BEYOND BLUEPRINTS: NAVIGATING ARCHITECTURAL TRANSFORMATIONS IN VIRTUAL REALITY

MOHAMMADREZA MEHDIZADEH

SUPERVISOR: PROF. FILIBERTO CHIABRANDO
CO-SUPERVISOR: ARCH. MICHELE RAMELLA OTTAVIANO
ASSISTANT: PROF. VINCENZO DI PIETRA

THESIS PROJECT | MASTER'S DEGREE COURSE IN ARCHITECTURE FOR THE SUSTAINABILITY DESIGN | POLITECNICO DI TORINO

A.Y. 2023_24

BEYOND BLUEPRINTS: NAVIGATING ARCHITECTURAL TRANSFORMATIONS IN VIRTUAL REALITY

Mohammadreza Mehdizadeh

Supervisor: Prof. Filiberto Chiabrando
Co-supervisor: Arch. Michele Ramella Ottaviano
Assistant: Prof. Vincenzo di Pietra

Master's degree course in
Architecture for the sustainability design

Id: 289478
A.Y. 2023-2024

Politecnico di Torino

Abstract

In Italy, the architectural spaces represent a blend of preserving heritage and embracing contemporary functionality which day by day get confronted with new approaches. This thesis deals with showcasing an exploration through advanced technologies and possible architectural innovations, considering the revival of an abandoned brewery in Pordenone, Italy.

At the core of this adventure lies the transformable potential of laser scanning, 3D modelling, and virtual reality (VR) technologies along with devices. These tools are to redefine the boundaries of architectural presentation, immersing stakeholders in the journey of architectural restoration.

The abandoned brewery, serves as the base-ground for this technological and design metamorphosis. The thesis outlines a precise process that starts with laser scanning using Lidar scanners, capturing every face of the structure. This data is then simply transformed into digital form through 3D modelling in Revit and 3ds Max, resulting in an intelligent digital representations, which consequently transits into the immersive domain of virtual reality, with the help of Unreal Engine.

Here, the brewery is not just visualized but experienced. Stakeholders step into a recreated, fabricated virtual world, enabling them to explore, analyse, and engage with the architectural vision on a more realistic level. This thesis is not solely a manifesto to technological approaches. It is also a celebration of the deep impact architecture can bring to communities. The renovation happens as to bring a multifunctional space, offering a co-working area, a restaurant that works with the local brewery, and an underground gym with parking lots. These elements increase community engagement, helps the local economy, and improve the collective identity of the neighbourhood.

This thesis shows a harmonious interpretation of tradition and innovation, where technology serves as a data for architectural developments. It enhances the past, reshapes the present, and finally, defines the future of architectural restoration in an increasingly digitized era.

Keywords: architectural restoration, laser scanning, 3D modelling, virtual reality, Unreal Engine, community revitalization.

| 2023-24

| 2023-24

Thesis Statement

Architectural presentation is being significantly impacted by the transformable potential of 3D modelling, laser scanning, and virtual reality technologies in the fields of restoration and adaptive reuse of abandoned architectural spaces. In addition to reviving a historic brewery, this study illustrates the manner in which the use of point cloud data, 3D data acquisition and modelling in Revit and 3ds Max, and it's immersive visualization in Unreal Engine further enhances community engagement, boosts design exploration, and remakes architectural presentation methods underneath the context of sustainable and functional architectural revitalization.

Table of contents

1 [First Stop]

2 [In Technology We Trust]

3 [Building Documentation and Modelling Work-flow]

4 [Virtual Reality Implementation]

5 [Comparative Analysis]

6 [Refrences]

Introduction

The preservation of our cultural legacy while meeting the needs of modern society is exemplified by the adaptive reuse and restoration of old structures in the field of architecture, which unites tradition and innovation. This thesis explores the harmonious interplay between advanced technology and architectural design in the restoration of an abandoned brewery in Pordenone, a forgotten relic. It sets out on this trip across these domains.

Tucked away behind the sturdy brick walls of this formerly bustling brewing establishment is an architectural blank canvas full of possibilities. The building is a potential as well as a problem because of its worn-out exterior and interior.

It calls for a rebirth that honers its industrial history while also looking forward to a new era represented by an underground gym, a café featuring locally brewed beer, and co-working spaces that will open up new possibilities for the community.

The objective of this thesis is to illustrate the potentials of new technologies that have changed the architectural restoration industry for good. It expands the art of architectural presentation by accepting the link between 3D modelling, laser scanning, and virtual reality (VR). This is a narrative of sustainable investigation and observation, that revive a community via a blend of architectural ambition and digital precision, providing an abandoned structure new life.

This study investigates the process of transforming reality into digital form via the perspective of technological proficiency. The brewery's ancient walls and collapsing ceilings are captured in all their detail by laser scanning, serving as an architectural monitor. These digital echoes then being used are methodically reassembled into intelligent representations of the real world using 3D modelling in software like Revit and 3ds Max.

Yet, the adventure is not over, Through the use of virtual reality, the story surpasses the constraints of screens and blueprints, urging everyone to cross the lines that separate the imagined and reality. By generating immersive experiences, the Unreal Engine bears on the role of the storyteller, letting users to enter the transformed brewery, experience its energy, and simultaneously participate in its growth.

The thesis acknowledges the crucial impact that architecture has on the communities it serves, alongside the technological marvels. Re-purposing the brewery into a multi-purpose facility fosters civic engagement, local economy, and reinforces the area's sense of belonging.

This thesis is, in essence, a story of invention as much as renovation, a monument to the strength of technological precision combined with architectural inventiveness. In an increasingly digitalized world, it is a trip that re-imagines the present, explores the history, and determines the future of architectural restoration.

2

In technology we trust

2|

2. 1| Virtual Reality in Architectural Visualization:

.Fig 01. *Augmented Reality - architectural presentations*

Virtual reality has recently become a much broader field, finding applications in medicine, architecture, military training, and cultural heritage, among other fields. With this growth has come some discrepancy in the definition of the medium: while in some fields VR is used to refer to 360 ° immersive panoramas and videos, in other fields it refers to fully-realised interactive CGI environments (Walmsley & Martinez, 2020).

Immersive Experiences for Architectural Visualization:

The presentation of an artificial environment that sufficiently substitutes a user's real-world surroundings to allow the user to suspend disbelief and fully interact with the produced environment is known as immersive virtual reality, or immersive VR. VR gaming and VR treatment are two examples of applications where immersiveness is crucial (Wigmore, 2016).

The Birth of Immersion:

Immersive VR visualization and interaction with data is relevant for scientific evaluation and also in the fields of training and education. It also allows an active interaction with the representations, e.g., in drug design. We can walk through brains or molecules, and we can fly through galaxies.

The requirements and level of interaction will vary depending on whether this "walk" is for professional use, for students, or for the general public. Immersion in the data could take place alone or in a shared environment, where we explore and evaluate with others.

The data could be static, or we could be immersed in dynamic processes. The data should be viewable in multi-scale form (Slater et al., 2016) .

Transcending Boundaries:

The future of VR extends beyond individual experiences, as social VR platforms are on the rise. Users can interact and communicate in virtual environments, attending conferences, concerts, or simply socialising with friends from around the world. VR will redefine the concept of "telecommuting", enabling teams to collaborate in shared virtual workspaces, transcending geographical limitations.

The future of Virtual Reality is incredibly promising, as this ground-breaking technology transcends boundaries and reshapes numerous aspects of human life.

The continuous evolution of hardware, expansion of content, and adoption across various industries will propel VR to be a dominant force in the global landscape (virtual reality: unraveling the boundaries of the future, 2023).

Understanding Scale and Proportion:

In the fields of architecture, engineering, and construction (AEC), where three-dimensional (3D) space has an unbreakable connection to the built environment and visual interaction is vital, augmented reality (AR) and virtual reality (VR) are tools that are crucial yet neglected.
Since the 1990s or so, professionals associated with the built environment have used VR and AR, although to a lesser extent, to assist in the

visualisation of design, building, and city services. But these tools have more to offer. For instance, (AR) is a technology that alters the actual world by overlaying data and artificially generated images to improve the user's contextual experience of their surroundings.

A head-mounted display (HMD), tablet, or mobile device is employed to visualize the augmentations. However, VR is a technology that uses hand-held displays (HMDs), glasses, and multi-display set-ups to produce fully artificially produced virtual environments that change the user's perspective of what is around them.

Use cases for AR and VR in the AEC industries:

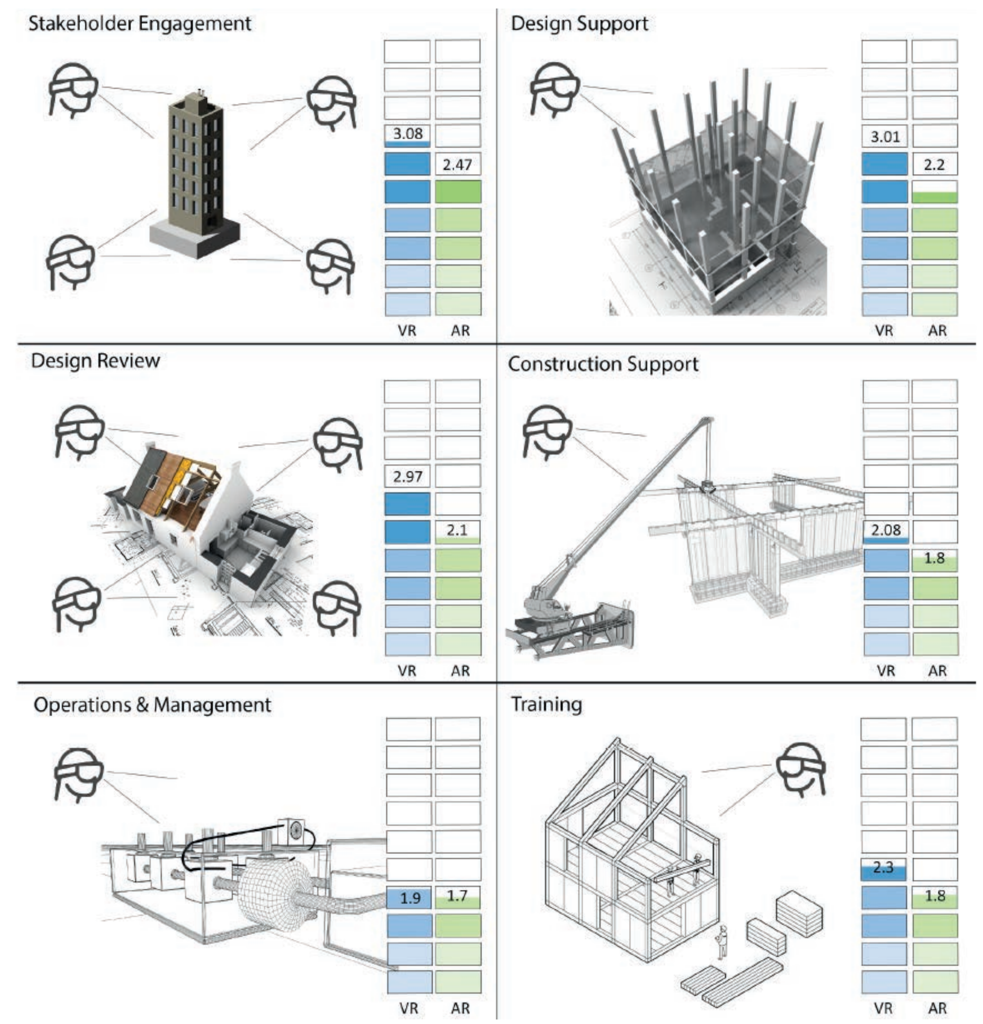
A total of six general use-cases that have been proposed by Delgado et al in a paper called A research agenda for augmented and virtual reality in architecture, engineering and construction. Advanced Engineering Informatics.

Below is an overview of the use-cases supplemented with examples drawn from the literature, namely: Stakeholder input is the initial step. Design support is the next. Design review is the third. Construction support, which is divided into four subcategories: tracking progress, construction safety, construction planning, and operative support; operations and management serve as the fifth and sixth. Finally, training.

As figure 02 gives illustrations of the six applications along with the rate of AR and VR adoption for every scenario. The image's objective is to better the reader's comprehension of each use-case by offering visual clues and indications.

Keep note of the fact that as both AR and VR grow, their distinctions become fewer and fewer. There is not much of a difference in the options, interfaces, advantages, operational needs, or obstacles. To give greater insight of the study carried out by Delgado, setting, instances for virtual reality and augmented reality have been treated independently for every scenario.

The use-cases of 1 to 3 will showcase the intentions of this thesis and will draw a better picture on how the VR will be implemented and tested in these cases:



.Fig 02. *Case studies of AR and VR in the AEC industries, along with an estimate of their adoption rates (see Section 4.2). According to the given use-case, the plots show the degree of adoption in projects (1 = not used, 2 = early testing, 3 = basic implementation, 4 = partially used, and 5 = fully implemented).*

Stakeholder engagement:

VR illustrations. As previously mentioned by Juan et al. (2018) and Ozacar et al. (2017), virtual reality (VR) was thoroughly tested for involving stakeholders in real estate projects. This is because VR is the perfect tool for submerging stakeholders into a virtual environment, which enables them to visualize and experience the final product.

A virtual reality (VR) system to visualize various sustainable building methods in rural areas was provided by Kini and Sunil (Kini & Sunil, 2019), while Xia (Xia, 2013) described the creation of a VR system for

virtual tours of campuses. The majority of current research has been devoted to enabling multi-user functionality. For instance, Lin et al. (Lin et al., 2018) presented a VR approach to improving the communication between design teams and healthcare stakeholders. Du et al. (Du et al., 2018) presented a multi-user VR platform that allowed several parties (e.g., clients, architects, engineers, and general contractors) to interact in a unified VR environment, improving the stakeholders' engagement and communication.

Design assistance:

Virtual reality and augmented reality will assist architects better grasp the outcomes of their decisions and recognize the effects of those actions.

VR illustrations. The authors Roach and Demirkiran (Roach & Demirkiran, 2017) introduced a VR-enabled 3D modelling program that makes the process of creating 3D models easier. The authors conducted a comparison between their virtual reality software and other VR-enabled 3D modeling programs, such as Google Blocks and Make VR Pro, as well as with more conventional 3D modelling programs, such Blender, Free Cad, and Solid-Works. The authors found that, even for extremely basic geometries, VR-enabled modelling software is quicker, more user-friendly, and easier to use than traditional 3D modelling software.

As Delgado continues, a virtual reality system for object modelling and city planning was described by Nguyen et al. (Nguyen et al., 2016). It featured gesture detection and unique communication protocols. Using virtual reality settings, Motamedi et al. (Motamedi et al., 2017) demonstrated a method for evaluating the efficacy of Japanese subway station signs. Finally, Natephra et al. (Natephra et al., 2017) introduced a virtual reality system that lets designers explore a range of different designs in authentic settings, allowing them to recognize qualitative aspects in addition to the quantitative analysis carried out with conventional lighting simulation tools.

The Review of the design that Delgado carried out demonstrate the fact that with the use of augmented and virtual reality, intended use can be communicated more clearly, designs can be reviewed more quickly, problems can be found more quickly, and sign-off can be completed more quickly.

VR illustrations. In a research involving manufacturing engineers, Berg and Vance (Berg & Vance, 2017) assessed the benefits of adopting virtual reality (VR) for design reviews by having them complete them in a projection-based VR environment.

The participants were able to observe and work with the geometry at actual scale thanks to the technology. The participants improved their comprehension of the spatial linkages between product components and the interactions needed to construct the product, according to the authors.

A VR system for the design evaluation of hospital patient rooms was provided by Dunston et al. (Dunston et al., 2011). According to the authors, design evaluations enhanced by virtual reality lead to better interactivity and more power over design choices. A VR environment-based approach to facilitate constructibility analysis sessions was introduced by Boton (Boton, 2018).

The technique makes it possible to convert BIM-based construction simulations for immersive visualisations into a virtual reality application.

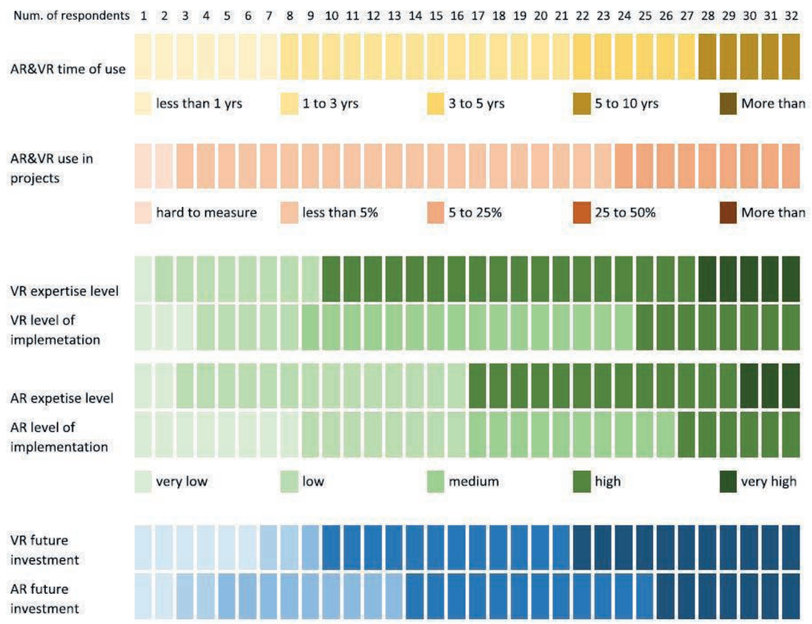
Virtual reality has also been used to evaluate the comfort of occupants in a range of environments, including airplane cabins and subterranean retail streets (d'Cruz et al., 2014; Sun et al., 2020).

By altering the street width to building height ratio, Liu and Kang (Liu & Kang, 2018) used virtual reality to investigate the relationships between urban environments and visual and audio comfort in streets, and Echevarria Sanchez et al. (Sanchez et al., 2017) created a VR system that allows to evaluate how visual aspect can reduce noise discomfort.

Analysis of AR and VR use in the AEC industries:

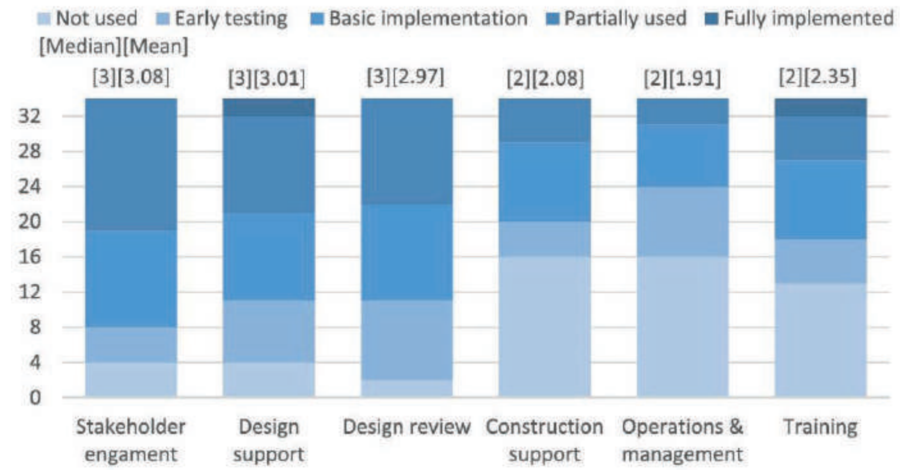
The AEC sectors continue to have poor adoption rates for AR and VR (Delgado & Manuel, 2019). According to a 2017 survey on the maturity and application of AR and VR conducted among major construction businesses and infrastructure suppliers, just 37% of construction organizations had any experience with these technologies (MTC, 2017).

Adoption overall, degree of knowledge, and potential future investment:
The findings of the quantitative analysis conducted in a research by Delgado et al. Are shown in Fig. 03, which offers a general picture of the acceptance levels of AR and VR, knowledge levels, and upcoming investments.



.Fig 03. *The overall adoption, skill, implementation, and projected investment levels of AR and VR.*

Figure 04 shows the adoption rates of VR by use-case. With a median value of 3, user interaction, design support, and design review have the highest degree of adoption; in contrast, operations and management, training, and construction support have a median value of 2. Observe that the mean value of training is somewhat greater than that of operations and management and construction support. It is evident from Fig. 04 that the majority of VR utilization has occurred during the project life-cycle's design phase.



.Fig 04. *Levels of adoption of Virtual Reality for the six use-cases defined in the AEC sector. Note that "fully implemented" only was recorded for design support and training.*

Engineering-grade AR and VR devices:

The following category gathers the technical specifications needed for AR and VR devices to be utilized for the six use cases that have been identified:

. Comfort and safety approved
. High accuracy tracking
. Improved indoor localisation systems
. Dynamic 3D mapping of changing environments
. Explicit indication of accuracy
. Larger model capacity
. Longer battery life (Delgado et al., 2020).

Data visualization within a 3D temporal and geographical context:

Usually, data visualization and analysis have been done with the help of the two-dimensional screens, having zero geographical setting or connection to the original genuine environment. Yet, displaying important information in the task's original context could greatly improve many study activities. The foundation for visualizing data in a manner that increases its worth and makes it simpler to use and analyse is provided by virtual reality and augmented reality settings.

