable during the virtual reality mode like displaying the properties, object selection, and modifying the objects position. If these features to be added into the enscape3d, it will help the significantly space management with virtual reality.

Some of the important benefits of this thesis are,

- Help designer to involve user's requirement in the management process with the help of fast and reliable solution using virtual reality.
- The users (patients, doctors, and staff nurse) of Ospedale di Communita are provided opportunity to create pleasant environment during their use of the building.

- Astanteria building is a historical building with historical significance in its architecture hence to protect historical elements are kept as they exist. The design of roof-top winter garden is made considering the existing architectural value of the historical building.
- The O.d.Cs require flexible and short-term solutions for providing the service having the people as the main core of the design process, hence the transportable, detachable and prefabricated metal container blocks are designed to meet the need of additional beds during the time of pandemic similar to one we faced in the past 2 years.
- The cost of the equipment like Powerful Desktop and HMD are high, hence the initial cost to be invested become more.

Recommendations

The AEC industry is growing with new technologies with advanced design tools and techniques. Here in this thesis, I have used one of such technology for O.d.Cs. in future it is possible to study Extended reality for space management in AEC industry could be a step up. The software developer of enscape3d can use the interoperability results to improve their software for better integration of features. Finally, Architecture Engineering Construction industry is one of the fast-growing industries with more and more research-based development to enhance the life of living of people, if it is possible the researcher can find literature review to develop the more research concepts.

Appendix

In this section, the rendering of the model is presented.

Figure 33 Model rendered on Revit Architecture.

Figure 34 Model rendered in Enscape3D.

The enscape3d model can be viewed on any web browser using the following link,

https://api2.enscape3d.com/v1/view/94013870-21b1-4fc7-b817-1dddf3764e7d

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