In one case, Rowen et al. Reported that the marine captains behave much more effectively when they can see info in contexts utilizing augmented reality displays.

Sadly, the methods for visualizing data in AR and VR that are now in use are only extensions of the "window paradigm" desktop visualization techniques, which arrange and visualize data on predetermined rectangular rectangles (Rowen et al., 2019).

It is necessary to develop novel and creative visualization techniques that allow data to be shown both geographically and temporally, going beyond the window paradigm often found on paper documents and tablets.

Furthermore, research has to be done on the implications that new augmented reality displays imply for data visualisation in a geographical context. A conceptual framework was introduced by Willett et al. (2016). It formalizes and classifies various kinds of visualisations according to

the connections between the physical and visual representations of data and the real-world objects that the data correlates to.

The classification consists of four categories: (a) embedded physicalization, (b) placed physicalization, (c) embedded visualization, and (d) non-situated physicalization.

This is a good start toward formalizing research in this field, but there are still a lot of unanswered questions. For example, there is no clear indication of when contextualizing data can lead to richer insights or needless complexity, how to measure the perceptual distortion caused by contextualizing data, and how these distortions differ from those observed when using more conventional 2D data visualisation techniques (Delgado et al., 2020).

It is imperative that AR and VR systems are smoothly linked with other software systems utilized in the AEC sector, including enterprise databases, building management systems (BMS), FM, cloud-based BIM solutions, SCADA systems, and business databases. New use-cases amongst the parties involved will arise from a smooth integration that doesn't require programming involvement, building a strong technological ecosystem (Manikas & Hansen, 2013).

New capacities

Recognition of objects and gestures:

Many cutting-edge technologies rely on object identification as a fundamental technique. It makes it possible for autonomous vehicles to detect stop signs and tell a person from a lamppost, for instance. Likewise, automated object and gesture recognition is essential for AR and VR applications. It makes it possible for autonomous vehicles to detect stop signs and tell a person from a lamppost, for instance. Likewise, automated object and gesture recognition is essential for AR and VR applications. The ideal AR and VR systems should be able to identify every object in the users' environment without the assistance of pre-existing markers or 3D models.

Real-time model adjustment:

Real-time and run-time virtual model modification is a prerequisite for AR and VR systems. Usability is further hampered by the fact that BIM and

3D models used for AR and VR visualisations are typically unrelated and unlinked.

Reduced realism and instantaneous obscuration

Diminished reality employs a variety of methods to conceal real-world things from users' perspective, in contrast to augmented reality (AR), which incorporates computer-generated elements into the actual world. Because real-time occlusion prevents portions of virtual items hidden behind real-world objects from being rendered from the user's point of view, it allows for more realistic augmentations. Future augmented reality systems must be able to do both real-time occlusion and decreased reality since actual objects frequently obstruct augmentation.

Capturing the environment automatically:

A strong system capable of capturing the user's environment in real time is a significant new feature for AR and VR systems. For instance, in order to prevent collisions, VR systems must sense their users' surrounds and warn them of any things that may be close. Similarly, for AR systems to correctly overlay virtual objects, their surroundings must be accurately mapped (Delgado et al., 2020).

The use of Virtual Reality (VR) and interactive real-time rendering in urban planning and building design:

The use of 3D city models and Virtual Reality (VR) are becoming more common in urban planning and building design. VR is a visualization and communication medium that makes it possible for all interested parties to have access to a common representation and a better understanding of the planned urban environment.

In the urban planning and building design process there are many different stakeholders involved with different backgrounds and information processing capabilities. VR can facilitate processes so that participants can better understand, identify and analyse problems together to improve communication and decision-making and thereby the future urban environment (Al-Kodmany, 2002) (Kjems, 2005).

When creating 3D building models in construction, additional resources have to be assigned for the conversion into a realistic visual representation or the buildings have to be recreated from scratch for the different

3D formats for visualization, which are most likely incompatible among each other.

If the engineers decide to produce more versions of those models, it will take a lot of time and money to include the most recent modifications into the VR sceneries. Furthermore, each import requires the definition of the entity's visual representation in three dimensions in order to employ realistic materials in the depiction. The construction sector might greatly benefit from reducing complexity and automating this process of migrating into VR presentations (Hilfert & König, 2016).

VR for urban development:

Virtual reality (VR) technology has been increasingly utilized in the field of urban design as a tool for visualizing and assessing design proposals. VR allows designers to experience and interact with a virtual environment as if they were physically present, providing a more immersive and realistic representation of the proposed design (Meines, 2023).

Potential benefits of VR in urban development:

Freedom of the design: allows VR media to be used in any planning scenario and in particular to create more variants compared to conventional planning processes.

Adaptivity: Individual planning variants can be easily created by using parameters. Specific details of planning variants can also be investigated by changing the focus of the VR scenario.

Sensor-motor Manipulation: Sensor-motor Manipulation is not a feature commonly encountered in planning processes. However, it can be useful to validate the handling of objects or the spatial interactions with objects, for example if a door can be opened easily or if a staircase offers sufficient space for a two-person passage.

Reproducibility: reproducibility ensures that a variant can be validated over and over again, for example to increase the decision-making reliability of a citizen participating in the planning process.

Standardization allows adopting defined solutions from other contexts, for example by means of a component library, and test them as variants. Presence: Presence ensures that attention is focused to a large extent on the variants being evaluated or on the solution being designed. Collaborative scenarios may also support interaction between citizens.

Privacy: If necessary, the planning variants may also be evaluated without impairing the public and vice versa the public not being aware of the evaluation.
Reduction of risks and costs: The use of VR scenarios lowers the costs compared to real scenarios and renders the creation of physical models largely redundant. The dangers of real on-site inspections are also reduced, for example in road traffic or during inspections of facilities being planned, such as wastewater treatment plants (Meines, 2023).

2. 2| Unreal Engine for Real-Time Rendering

Unreal Engine stands as a revolutionary tool in the realm of architectural visualization, offering advanced capabilities for real-time rendering and interactive experiences.

Developed by Epic Games, Unreal Engine is a powerful game engine that has found extensive applications beyond the gaming industry, notably in architectural visualization.

The idea of object-oriented programming, the creation of computer-generated visuals, and reusable code via libraries are the three primary advantages of utilizing a gaming engine such as Unreal Engine.

The engine includes libraries specifically designed for game creation; instead of worrying about how to create a game, use the provided code to concentrate on the concept rather than the specifics.

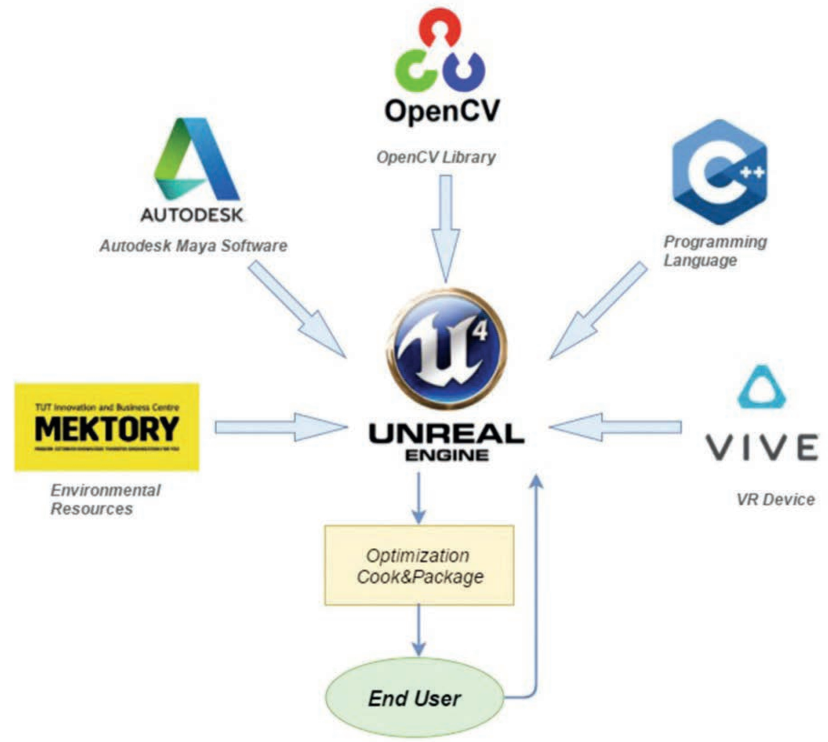
Additionally, classes may be created the conventional manner _ that is, using object-oriented programming _ but in a highly understandable fashion. One example of this is the Character class, which has all the code required to create a character in the game (Torres-Ferreyros et al., 2016). Since Unreal Engine 4 is one of the most popular and widely utilized physics engines, it was selected to build the virtual world. Prior benefits for the chosen physics engine might include high compatibility, low maintenance costs, and great efficiency for VR applications.

Moreover, Unreal Engine fulfils the same positive expectations as other popular gaming engines. Using major game engines may have several advantages, including the idea of object-oriented programming, the

process of computer-generated visuals, and reusable code via libraries (Torres-Ferreyros et al., 2016). Meshes and partially the environment are modelled using Autodesk Maya 3D animation, modelling, simulation, and rendering tools, if desired (Kose et al., 2017).

Autodesk Maya 3D animation, modelling, simulation, and rendering software is used to model meshes and partly environment as a preference (Kose et al., 2017). The OpenCV computer vision library is available for free and is used to show a camera in a virtual setting. Creating Mixed Reality (MR) environments is made possible using OpenCV.

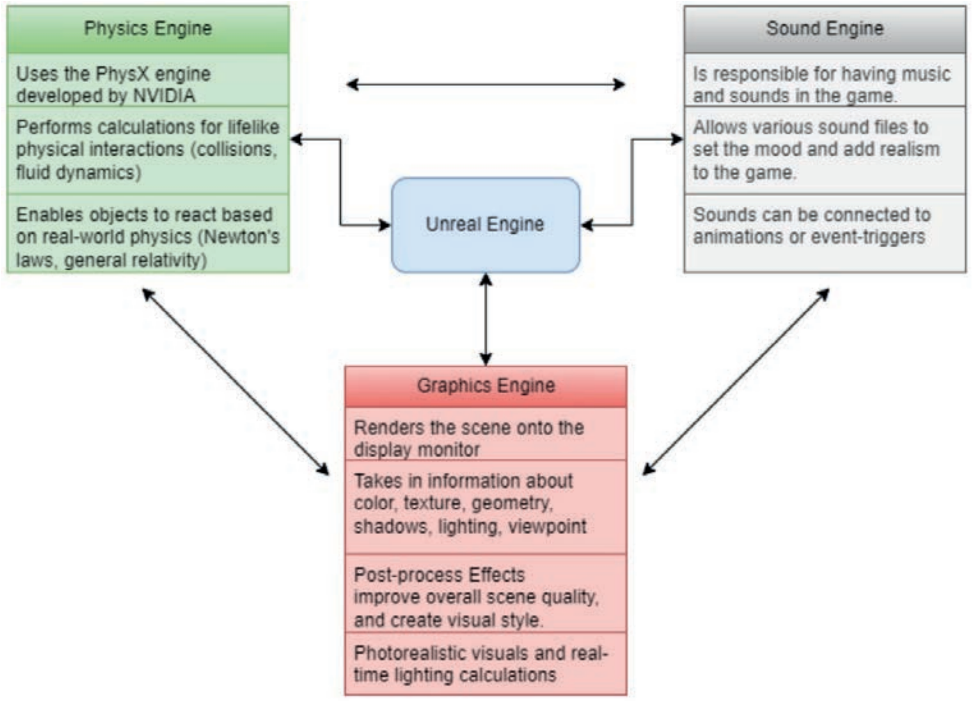
Three formats are often used to express MR. These three versions are known as virtual reality (VR), augmented reality (AR), and augmented virtuality (AV). By combining and registering, real and virtual material in augmented reality may be integrated through the actual environment. When it comes to approaching real-world items in a virtual environment, AV and VR are getting closer. According to Jayawardena and Perera (2016), real things may be merged into the virtual environment, allowing for synchronous interaction with them in mixed reality. A thorough procedure is displayed in Fig. 05.



.Fig 05. *Process of the application*

Key features and techniques

The Unreal Engine is composed of three main parts (Lee, 2016), each with its own relationship and components, as depicted in Figure 06 These parts include the Sound Engine, responsible for handling music and sound in the game, the Physics Engine, which performs calculations for lifelike physical interactions, and the Graphics Engine, which handles Rendering. The integration of these different engines within Unreal enables seamless communication between them.



.Fig 06. *Different components of Unreal Engine*

Ray-tracing in Unreal

Unreal uses ray-tracing to model the behaviour of light. It simulates the path of individual light rays as they interact with objects and surfaces. Unreal Engine uses real-time ray-tracing, which combines ray-tracing with rasterization techniques (What Is Real-time Ray Tracing?, n.d.). This hybrid approach allows for real-time light interactions. Unlike traditional rasterization methods, which approximate lighting effects using simplified algorithms, ray-tracing in Unreal Engine calculates the path of light rays as they bounce, reflect, and refract through a scene. This leads to more realistic physical lighting, with realistic shadows, reflections, and global illumination (see Figure 07).

One of the advantages of ray-tracing in Unreal Engine is its speed and efficiency. Unreal Engine uses a variety of optimization techniques, to achieve real-time or near-real-time rendering performance. This means that complex scenes with dynamic lighting can be rendered smoothly and interactivity.

The speed and efficiency of real-time ray-tracing in Unreal Engine make it an appealing possibility to explore as an alternative to traditional daylight analysis tools like Honeybee. Honeybee, which uses Radiance for accurate daylight simulations, can be computationally intensive and time-consuming, especially in dealing with complex geometry (Meines, 2023).

.Figure 07. *Realistic physical lighting in Unreal (What Is Real-time Ray Tracing?, n.d.)*

Real-Time Rendering for Architectural Visualization:

Real-time rendering is concerned with rapidly making images on the computer. It is the most highly interactive area of computer graphics. An image appears on the screen, the viewer acts or reacts, and this feedback affects what is generated next. This cycle of reaction and rendering happens at a rapid enough rate that the viewer does not see individual images, but rather becomes immersed in a dynamic process.

There is more to real-time rendering than interactivity. If speed was the only criterion, any application that rapidly responded to user commands and drew anything on the screen would qualify. Rendering in real time normally means producing three-dimensional images.

Interactivity and some sense of connection to three-dimensional space are sufficient conditions for real-time rendering, but a third element has become a part of its definition: graphics acceleration hardware.

Some excellent examples of the results of real-time rendering made possible by hardware acceleration are shown in Figures 08 and 09 (Akenine-Möller et al., 2018).

.Fig 08. *A shot from Forza Motorsport 7. (Image courtesy of Turn 10 Studios, Microsoft.)*

.Fig 09. *The city of Beauclair rendered in The Witcher 3. (CD PROJEKT® , The Witcher® are registered trademarks of CD PROJEKT Capital Group. The Witcher game © CD PROJEKT S.A. Developed by CD PROJEKT S.A.*

Instantaneous Visual Feedback:

Unlike traditional rendering methods that involve time-consuming rendering processes, real-time rendering within Unreal Engine provides architects and designers with instantaneous visual feedback as they manipulate design elements.

This immediacy eliminates the need for long waits, allowing for rapid design exploration and iteration. Architects can visualize the impact of changes in real-time, whether it's modifying materials, adjusting lighting conditions, or experimenting with spatial configurations.

In conclusion, the benefits of using Unreal engine and real-time rendering for building designs are as follows:

.Enabling Dynamic Decision-Making
.Photo-realistic Visuals and Lighting Simulation
.Creating Visual Authenticity
.Illuminating Realistic Environments
.Emphasizing Material Realism
.Interactive Exploration and User Engagement
.Creating Experiential Connections
.User-Centric Design Validation
.Iterative Design Dialogues

2. 3| Point Cloud Scanning and Data Processing:

History of Point clouds:

By combining historical documentation with 3D surveyed data, it is now possible to support the digital reconstruction of non-existent architectures, gradually creating their three-dimensional digital models from simple shapes to extremely complex virtual prototypes (Guidi et al., 2014).

Geographic Information Systems (GIS) were the original form of point cloud surveys. A computer system is called a Geographic Information System (GIS). that evaluates and presents information that is cited. Maps, data, and analysis findings can be examples of this.

Spatial data is created and analysed using GIS software. This data may be represented as rasters (images), points, lines, or polygons. Diverse terrains were analysed using GIS. The 1960s saw the creation of GIS as a tool for managing and analysing spatial data. Utilized for terrain analysis and mapping.

In the 1990s increased accuracy meant GIS began to be used for other Tasks. Beginning to expand from terrain to surveying and accident investigations. In the 2000s, GIS began to create digital twins of assets. In the 2010s, GIS would be used for creating 3D models from point clouds. This allowed for even more accurate simulations and analyses.

Creating accurate point cloud data, that could create a three-dimensional map of an object. Point cloud learning has lately attracted increasing attention due to its wide applications in many areas, such as computer vision, autonomous driving, and robotics (Leslie, 2022).

How to Create a Point Cloud Scan:

With the rapid development of 3D acquisition technologies, 3D sensors are becoming increasingly available and affordable, including various types of 3D scanners, LiDARs, and RGB-D cameras (such as Kinect, RealSense and Apple depth cameras). 3D data acquired by these sensors can provide rich geometric, shape and scale information.

Complemented with 2D images, 3D data provides an opportunity for a better understanding of the surrounding environment for machines. 3D data has numerous applications in different areas, including autonomous driving, robotics, remote sensing, and medical treatment 3D data can usually be represented with different formats, including depth images, point clouds, meshes, and volumetric grids.

As a commonly used format, point cloud representation preserves the original geometric information in 3D space without any discretization. Therefore, it is the preferred representation for many scene understanding related applications such as autonomous driving and robotics (Gue et al, 2020).

Prior to taking a cloud scan, you must choose the approach that works best for you. Cloud point scanners come in three different varieties.
On land, Mobile or Drone.

The terrestrial laser scanner (TLS) is the most widely used kind of scanner.TLSs have a range of several hundred meters and are fixed in one place. Utilized for surveying sizable regions, like forests or building sites.

Mobile Scanners:

Mobile scanners are lightweight electronics that have been created to be used on the go. Even though they are much more adaptable than TLSs, they're capable of less range. Mobile scanners are more convenient to use and offering a same result as others.

Scanning small objects to bigger ones is a common use for portable scanners. This makes it possible to scan smaller objects in greater detail. Generating a 3D model with improved quality.

Drones Scanners: A comparatively new technology that is gaining popularity is the drone point cloud scanning device. They're tiny drones that scan objects from above employing lasers. This makes it potential to scan the object in 360 degrees. Helpful for obtaining details that are shielded from view from the ground.

Make a Point Cloud Scan of a Desired Area:

You need a 3D scanner in order to create a point cloud scan. A 3D laser scanner, like the Leica RTC360, to scan the object. Laser beams are released by this device in all directions, and when they strike a surface, they return points. The gap between these beams and the object they hit is subsequently determined by the software.

Only data points that are in the scanner's line of view can be recorded. The scanner must be moved around an object in order to capture all of its details. Make numerous scans from various perspectives and vantage points.

It is possible that certain features will be lost in a single scan taken from one angle. It may produce a precise 3D map of the item by taking into account all angles. Point cloud processing converts point cloud data into a usable format. 3D representations. There are several ways to accomplish this, however most software creates a surface model or mesh.

Surface forms perform more for investigation and representation, however mesh models are used for creating 3D printing files. A few crucial considerations need to be made when converting a collection of points into a 3D model:

_ The ultimate model's quality will be subject to the point cloud's resolution. The level of detail of the model rises as it gains resolution.

Data Processing for Accurate Models:

While point clouds are a wealth of spatial data, they require processing to transform raw data into accurate 3D models that represent the building's geometry.

Data processing involves registering and aligning multiple point cloud scans taken from different vantage points.

Advanced software tools, such as Autodesk Recap or Faro Scene, enable architects to create coherent and comprehensive 3D models that reflect the true conditions of the building.

2. 4| LiDAR Scanning Mechanisms

THE advances in depth-based scanning technologies and the large-scale availability of point clouds of urban scenes have triggered an ever-increasing demand for accurate and efficient reconstruction of urban models from these acquired data. Over the past few decades, point clouds from light detection and ranging (LiDAR) have been a major data source for mapping applications in the photogrammetry and remote sensing communities. In recent years, processing large-scale geospatial data, especially point clouds, has also drawn considerable attention from the computer vision, computer graphics, and robotics communities (Wang et al,. 2018).

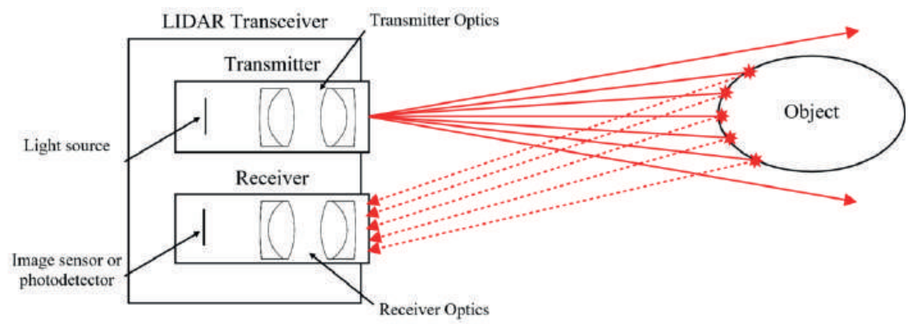
The last couple of years have witnessed several new developments in this direction and we primarily focus on updating with these recent algorithms, especially the reconstruction from LiDAR data (Wang et al,. 2018).

Light detection and ranging, or LiDAR, technology has been used in many different ways in recent years. The design of LiDAR systems has significantly improved over time, leading to a design with very low requirements for cost, size, weight, and power (SWaP) (Raj et al., 2020).

Aerial imaging with active (like LiDAR) and/or passive (like aerial cameras) sensors, as well as ground-based or vehicle-borne sensing methods (like mobile mapping) can all be used to create 3D building models. Using airborne LiDAR, a Digital Surface Model (DSM) is created that includes information about building roofs and topography that is typically hard to get with ground-based LiDAR. The facade models and DSM are then combined using Monte Carlo localization.

Being light and energy saving, the role of LiDAR in aerial and mobile platforms has in creased to facilitate mapping and obstacle avoidance which were traditionally thought to be challenging.

LiDAR Architecture Overview:



.Fig 10. *LIDAR - Light Detection and Ranging.*

A fully functional LiDAR system is made of four major subsystems namely laser range-finder, beam deflection, power management, and master controller units, as depicted in Figure 10.

These basic blocks are equally mandatory whereby a failure in any of these subsystems may lead to a loss in functionality of the LiDAR system. However, in the absence of the beam deflection subsystem, the LiDAR could still function as a 1D LiDAR, which is commonly known as a laser range finder (LRF)(Raj et al., 2020).

LiDAR point clouds, which are usually scanned by rotating LiDAR sensors continuously, capture precise geometry of the surrounding environment and are crucial to many autonomous detection and navigation tasks. Though many 3D deep architectures have been developed, efficient collection and annotation of large amounts of point clouds remain one major challenge in the analytic and understanding of point cloud data (Xiao et al., 2022).

Most methods in building modelling from aerial LiDAR focus on simple parametric building models such as polyhedral, prismatic, and flat roof models. The building models created from airborne solution are always coarse compared with those from the data collected from short distances such as ground-based or mobile LiDAR. Most methods using mobile LiDAR focus on generating photo-realistic building models because of the sufficient geometric information contained in the point clouds. The registration between images and range data is a prerequisite for 3D modelling using both data sources.

In the context of 3D building modelling, the mobile LiDAR technology has drawn intensive attention from the industrial and research communities due to its data collection efficiency and capability of providing data with street-level details (Wang, 2013).

3 Building Documentation and Modelling Work-flow

3|

3. 1| Rationale for Selecting the Abandoned Brewery:

In this chapter, the focus shifts towards the initial phase of the thesis project. The case study of the project is a old abandoned brewery located in Pordenone.

The selection of the abandoned brewery as the focal point of the thesis project is rooted in a multifaceted rationale that aligns with the project's objectives and ambitions.

The brewery's historical significance, architectural qualities, and potential for adaptive reuse contribute to its suitability as a subject for renovation. This section explores the reasons behind choosing the brewery and elaborates on how its unique attributes harmonize with the project's overarching goals.

History of Pordenone, Friuli Venezia Giulia, Italy:

Pordenone is a city strategically situated in the north-eastern part of Italy, in the region of Friuli-Venezia Giulia. It serves as a cultural and commercial crossroads, drawing influences from neighbouring regions such as Veneto, as well as countries like Slovenia, Croatia, and Austria, owing to its geographical proximity to these areas (Pordenone Municipality, n.d.).

The city's rich history is reflected in its elegant historic centre, adorned with a procession of palaces along its main streets, alongside notable structures like places of worship and the Town Hall (Pordenone Municipality, n.d.). Pordenone is not only a hub for cultural events, including the renowned Pordenonelegge literary festival and Pordenone Blues Festival, but it also boasts a rich museum landscape and a lively cultural and musical scene (Pordenone Municipality, n.d.).

This unique blend of historical charm, modernity, and cultural vibrancy makes Pordenone an enticing destination in the Friuli-Venezia Giulia region.

Hints of the industrial history of Pordenone:

The peculiar orographic and hydro-graphic positions of Pordenone allowed the start of that process of industrialization which opened the doors to the industrial history of the city.

Already in the 18th century Pordenone was the second centre of the Veneto for the production of paper; but it is with the cotton processing industries that the city acquires an even more significant role:

The mechanical spinning of Torre (1843), which was the first cotton factory in the Veneto region, and for decades, the most important in the region and one of the largest in Italy, the mechanical weaving mill of Rorai Grande (1846) subsequently purchased by the Venetian cotton mill in 1895 and the Amman & Wepfer cotton mill (1875) which will become an industrial establishment particularly projected towards the future for ideas, innovations and machinery that will be used there.

The period 1896-1916 is full of events for the Pordenone area. Together with a strong social change, which took place through the consolidation of the first political parties and trade union organizations, we are witnessing the birth of new productive realities, which will find in Pordenone the springboard to reach real industrial levels, especially in the second postwar. Examples are the Savio workshop for the repair of textile machines (1911) and the Zanussi workshop-chimney shop (1916).

In the food field there were various artisan productions;
In chronological order we recall: the modest Celeste Massaro brewery, with only three workers (it produced beer and vinegar) which failed to have significant success; the F.lli Momi brewery, created in 1880, and which had a production of 13,000 hectolitres of beer a year.

Founded near Piazza della Motta, in the 1920s the company had about a hundred employees led by master brewers of German origin. After its liquidation in 1928, the buildings were occupied by the Pavan cellars, which moved elsewhere in 1971. Finally, the Società Anonima Birra Pordenone which annually produced (Martin, 2013).

Pordenone underwent a great environmental transformation in the 60s and 70s, which if on the one hand allowed its development, on the other caused the loss of architectural assets that had contributed to its growth in the past.

Chapter 3

| 2023-24

The industrial architecture of the past is destined, over time, to deteriorate and disappear, bringing with them those important physical traces to which local memory and tradition are linked.

Therefore, with a view to safeguarding and conserving these industrial archaeological assets, this thesis work aims to be a proposal for the conservation and reuse of the historic building that belonged to the Società Anonima Birra Pordenone (Martin, 2013).

The Società Anonima Birra Pordenone:

.Fig 11. *Brewery brand Image - Historical archive of Pordenone manicipality*

.Fig 12. *Google map of the brewery - 2023*

BEYOND BLUEPRINTS | Politecnico di Torino


.Fig 13. *Brewery Image back in 1939 - Historical archive of Pordenone manicipality*

In the Friuli landscape just described, among the food industries that produce beer, the S.A. Birra Pordenone is the company that, in the Pordenone area, has had the most success compared to other small competing business units.


.Fig 14. *Brewery Image back in 1939 - Historical archive of Pordenone manicipality*

In fact, on the eve of the war (1915), Birra Pordenone produced around a third of Friulian beer; while the remaining two thirds were produced by the direct competitors, Moretti and Dormisch of Udine (Camera di commercio industria artigianato e agricoltura Pordenone, n.d., P. 64).

After about thirty years of development and production of Birra Pordenone, the business stopped in the 1930s. In 1943 the German troops decided to convert the building into a military car park, while after the war it became the seat of a trucking company until its liquidation, from which the former brewery was definitively abandoned.

The reuse proposals:

The entire lot of the former headquarters of the S.A. Birra Pordenone becomes the subject of a first recovery plan in 1989, with a project by prof. Arch. Nicola Pagliara (Recovery Plan n° 25 of via Fontane).

The project envisages the conversion of the historic building into a cultural-museum centre, the construction of new buildings to house the Prefecture, the Police Headquarters and the civil engineering department and the insertion of new underground car parks. None of this is achieved and fourteen years later, in 2003, a solution was proposed by the Raffin architecture studio (archh. Italo Giorgio and Davide) for the implementation plan No. 1 - P.R.P.C of via Fontane.


.Fig 15. *Postcard 1989, taken from the report by Studio Raffin*

The intent is to create the "citadel of security" in which all personal services were included in the same area: the Police Headquarters, the Traffic Police and the Prefecture (the latter inside the former brewery); they develop around a square, exclusively for pedestrians, from which it is possible to access the underground car parks.

For economic reasons, the project was not carried out, but was reduced to the sole construction of the current Police Headquarters, for which a new project will also be commissioned by the Raffin studio of Pordenone. The Questura, inaugurated on 21 June 2013, stands tall in front of the historic former brewery, which is thus surrounded by a fence and abandoned to its fate.

.Fig 16. *Brewery position map date back in 1940/1970*

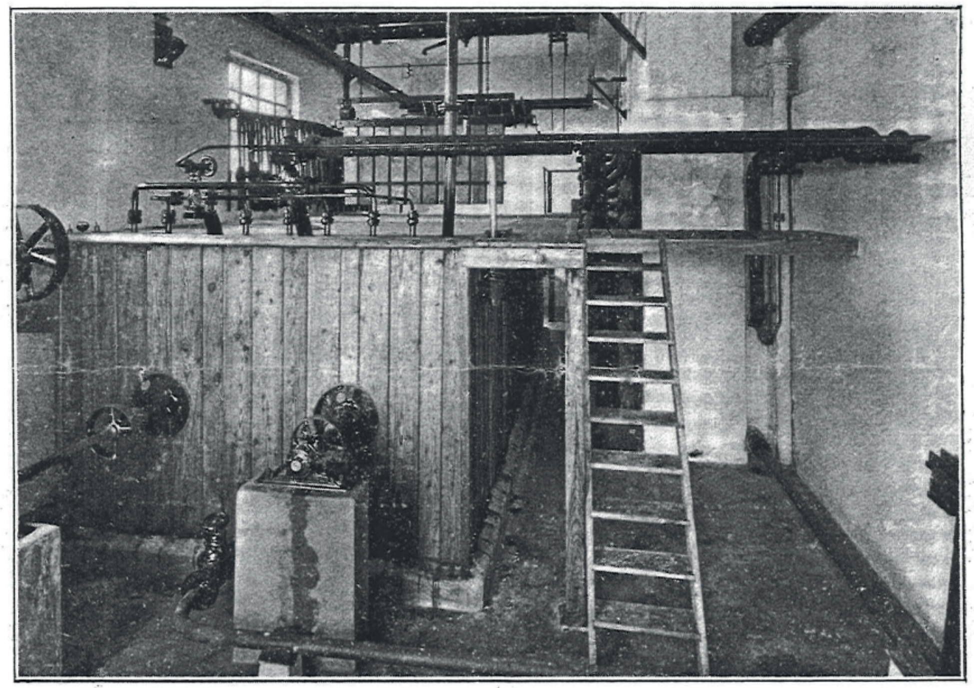
Currently the former brewery is bound by the Superintendency of Cultural Heritage and falls, according to the P.R.C. Of the Municipality of Pordenone in the industrial archaeology area, while the area is classified as facilities for associative life and culture (Martin, 2013).

The current state of the brewery:

The building in question is catalogued and filed by the Regional Centre for Cataloguing and Restoration of Cultural Heritage, (property code 33961) corresponding to the AI 457 form in the "industrial archaeology" class and to the A 7573 form for the "buildings" class. It is a large building, resulting from the juxtaposition of two bodies that define a plant with a rectangular base. The building to the east, which for simplicity we will later call "building A", is spread over three floors above ground served by the stairwell and the goods lift. The body to the west, on the other hand, which we will identify as "body B" rises on two floors above ground. For both bodies there is also a basement used as cellars.

From a structural point of view, the analytical description of the Regional Centre reports the presence of continuous foundations built in stone masonry, while the vertical structures are in brick masonry.

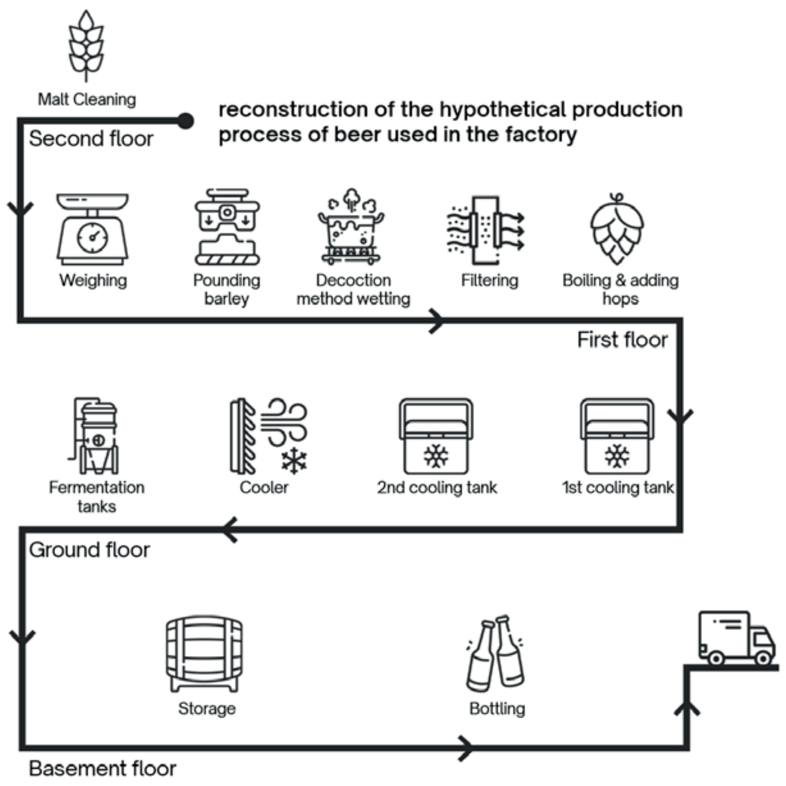
On the ground floor, the presence of an opening, partially demolished, in the masonry made it possible to reveal the existence of two air gaps in the thickness, suggesting their presence in all the perimeter masonry of the ground floor.

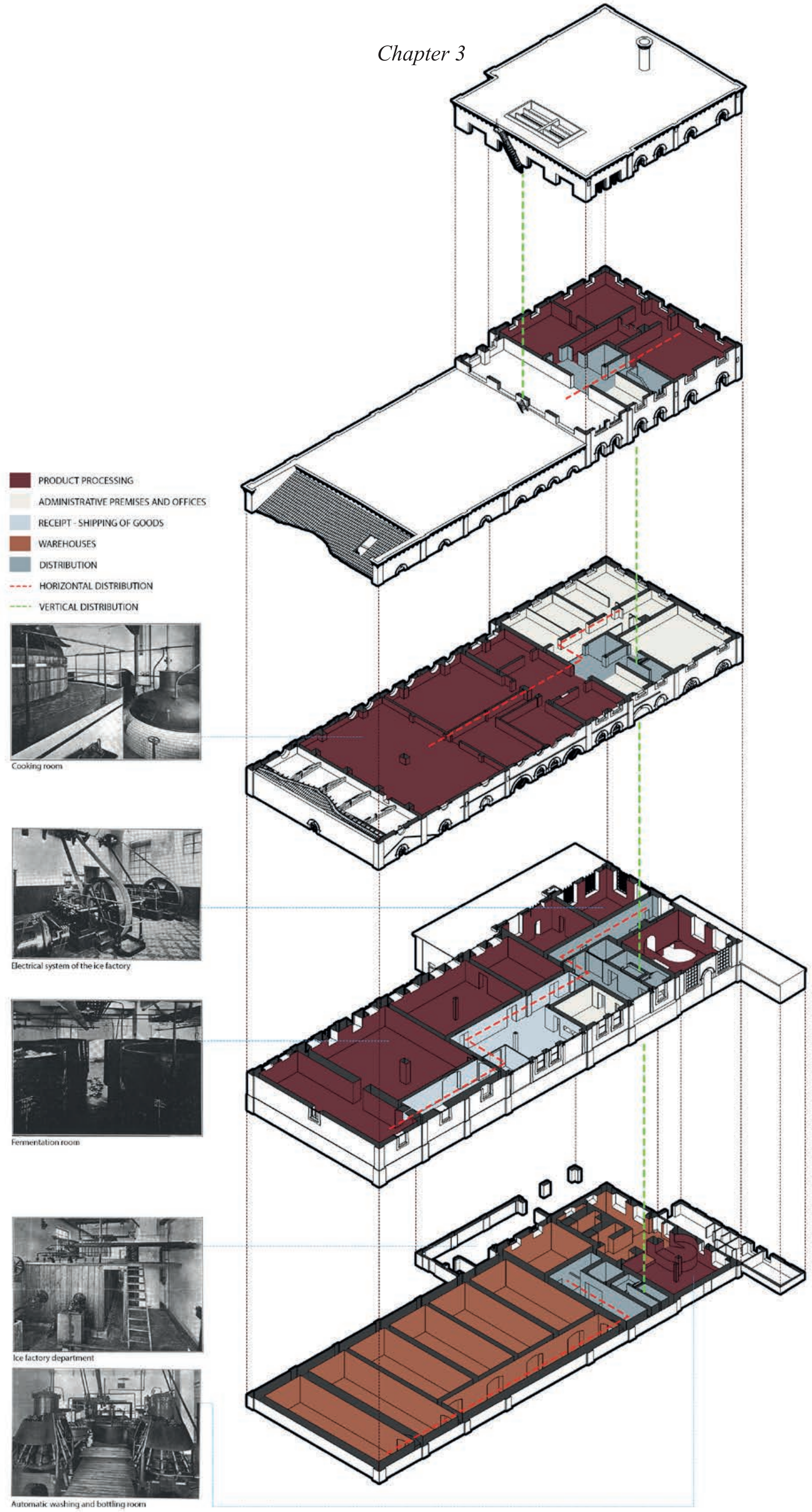


.Fig 17. *Inside of the brewery*

The floors are made of reinforced concrete with vertical beams; the roof is of the flat type made of brick and concrete while towards the west, the last span has a single pitched roof, with a wooden truss structure and a traditional roof covering in brick tiles. This pitched roof is hidden in the north and south elevations by the facade itself. The consolidation of the various walls is made up of metal tie rods along the two directions, longitudinal and transversal, as evidenced by the rectangular anchoring plates on the outside.

In here you can see the work process of brewery through out the building:





Internally it is still visible, in some rooms, the covering of the flooring now in decorated ceramic tiles, now in herringbone parquet, while on the walls large areas are still covered with wallpaper. On the first floor, the partial detachment of the plaster from some walls has highlighted their construction with the wattle technique. On the top floor there is the machinery for the operation of the freight elevator of which the loading cabin and the lateral iron guides remain. Throughout the building, colonization by birds has caused the formation of a layer of guano on most of the floors.

The north, east and south elevations of the building have a white plaster finish and are vertically marked by pilasters in exposed brick which coincide, internally, with the position of the bracing walls. The openings are large round arched windows, which decrease in height on the upper floors, while on the ground floor they alternate with the entrance and unloading/loading portals. In all the openings there are iron frames made by dividing the windowed surface into regular geometric figures.

On the first floor of body B there are circular openings. All the openings, with the exception of the eight rectangular windows (two on the north and south elevations; four on the west elevation) are embellished with exposed brick frames; just as a cornice runs along the entire perimeter of the roof also made of bricks.

In the last bay on the left of the south facade, the sign of the pitched roof of the building added between 1925 and 1939, now demolished, is still visible today. Also visible are the traces (squared holes in the masonry for the interlocking of wooden beams) of the original mezzanine access to the ground floor, now destroyed (hypothetically created for greater ease of unloading/loading goods from the lorry trailer threshold) and the traces of the wooden shelter with a pitched roof covered in tiles (built between 1925 and 1939 and now collapsed) to protect the aforementioned mezzanine floor.

A brick chimney with a sawtooth cornice in the same material protrudes for about 300 cm from the roof of body A. Currently, the state of conservation of the building is classified as a ruin: most of the windows have no glass; all the openings on the ground floor have been walled up, while the spontaneous vegetation, made up of trees, flints, but above all creepers, has covered the entire body of the building with its unstoppable advance over the years, almost totally and mainly to the north.

From investigations directly on site, inside, the building shows modest signs of deterioration: the current lack of windows has led to numerous water infiltrations with consequent damage to the plaster on the walls and ceilings, causing, in some points, the detachment of the concrete cover of the floor beams and the formation of biological patina.

The reduced presence of cracks and the building's resistance to the seismic event in Friuli in 1976 testify to an accurate design and installation work of the building.

.Fig 18. *Current situation of the brewery _ July 10th 2023*

As stated by Eng. Englaro in his thesis, the vertical brick structures have not been calculated, but are consistent with the manual standards, as well as the original intended use of the premises for places used for the processing and storage of large liquid masses, there ensures the bearing capacity of these structures. The internal inspection made it possible to confirm the good structural condition of the floors, walls and stairwells where there are almost no deep cracks which could affect the stability of the building.

Externally, the roofs appear to be intact, with the exception of the opening of the skylight of body A (obtained by means of concrete beams) which shows the lack of windows, leaving only the wooden framework visible. The presence of some clay tiles and tiles of the Marseillaise type suggests that it was closed after construction. On the other hand, the presence of vegetation in the shaded areas and a shrubby individual near the skylight is evident (Martin, 2013).

1908

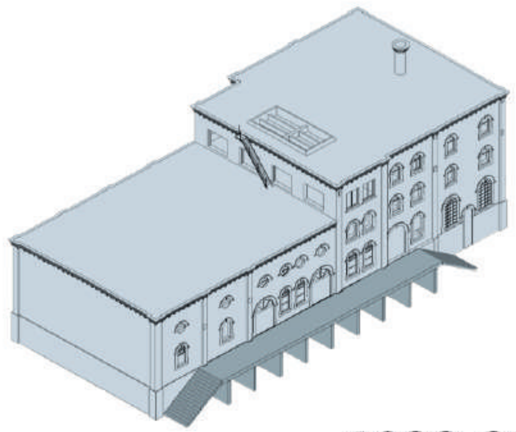
The "Società Anonima Birra Pordenone" is founded

The "Society anonymous Birra Pordenone", joint stock company was established on the initiative of avv. Arturo Ellero, cav. Guglielmo Taetz and cav. Riccardo Etro. born in December 1908 with the creation of the brand, and the following year, in February 1909, work began on the construction of the factory headquarters.

1909

The construction

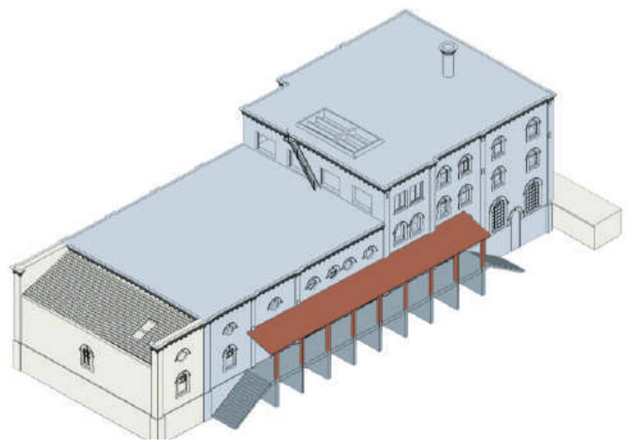
An executive committee headed by cav. Raetz as an engineer, architect and director.



1922-23

Renovation & expansion

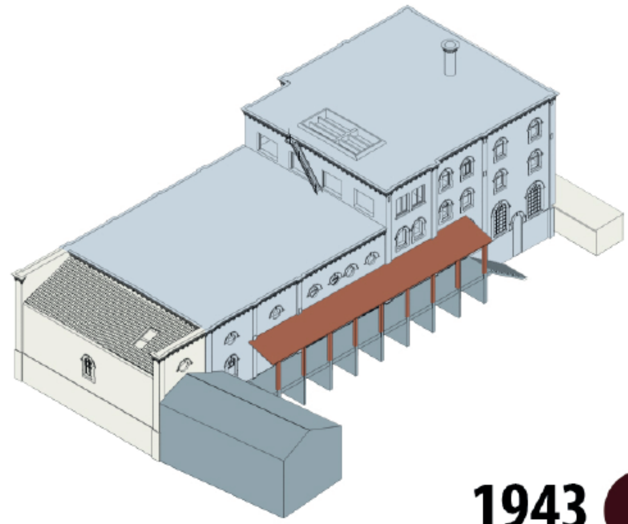
The factory is almost completely destroyed in the year of the invasion Austro-German and in 1922-23 it was rebuilt and expanded, as so that the Factory was equipped with machinery capable of producing up to 40,000 hectolitres per year.



1930

Cessation of activity

The factory remained active until the 1930s and then stopped and completely ceased its production.



1943

Conversion to a military car parking

After 1943, in the middle of the world war, the factory was transformed into a military fleet by the hands of the German troops. For a short time, in the years following the war, it housed a trucking company.
Following the cessation of the transport company, the factory will remain in a state of neglect until today, it will be the subject of two proposals for its redevelopment.

1989

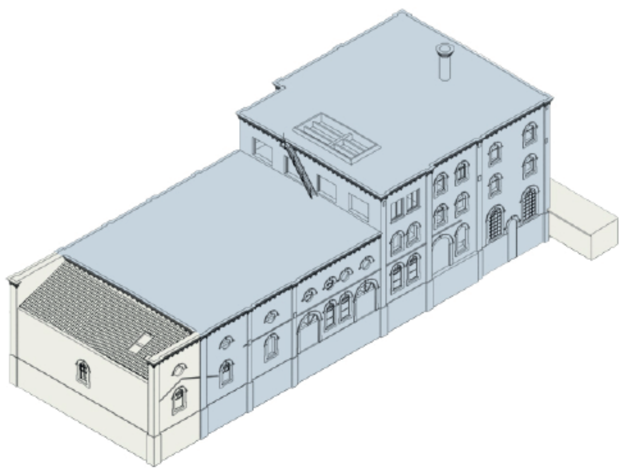
The first conversion proposal

The first, in 1989, with the recovery plan (Piano di Recupero n°25 di via Fontane) signed by prof. Arch. Nicola Pagliara, a project which hasn't seen
none of the proposed actions take place.
The project envisaged the preservation of the historic building into a cultural-museum centre, the construction of new buildings to edifici ospitanti la prefettura, the Police Headquarters and civil engineering department and the insertion of new underground parking lots.

2000s

Towards redevelopment

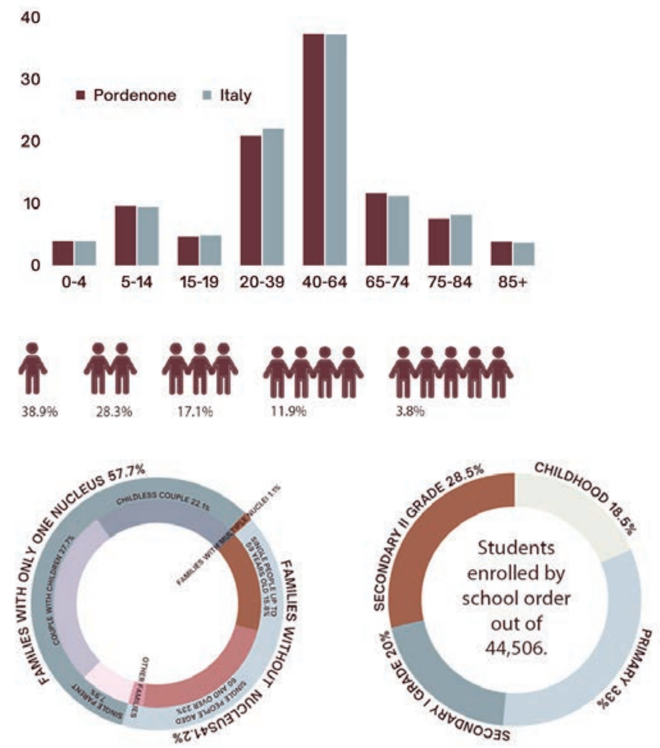
The second, in 2003, by the architects Italo Giorgio and Davide Raffin, with the implementation plan n°1 - P.R.P.C di via Fontane. The creation of the "citadel of security", with the insertion of the Questura and the Traffic Police in the area of Piazzale Palatucci, and Perfettura inside the brewery. From the proposed interventions, only the Police Headquarters will be buil t , with the project again by the Raffin architecture studio, inaugurated in 2013.



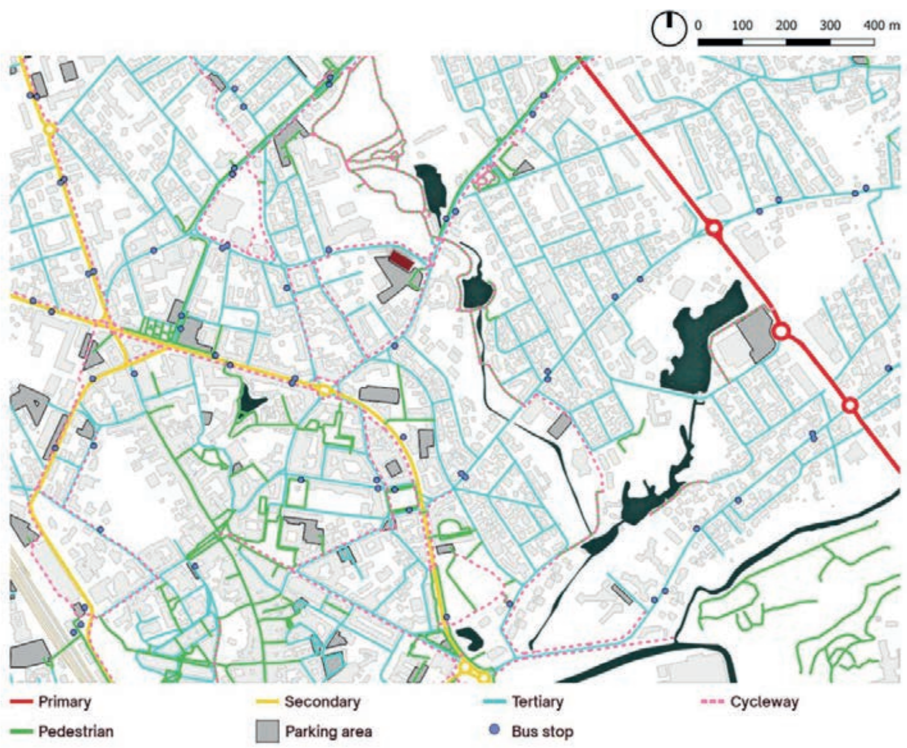
Representation of regional informative statistics of Pordenone in comparison to Italy, related to various aspects of the social and economic situation of the area, from the composition of the population and families to economic structure.

Resident population percentage out of 312,533 by age group and its comparison with Italy. Population density is higher in Venezia Giulia, in the central municipalities of Friuli and in the lower Pordenone area. The highest value is found in Triest with 2,400 inhabitants per square kilometre, followed at a distance by the municipalities of Udine (1,738) and Monfalcone (1,379) (instituto nazionale di statistica, 2022). which in statistic infogeraphy will be shown the information related.

Population and family statistics:



Transportation:



Urban fabric:

Economy & Business:

In Friuli-Venezia Giulia in 2017 there were 83,215 businesses, 1.9 percent of the national total. 360,803 employees work there, 2.1 percent of employees in Italy. In the region, manufacturing activity, with its 7,662 companies, represents 9.2 percent of companies, a higher value than the national figure (8.7 percent). The sector employs just under one employee out of three (29.4 percent), while in Italy it employs one out of five. The 18,308 trade enterprises (22.0 percent) account for 15.4 per cent of the employees, a lower percentage than the national figure of 20.0 percent.

The average size of businesses in Friuli-Venezia Giulia is 4.3 employees, higher than the national one (3.9). The companies with the largest average size (43.2 employees on average) deal with water supply, sewage networks, waste management and sanitation, a decidedly higher figure than the national one, where the sector shows an average value of 21, 3 employees. In all other sectors, the average size of the regional companies is between the minimum of 1.3 employees in real estate activities and the maximum of 13.9 employees in manufacturing activities (instituto nazionale di statistica, 2022), in the following legend it is been shown the

statistics of the matter based on the national institute of statistics.

Firms and employees by sector of economic activity in Friuli-Venezia Giulia

ECONOMIC ACTIVITIES	ENTERPRISES	EMPLOYEES	MEDIUM SIZE
Extraction of minerals from quarries and mines	30	226	7.5
Manufacturing activities	7,662	106,191	13.9
Supply of electricity, gas, steam and air conditioning	204	549	2.7
Water supply sewage networks, waste management activities	163	7,039	43.2
Buildings	10,255	26,387	2.6
Wholesale and retail trade, repair of motor vehicles and motorcycles	18,308	55,661	3
Transport and storage	2,180	16,713	7.7
Accommodation and food service activities	7,086	30,899	4.4
Information and communication services	2,049	7,980	3.9
Financial and insurance activities	1,788	15,625	8.7
Real estate activities	4,690	6,324	1.3
Professional, scientific and technical activities	14,043	23,211	1.7
Rental, travel agencies, business support services	2,308	27,853	12.1
Education	783	2,482	3.2
Health and social care	5,816	21,012	3.6
Artistic, sporting, entertainment and fun activities	1,276	3,162	2.5
Other service activities	4,574	9,490	2.1
Total	83,215	360,803	4.3

Surrounding context:

3. 2| 3D Data Acquisition: Point Cloud Scanning Process

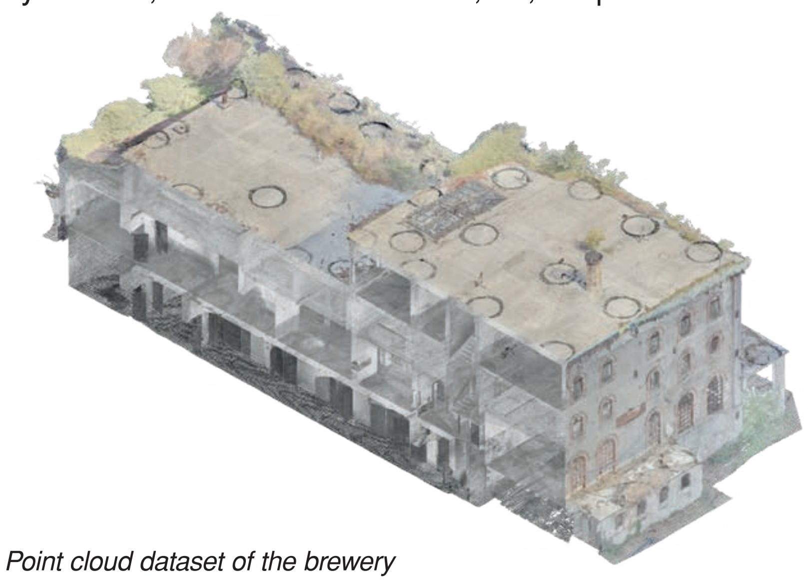
The Point Cloud Scanning Process is a foundational aspect of the thesis project, serving as the initial step in capturing the existing conditions of the selected abandoned brewery. This chapter outlines the intricacies of point cloud scanning, the technology involved, and the systematic workflow employed to generate accurate 3D representations of the building. The Point Cloud Scanning Work-flow encompasses a series of systematic steps designed to capture, process, and refine the raw point cloud data obtained from laser scanning technology.

Step 1: Laser Scanning Data Acquisition:

The process commences with the use of laser scanning devices that emit laser pulses and record the time it takes for the pulses to bounce back from surfaces. Multiple scans are performed from various vantage points to capture a comprehensive dataset that covers both the interior and exterior of the building.

Step 2: Data Registration:

The collected point cloud scans are then subjected to a registration process where they are aligned and merged to create a cohesive and accurate dataset. The point cloud scans of the brewery consisted of four set of complete scans of each level plus a scan of the façades, with accuracy of 2 cm, which concluded in 82,957,362 points.



.Fig 19. *Point cloud dataset of the brewery*

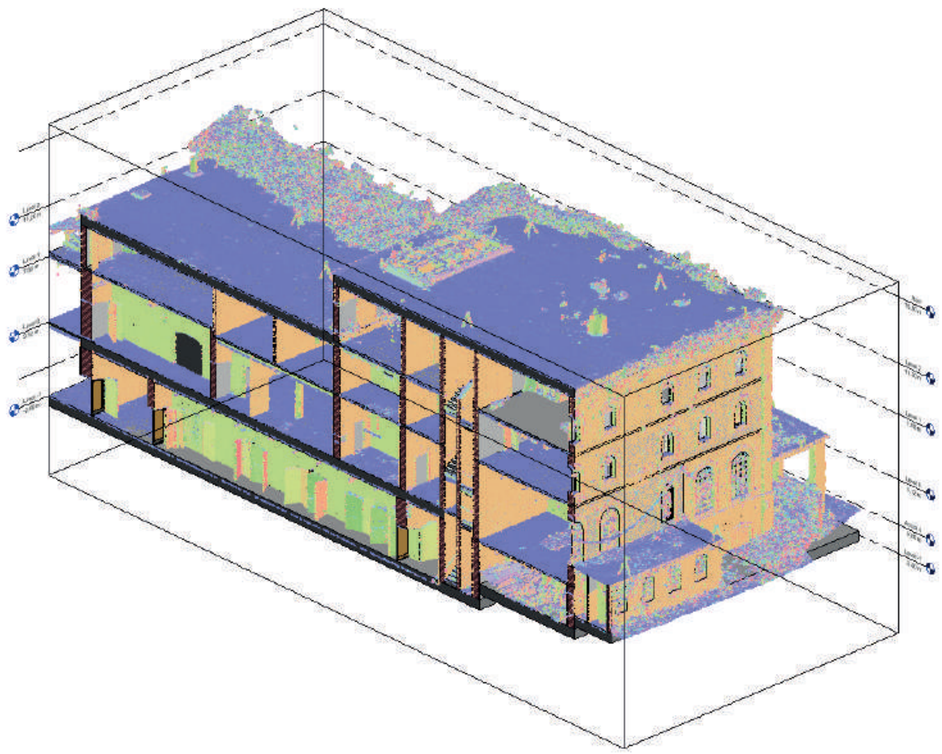
Advanced registration algorithms analyse common features in overlapping scans to establish precise alignments.

Step 3: Noise Reduction and Outlier Removal:

To enhance data quality, noise reduction techniques are applied to remove inaccuracies caused by factors such as environmental conditions or limitations in the scanning process. Outliers, which can skew the dataset, are also meticulously removed.

Step 4: Mesh Generation:

To transform point cloud data into usable 3D models, mesh generation algorithms are employed. These algorithms analyse neighbouring points and connect them to form surfaces, creating a coherent representation of the building's geometry.



.Fig 20. *Mesh generation of the brewery*

Step 5: Colour and Texture Mapping:

To enhance the visual fidelity of the 3D models, colour and texture mapping techniques are applied. These processes involve assigning colours and textures to the surfaces based on high-resolution photographs captured during the laser scanning process.

Significance of the Point Cloud Scanning Process:

The Point Cloud Scanning Process holds profound significance in the thesis project for several reasons:

Unparalleled Data Accuracy:

Point cloud scanning technology ensures a level of data accuracy and detail that traditional survey methods struggle to achieve. This precision is critical in capturing the complex geometries and architectural features of the abandoned brewery.

Seamless Transition to Digital Environments:

The accurate 3D models generated from point cloud data serve as the bridge between the physical and digital realms. They facilitate the seamless integration of the existing building into digital platforms like Unreal Engine, enabling architects to work within a digital environment that mirrors the physical space.

Informed Design Exploration and Visualization:

The high-fidelity 3D models derived from point cloud data empower architects to explore and visualize design concepts within the context of the existing building. This informed approach enhances design exploration, stakeholder engagement, and decision-making.

The technology and techniques involved in point cloud scanning ensure data accuracy, facilitate the transition to digital environments, and enable informed design exploration.

3. 3| Revit-Based Modelling of Existing Building Elements:

This chapter explores the pivotal process of creating accurate 3D models of the existing building elements of the abandoned brewery using Revit software. The Revit-Based Modelling process is instrumental in translating the point cloud data, obtained through laser scanning, into a

digital format that can be utilized for design, analysis, and presentation.

Leveraging Revit for Existing Building Modelling

The Revit-Based Modelling process involves a series of structured steps to create digital representations of the existing building elements:

Step 1: Point Cloud Data Import:

The first step entails importing the processed point cloud data into the Revit environment. Revit supports the integration of point cloud data, allowing architects to work with accurate 3D representations of the building.

Step 2: Model Element Extraction:

Architects proceed to extract individual building elements from the point cloud data, such as walls, columns, ceilings, and structural components. These elements are identified and segmented within the Revit environment.

Step 3: Parametric Modelling:

Once the building elements are extracted, parametric modelling techniques are employed. This involves defining the geometric and parametric properties of each element to create intelligent and adaptable 3D models.

Step 4: Integration of As-Built Data:

As-built data, including measurements and dimensions derived from point cloud data, are integrated into the Revit models. This ensures that the digital models accurately reflect the physical building's dimensions and spatial relationships.

Step 5: Detailing and Annotation:

To enhance the models' comprehensibility and utility, architects add detailing and annotations within the Revit environment. This includes annotations for materials, construction specifications, and other relevant information.

3. 4| Enhancing Details in 3ds Max:

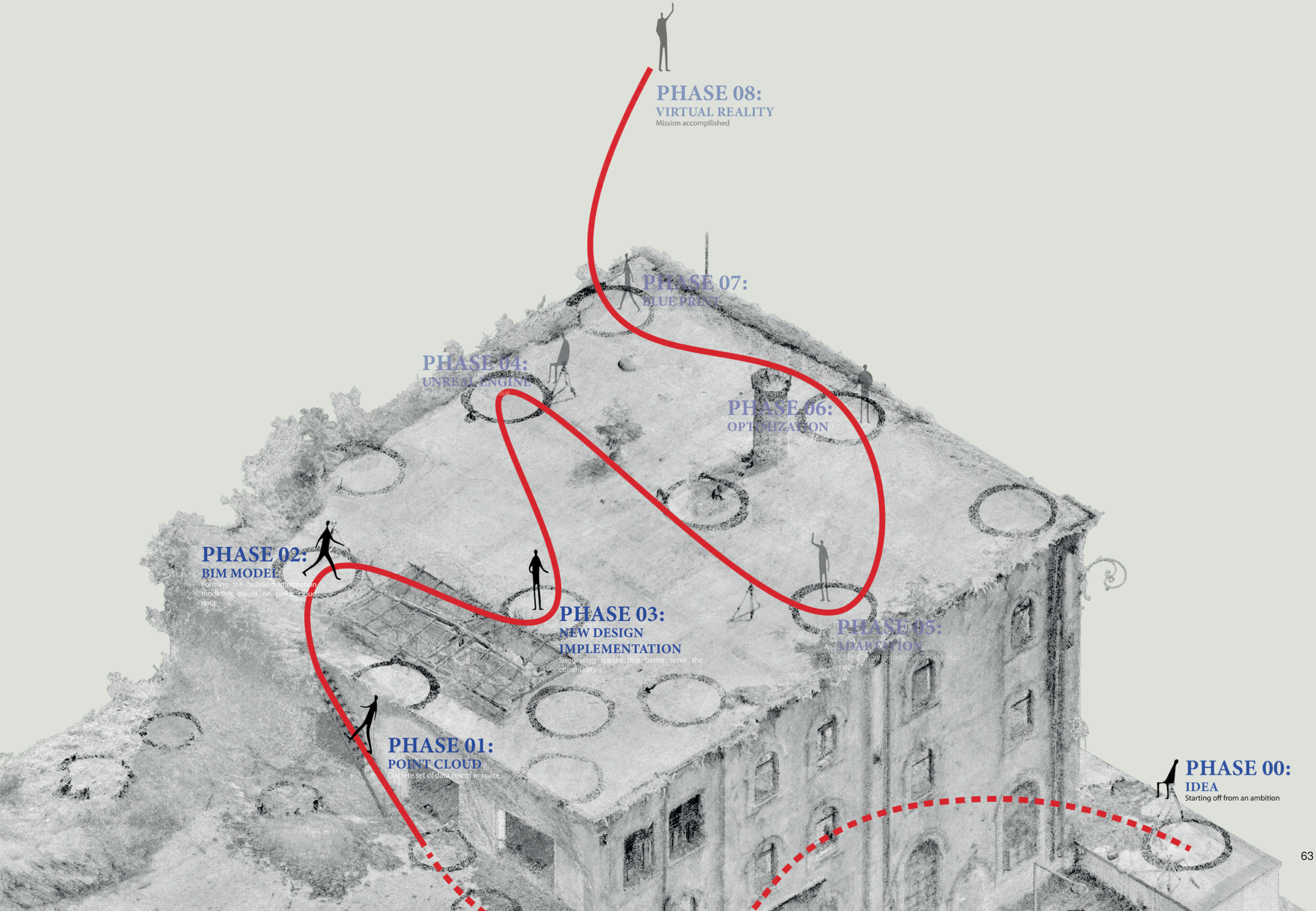
The process of Enhancing Details in 3ds Max adds a layer of visual richness and realism to the digital representations, preparing them for integration into the virtual reality environment.

Elevating Details in 3ds Max:

Step 1: Importing Revit Models:
The first step entails importing the digital models of the existing building elements, created in Revit, into the 3ds Max environment. This seamless integration allows architects to build upon the accurate base models.

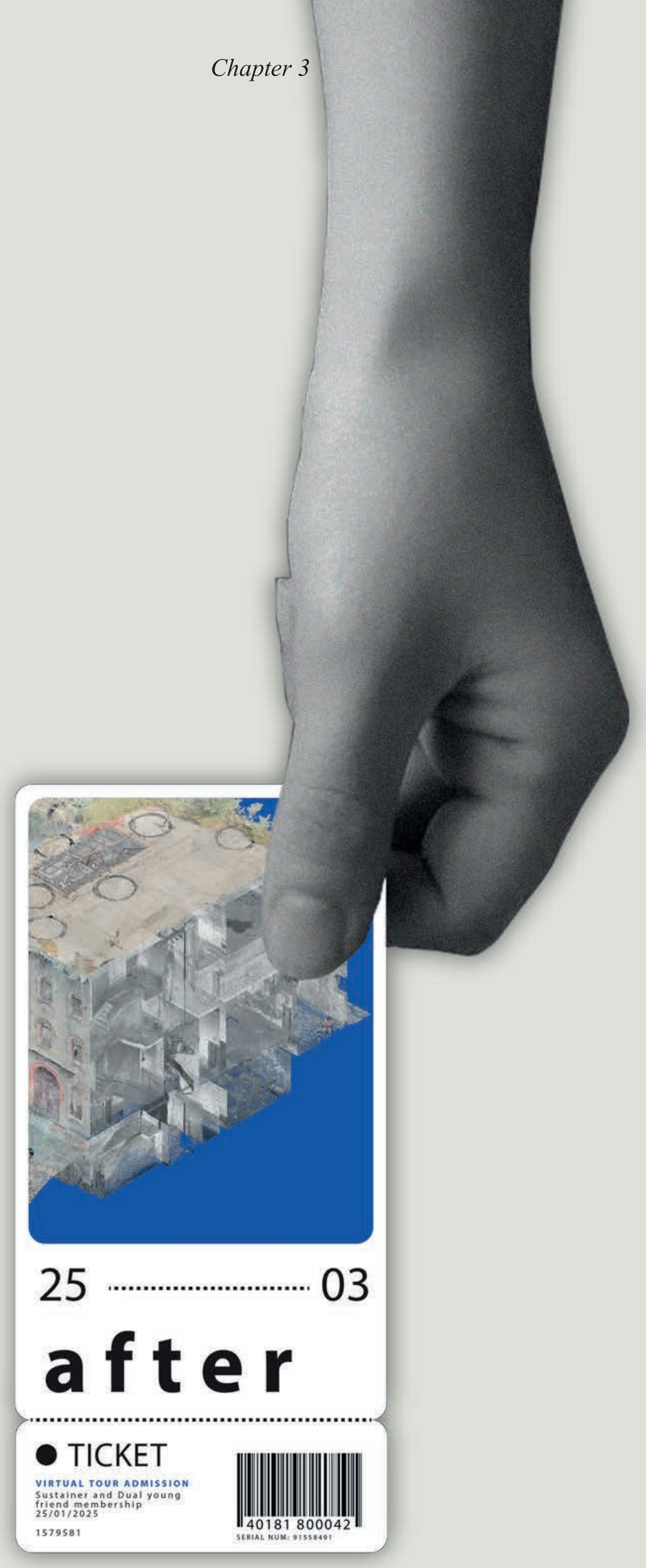
Step 2: Adding Fine Details:
To elevate the level of detail, fine elements such as fixtures, furnishings, and intricate architectural features are added to the 3D models. These details contribute to the models' realism and visual appeal, and they will be applied to the design within the Unreal Engine during the virtual reality presentation.

3. 5| Integrating Proposed Design Changes:


PHASE 08:
VIRTUAL REALITY
Mission accompilshed
PHASE 07:
BLUE PRINT
PHASE 04:
UNREAL ENGINE
PHASE 06:
OPTIMIZATION
PHASE 02:
BIM MODEL
Forming the building information modeling based on point cloud data
PHASE 03:
NEW DESIGN IMPLEMENTATION
Suggesting spaces that better serve the community
PHASE 05:
ADAPTATION
PHASE 01:
POINT CLOUD
Discrete set of data points in space
PHASE 00:
IDEA
Starting off from an ambition

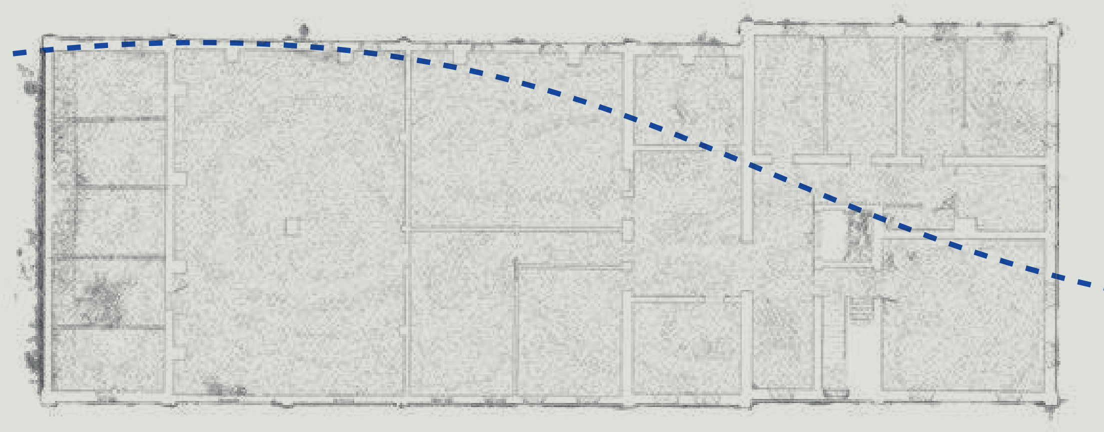

23
10
before
TICKET
40181 700982

CONCEPTS


25
03
after
TICKET
VIRTUAL TOUR ADMISSION
Sustainer and Dual young friend membership
25/01/2025
1579581
40181 800042

PHASE 01: POINT CLOUD

PHASE 01: POINT CLOUD

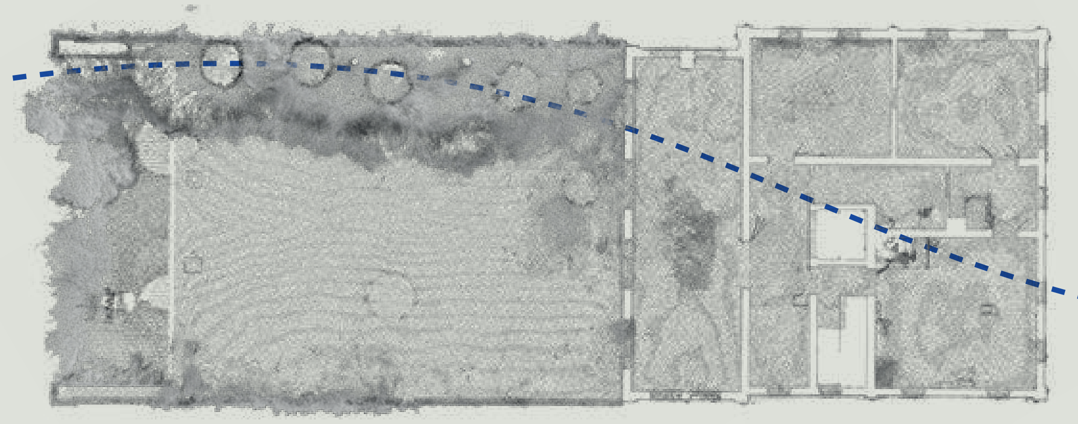


Second level plan

Scale: 1:200

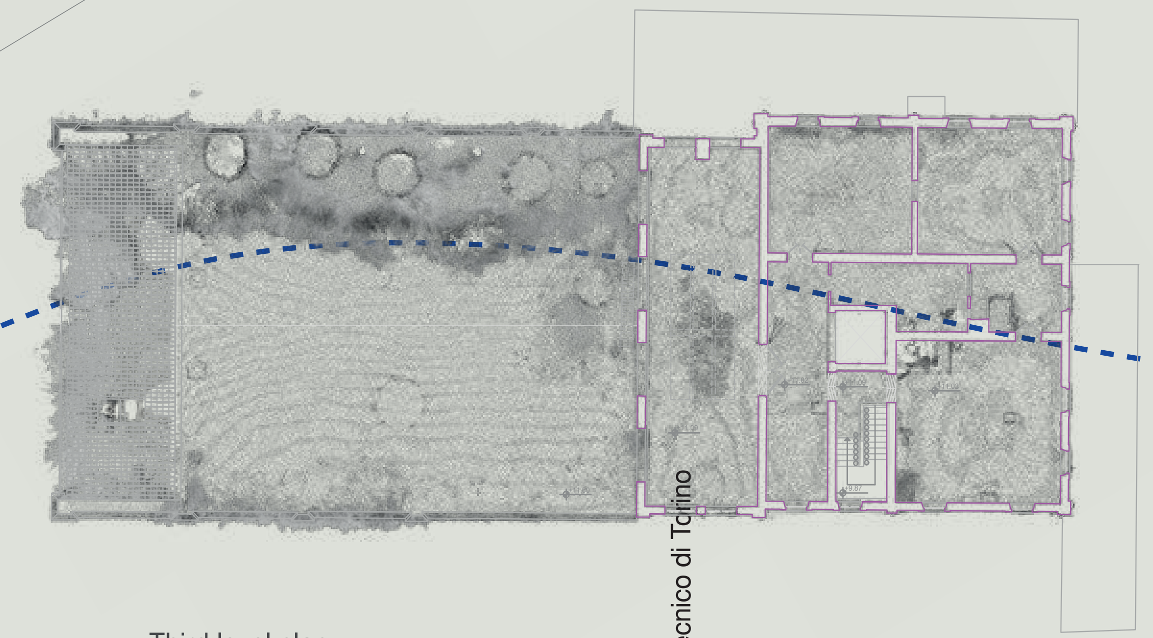
Second level plan

Scale: 1:200



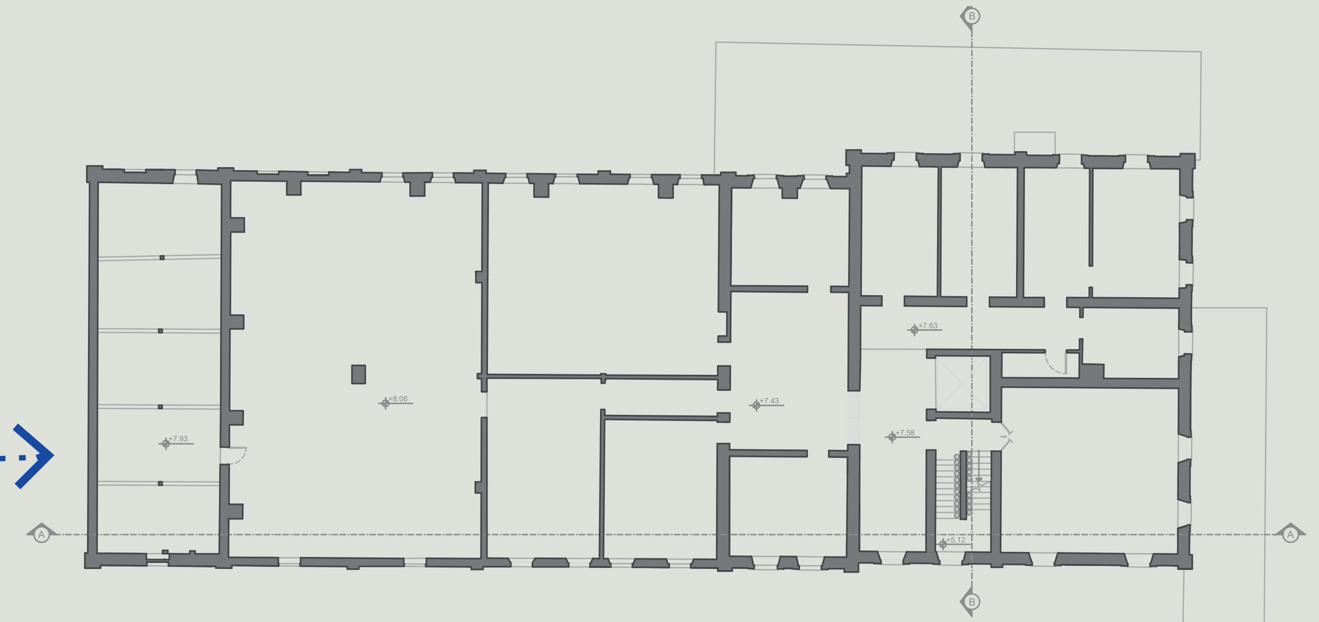
Third level plan

Scale: 1:200



Third level plan

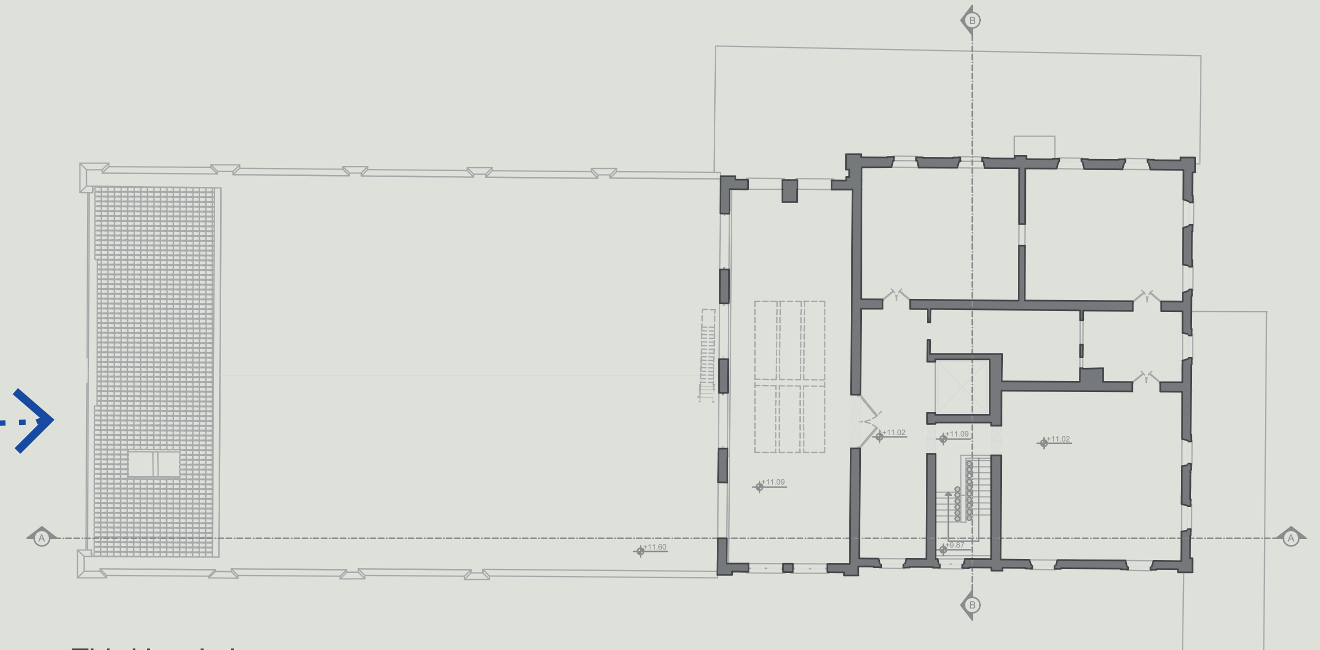
Scale: 1:200



Second level plan

Scale: 1:200

Building section — Primary elevation — Secondary elevation — Information

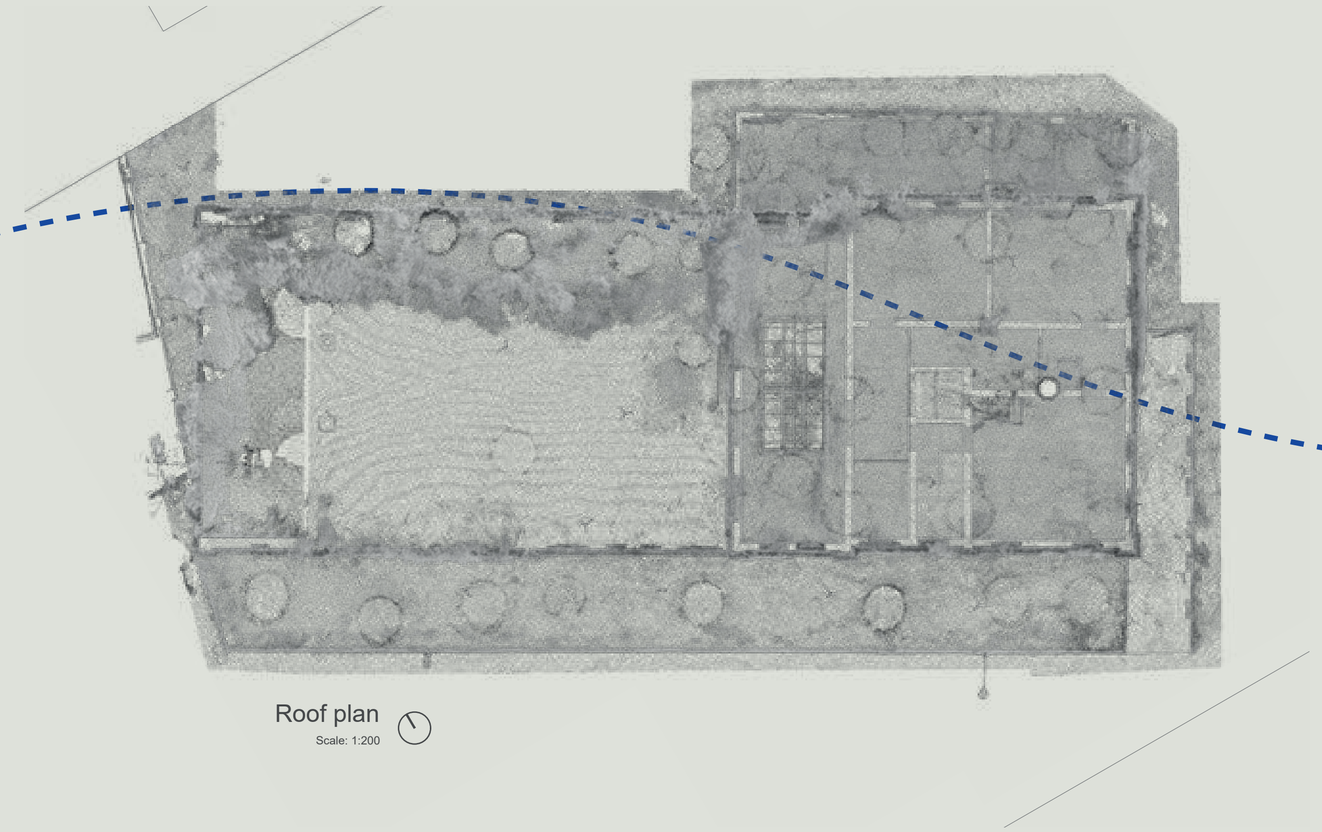


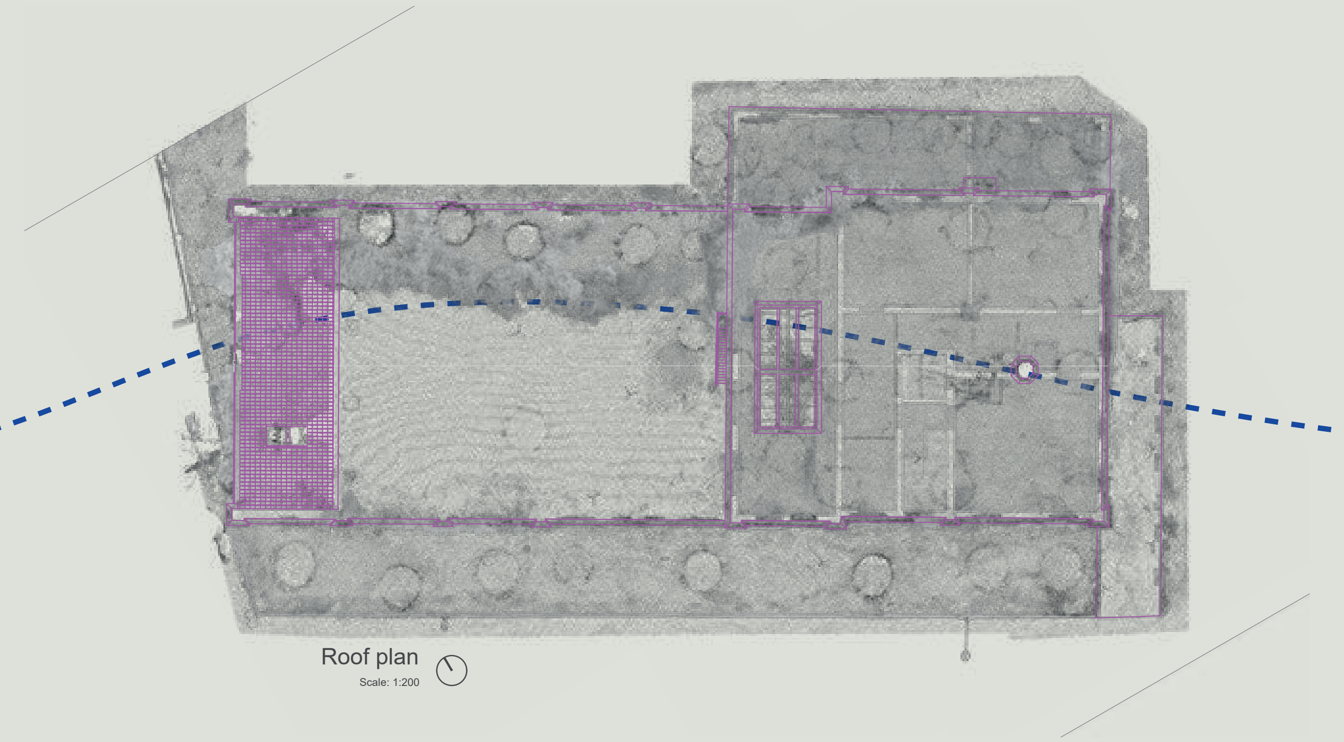
Third level plan

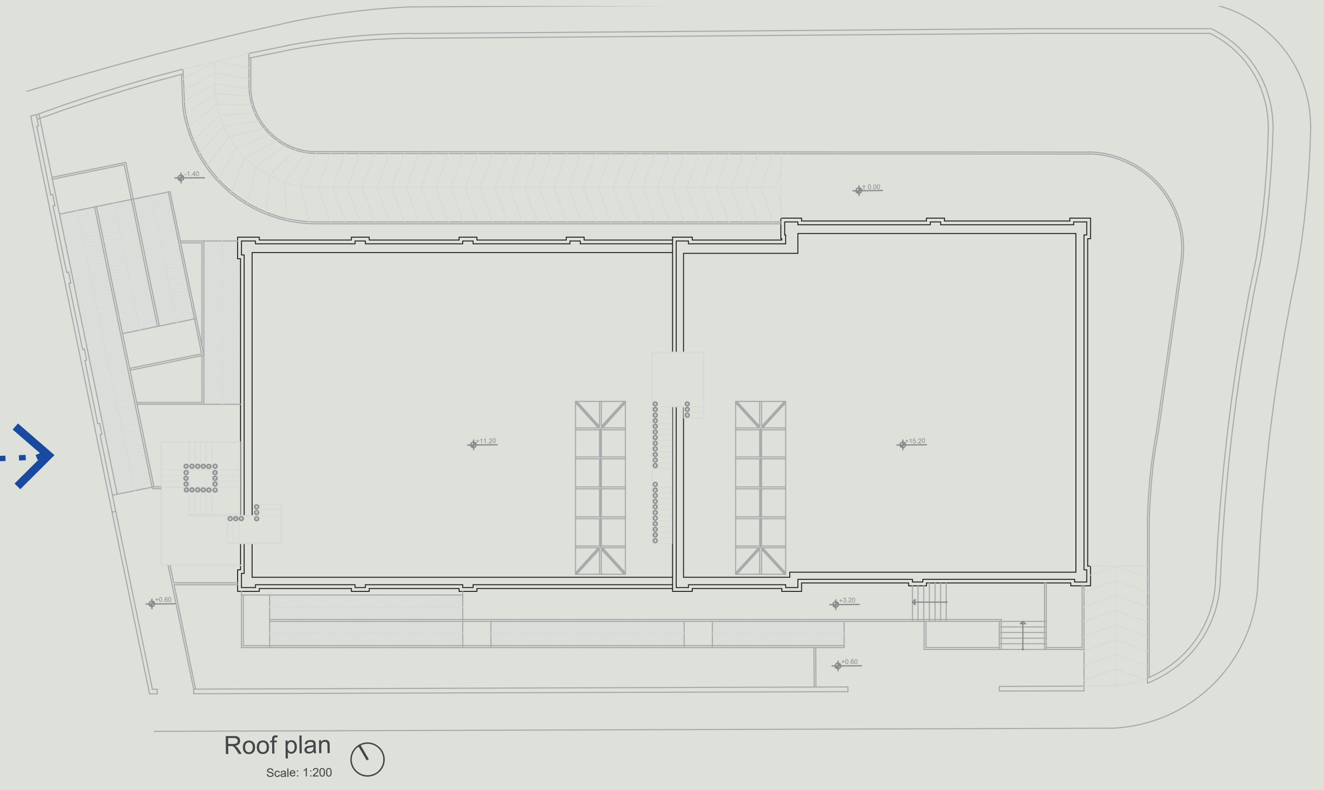
Scale: 1:200

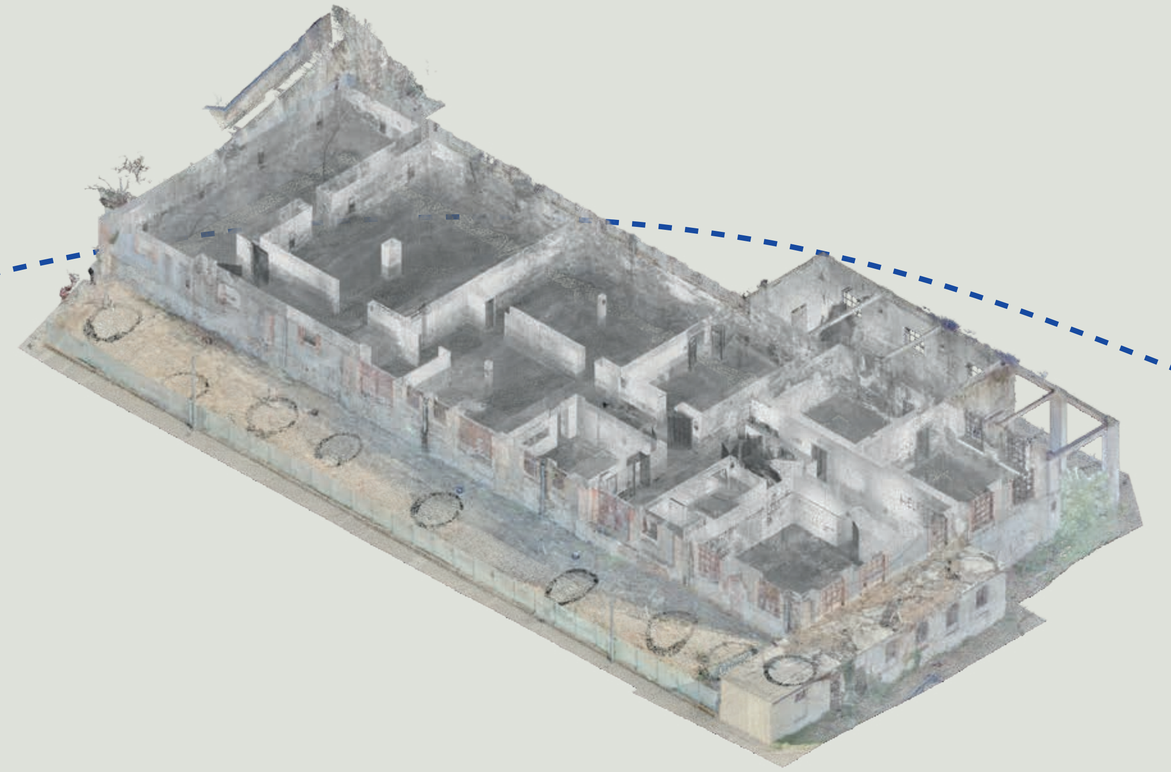
Building section — Primary elevation — Secondary elevation — Information

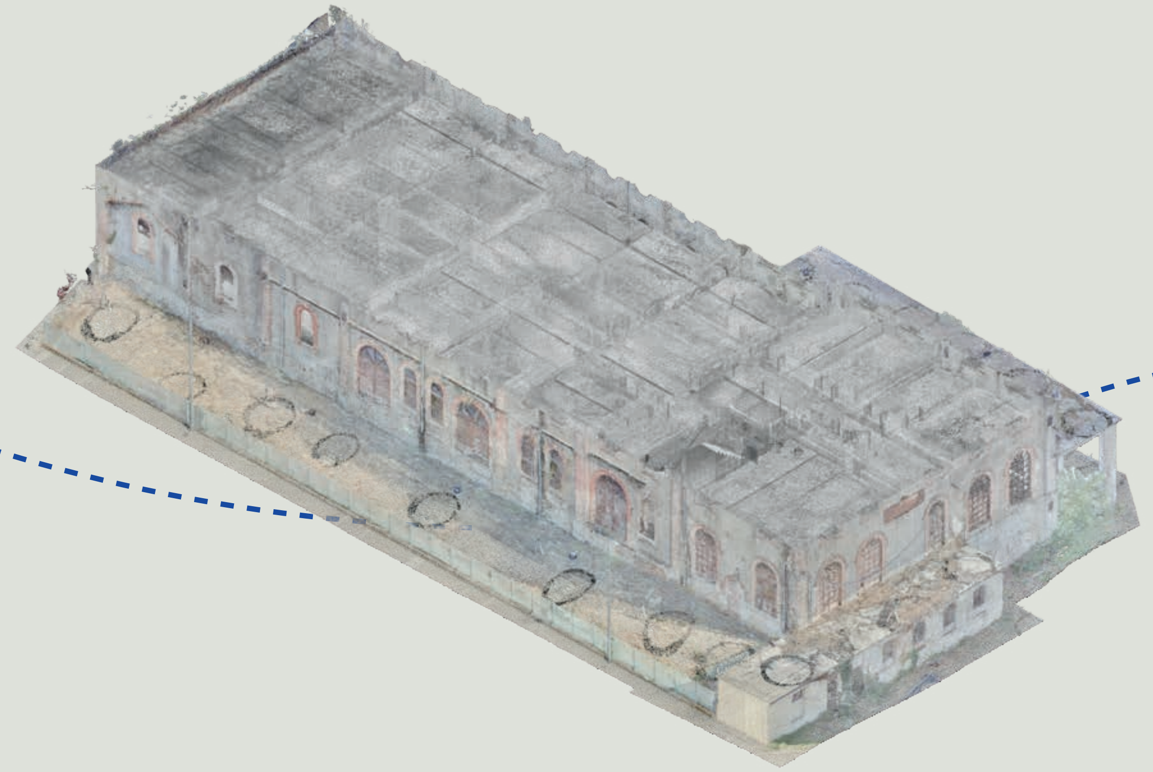
PHASE 01: POINT CLOUD

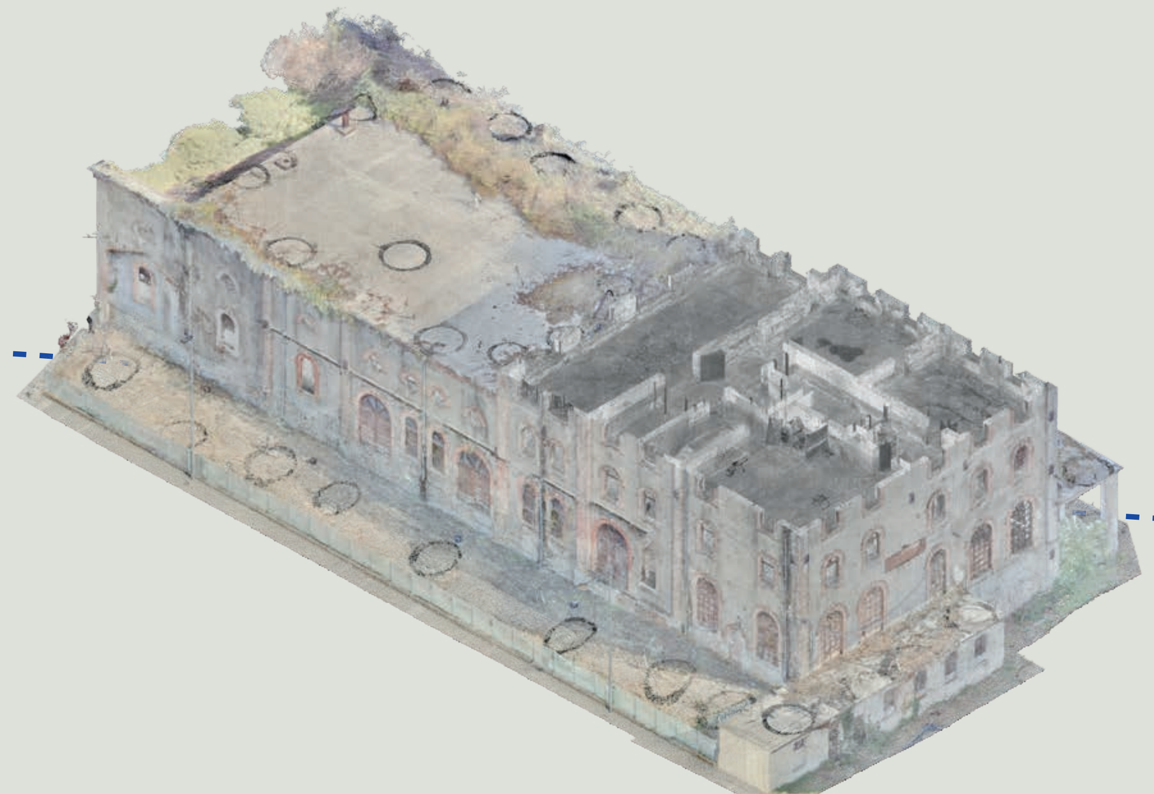


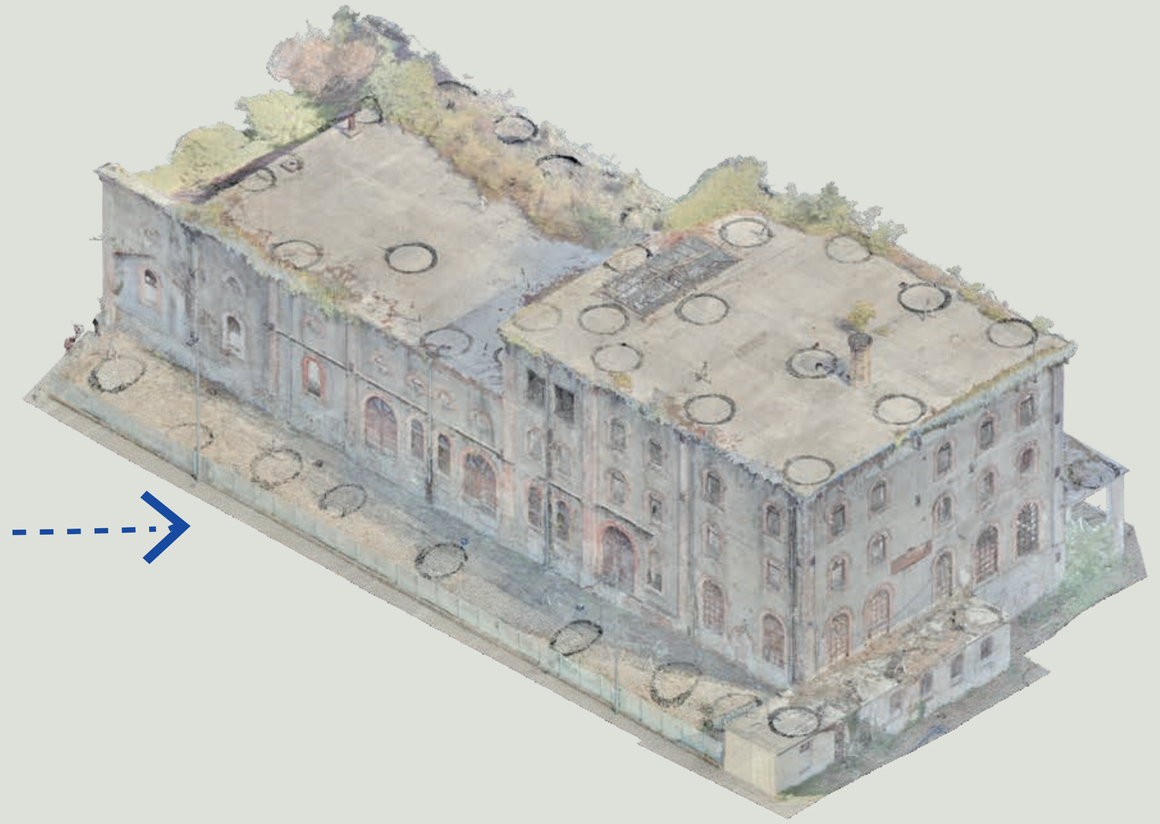




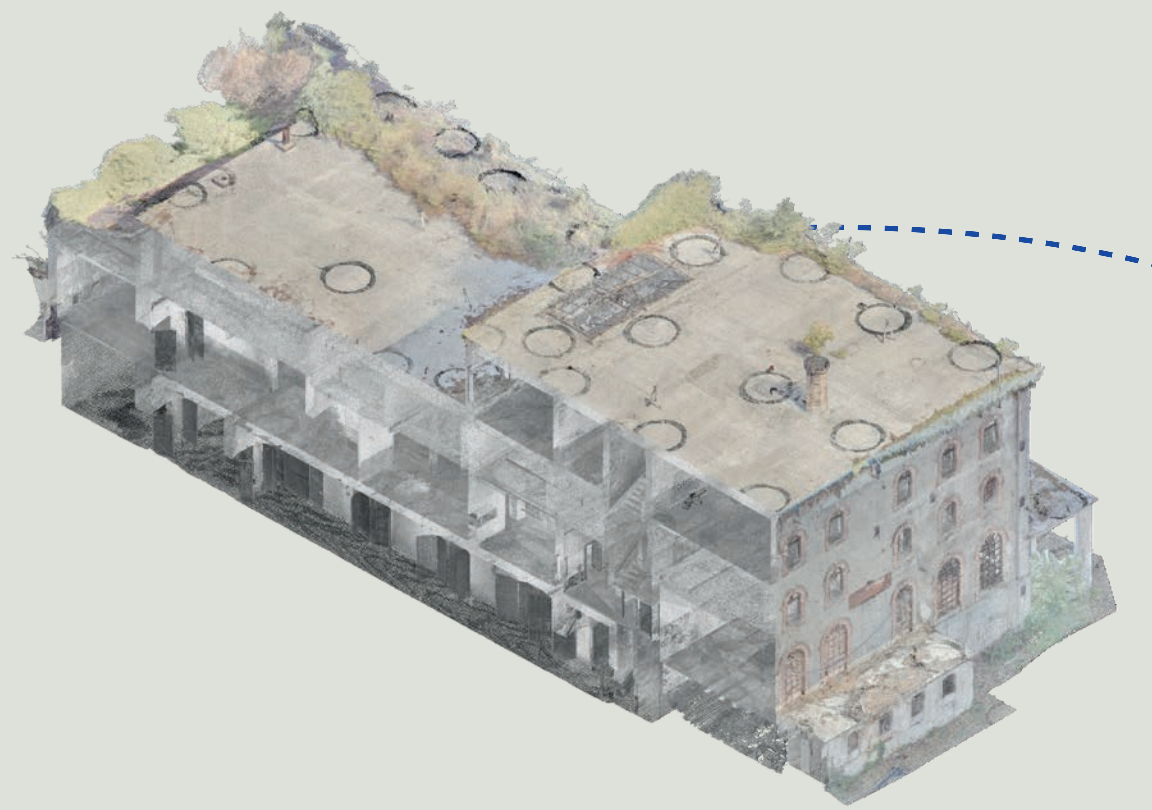


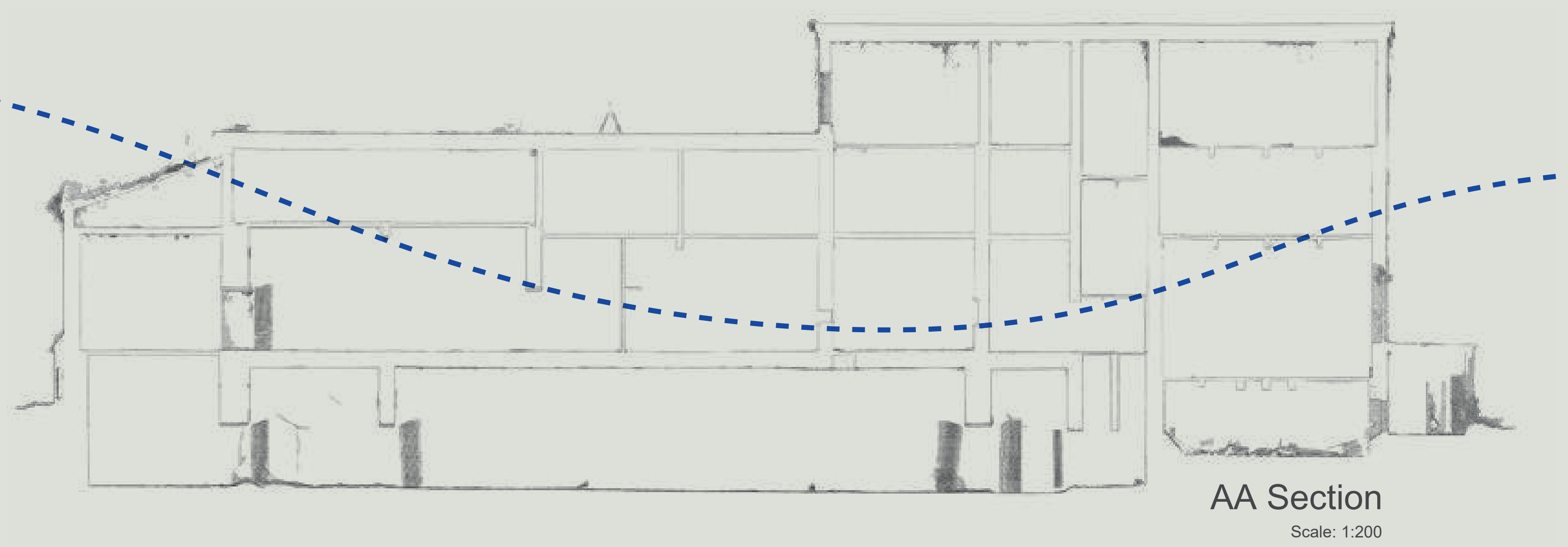


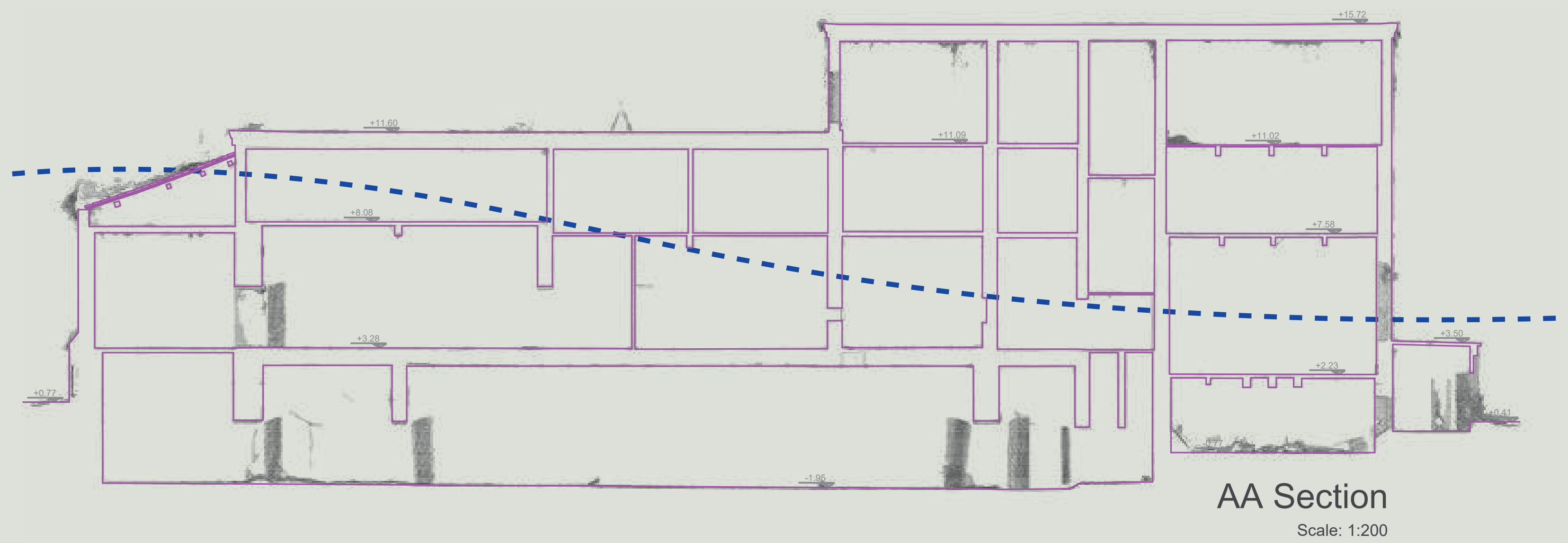


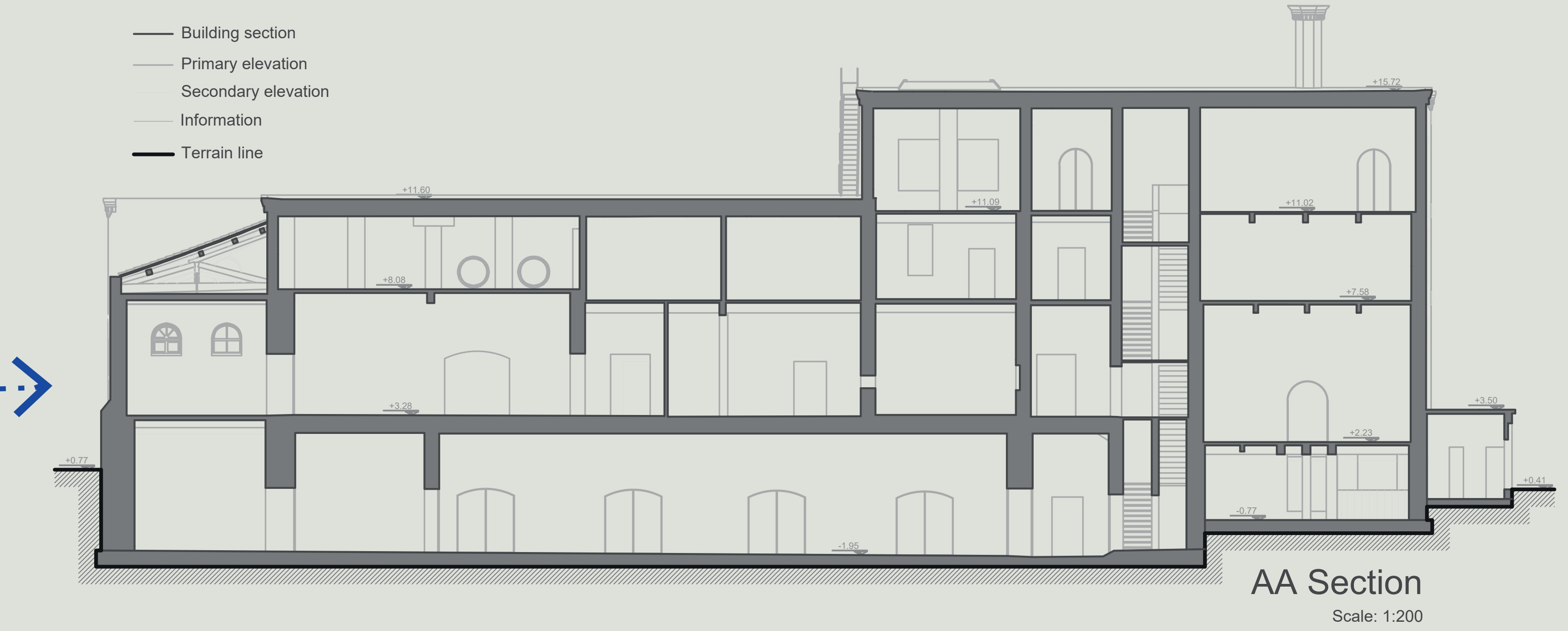


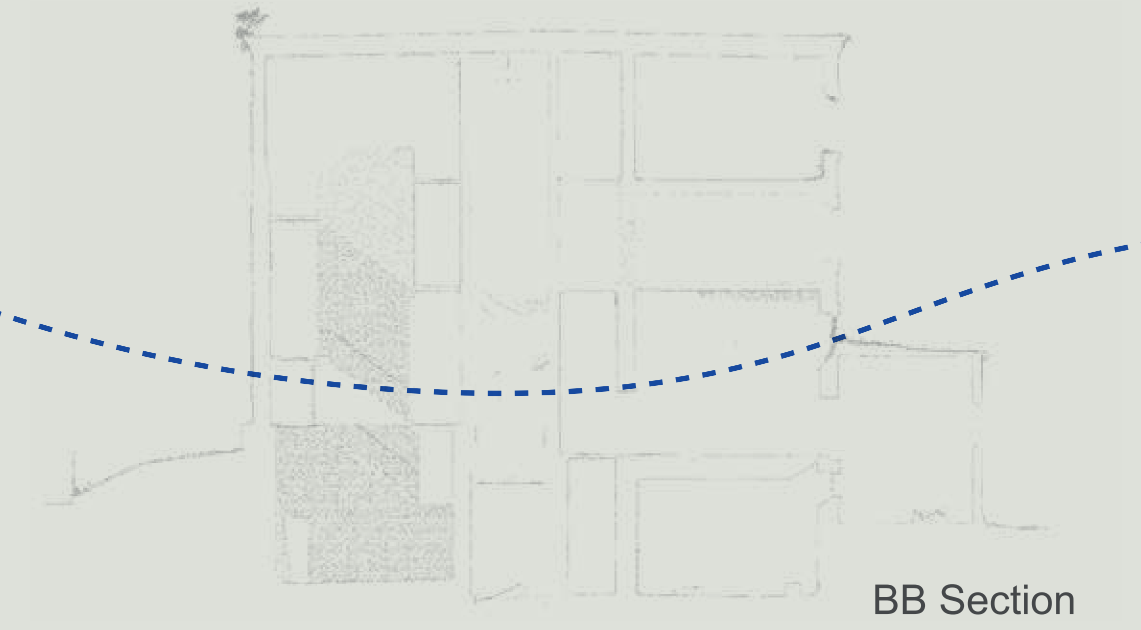
PHASE 01: POINT CLOUD

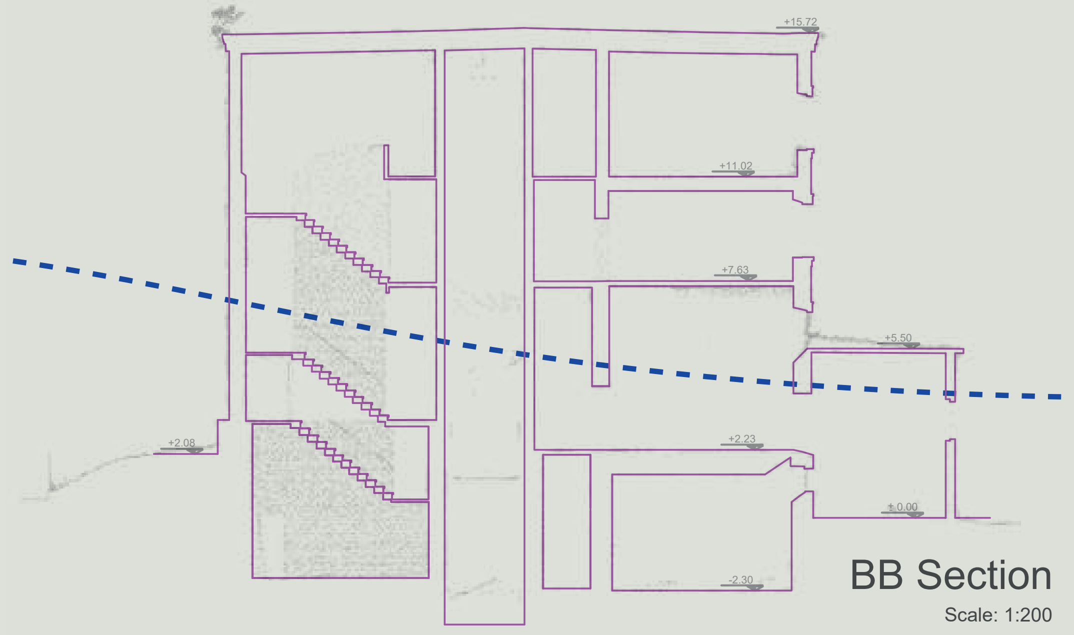


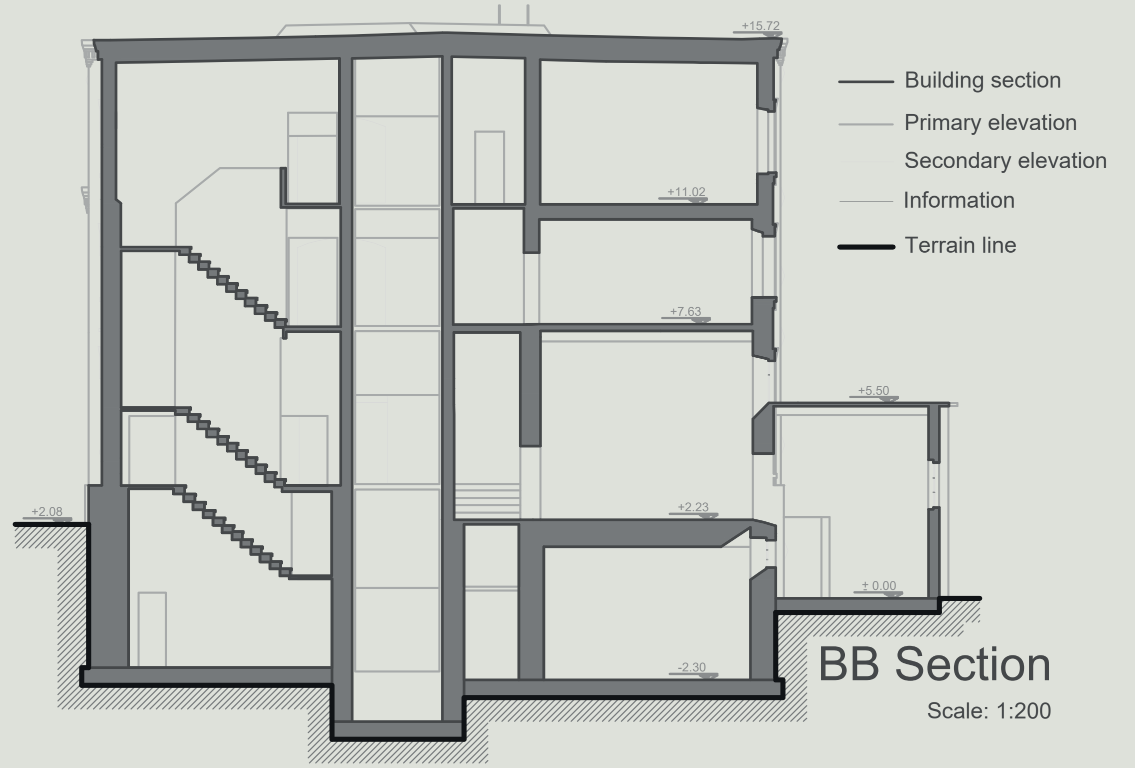








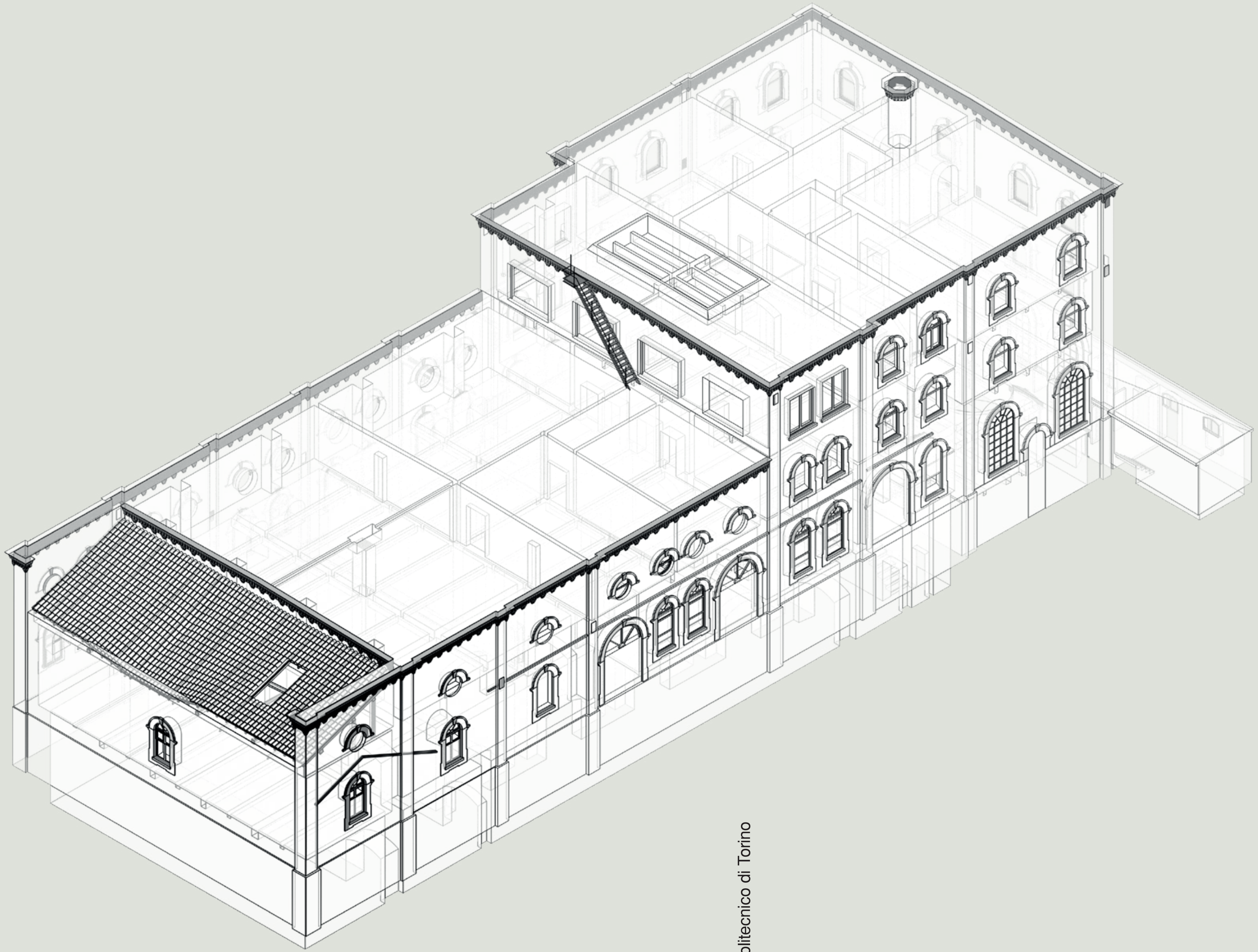


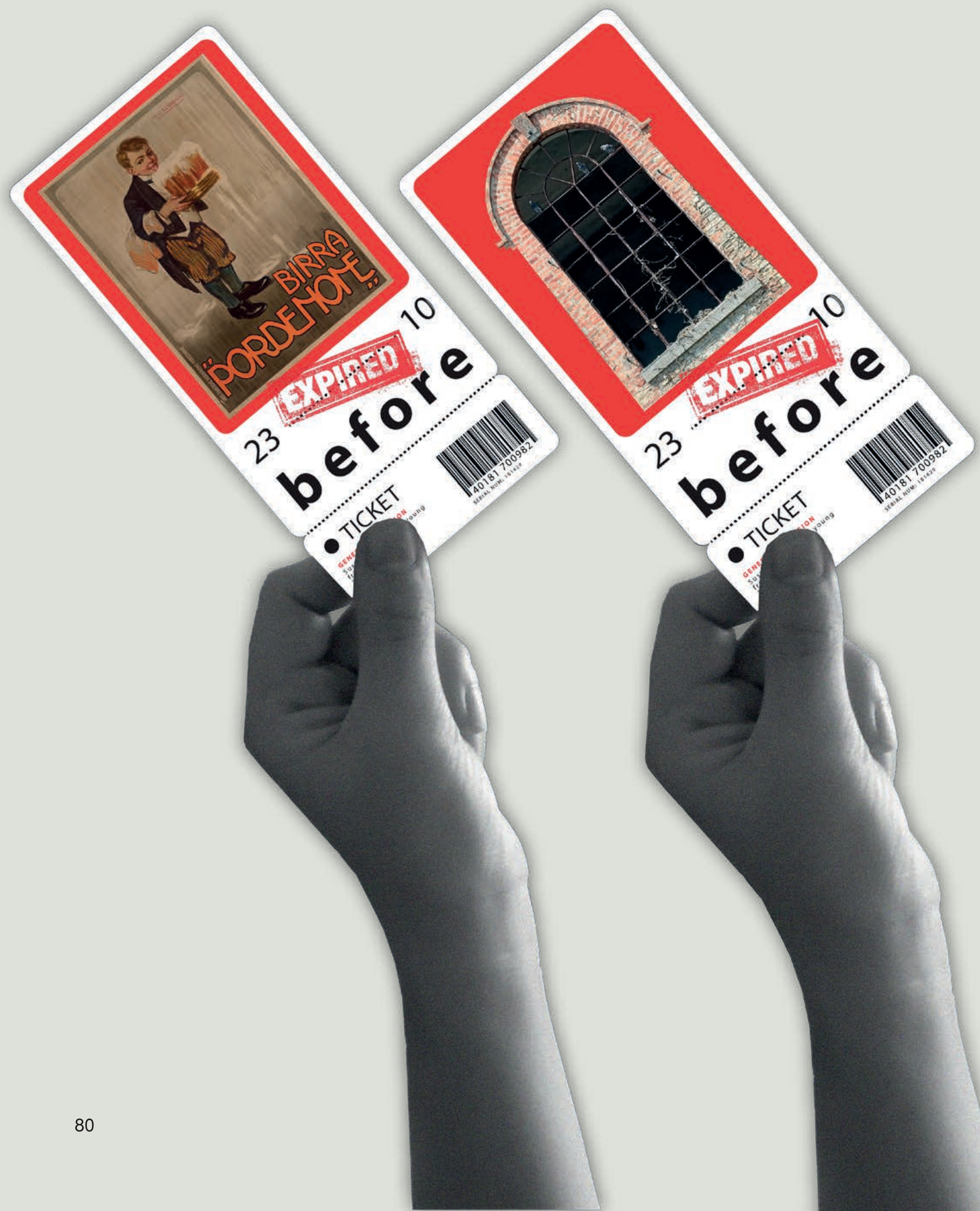


PHASE 01: POINT CLOUD

PHASE 01: POINT CLOUD

PHASE 02: BIM MODEL




BIRRA PORDENONE
EXPIRED
23
10
before
TICKET
40181 700982
EXPIRED
23
10
before
TICKET
40181 700982


25
COMING SOON
03
after
TICKET
UPDATING LEGACY ADMISSION
Sustainer and Dual young friend membership
25/01/2025
40181 800042
I CAN'T BUT WE CAN
25
COMING SOON
03
after
TICKET
CO-WORKING ADMISSION
Sustainer and Dual young friend membership
25/01/2025
40181 800042

CONCEPTS

Tool Box:

Architects: Caterina Tiazzoldi
Year: 2010
Location: Turin, Italy

The project is believed to meet the needs of a city in a phase of substantial transformation. From the functional point of view, the project consists in the creation of an open space with 44 individual workstations combined with other services and activities. The goal has been to keep the modular concrete structure unaltered.

The main span of the building has been divided lengthwise by a series of "filter volumes" used as technical spaces for storing lockers and equipment. On one side, there is the co-working space, on the other side, the corridors and the functional "box" containing shared facilities such as meeting rooms, print rooms, informal meeting spaces, mailboxes, a patio and a kitchen.

From the perspective of the design process the goal was to mediate between the plurality of users' needs and the coherence of the design. The concept of the project derives from the combinatorial Adaptable Component model developed by Caterina Tiazzoldi within the context of the research Lab NSU at the Politecnico di Torino and Columbia University. The variety of solutions is obtained by use of a unique design rule. A set of initially identical volumes acquire specialization or differentiation through the use of different materials (cork, rubber, polished paint according to the programmatic function hosted in the box.

The specialization of a generic volume occurs in accordance with a specialization generated by sound, thermal, and visual requirements.

Thanks to its unique features, Toolbox is an urban concept that draws its strength from the complexity, variety, and changeability of the contemporary city (Archdaily, n.d.).

Chapter 3

CASE STUDIES

.Fig 21. *Tool box*

EDIT:

Architects: lamatilda, Studio Amirante, Studio Cattaneo
Year: 2017
Location: Turin, Italy

The fundamental objective of the architectural intervention was, on the one hand, respect for the industrial heritage of the building that houses Edit, and on the other, the development of different, but not separate, areas in which the user could live and share ever-changing experiences.

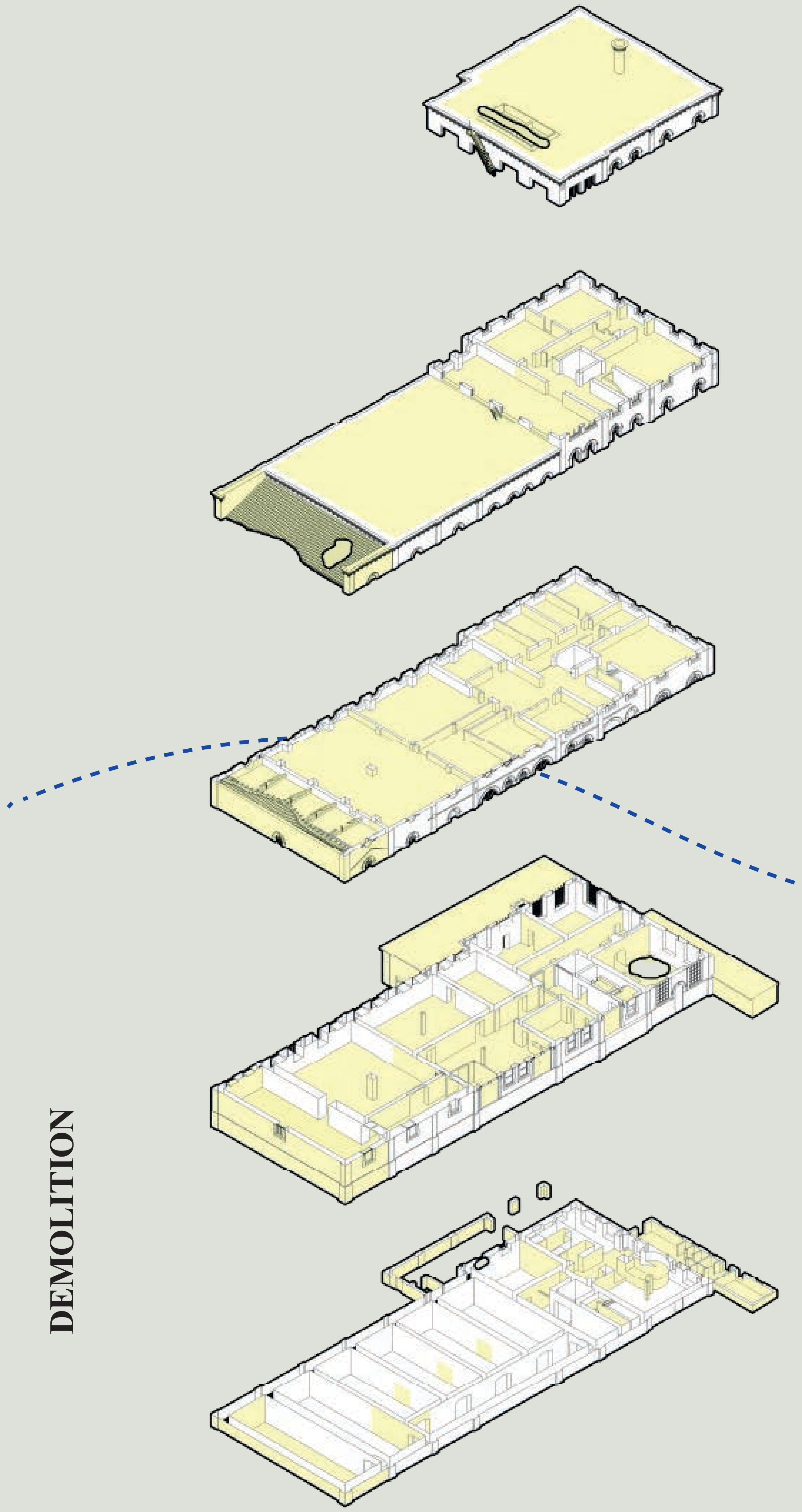
If the industrial character of Edit is particularly evident in the choice of brutalist finishes, its conceptual character, however, emerges from the exaltation of sharing, translated into a design approach where the idea of "everything in sight" becomes an effective synthesis of the new relationship between producer and consumer. From this perspective, the surface geometries are organized as real islands, to be enjoyed individually or together.

Finally, the identity project defines and enhances the idea of the "experiential kit": it is a visual journey, marked by a cloud of symbolic objects that characterize and tell the variety of Edit and its uniqueness. (matilde, n.d.).

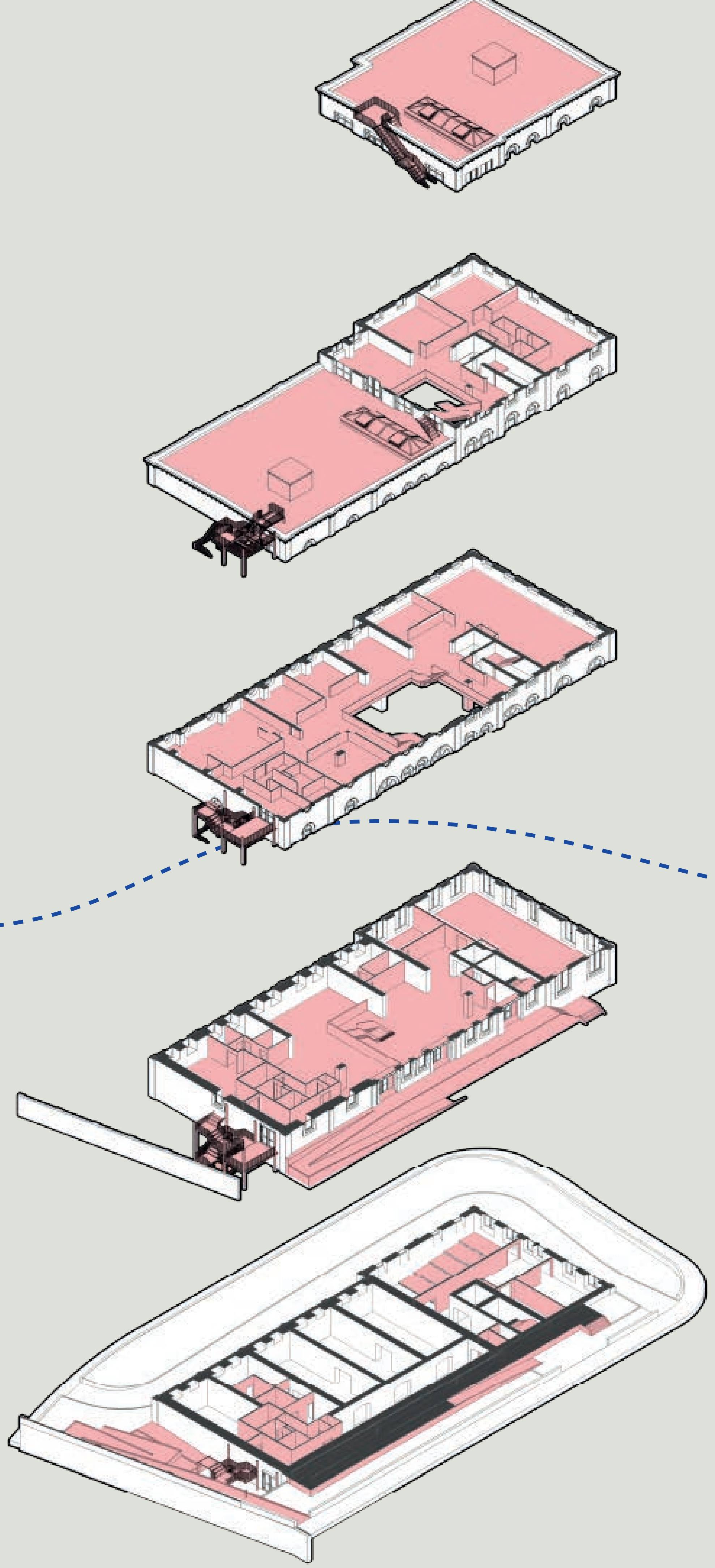
CASE STUDIES

.Fig 22. *Edit*

DEMOLITION

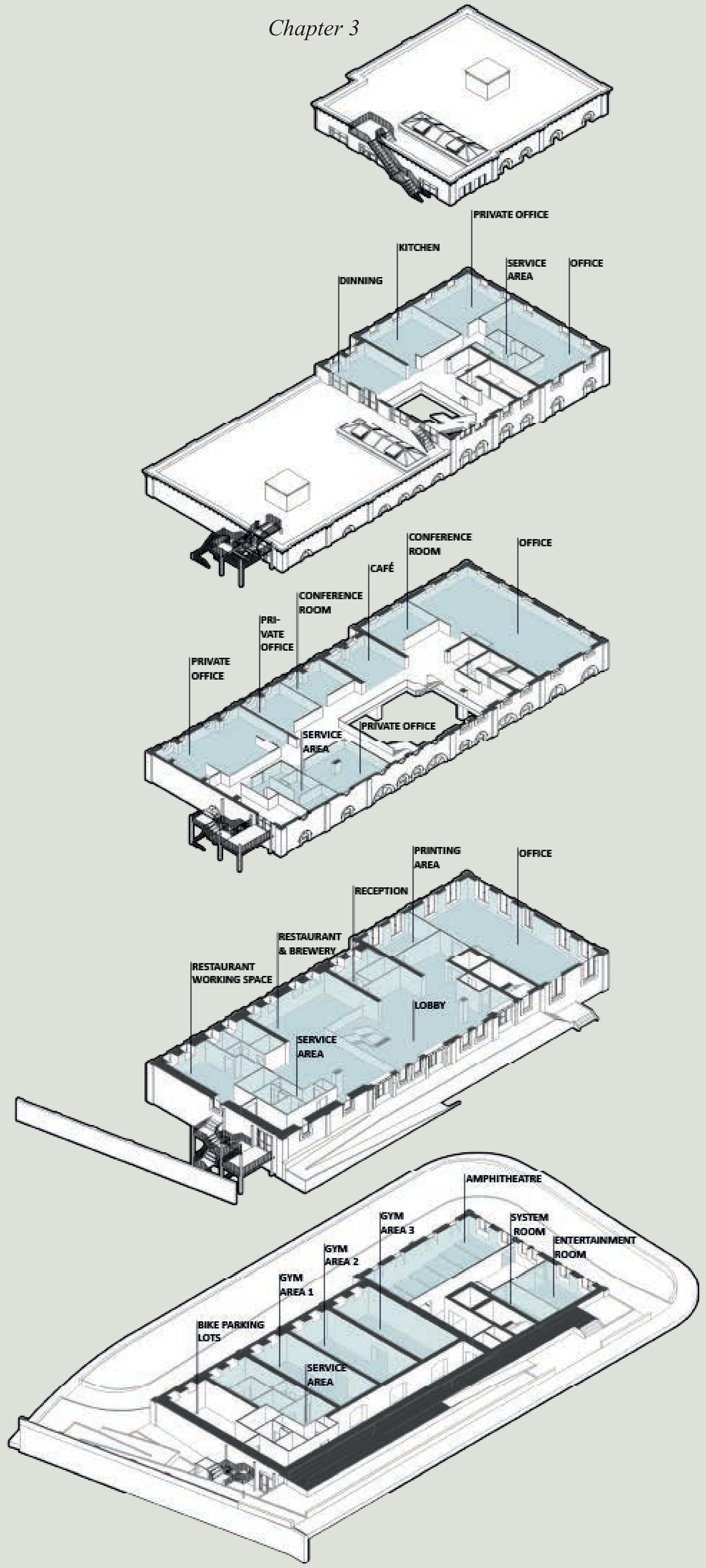


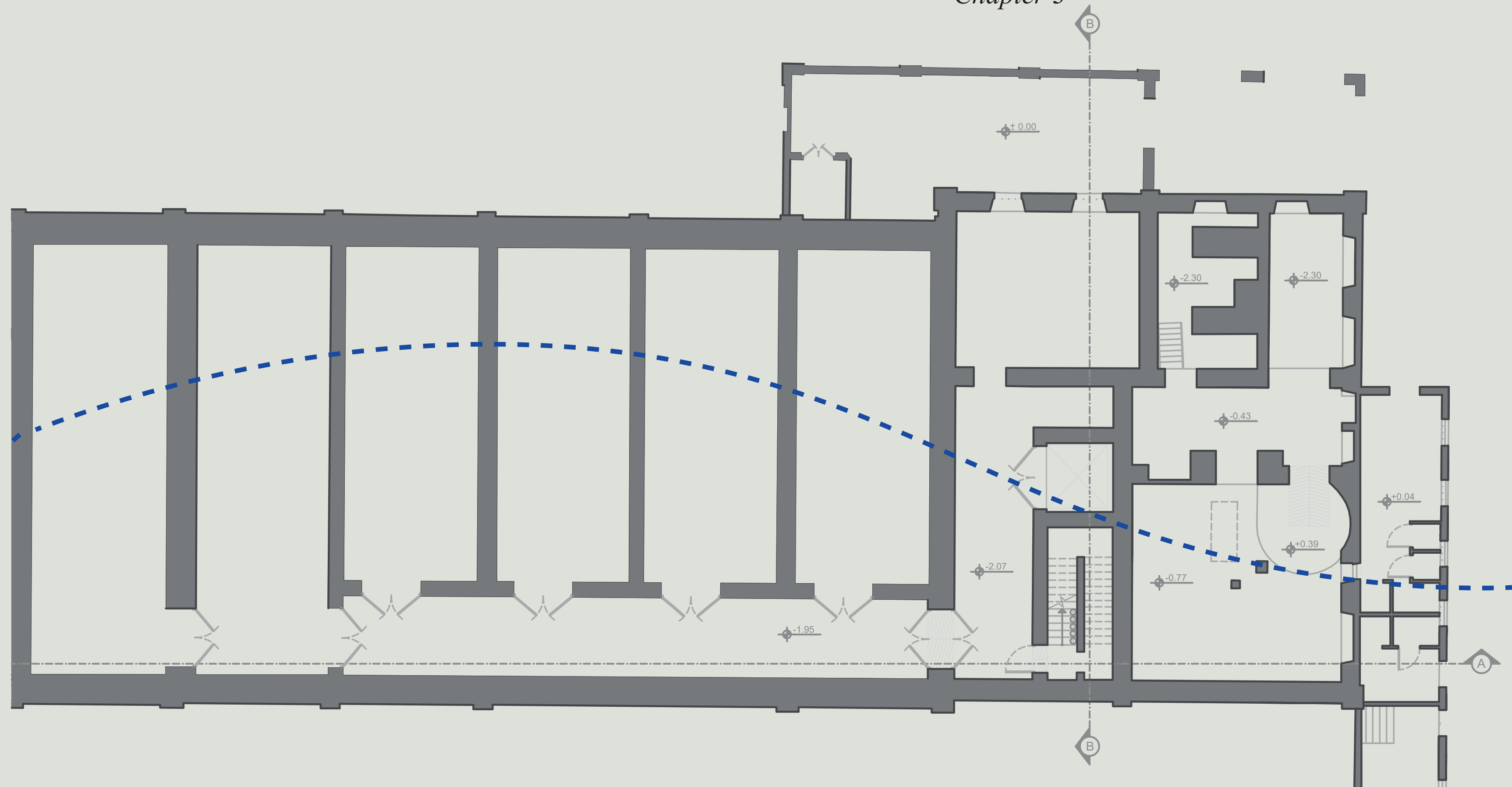
CONSTRUCTION



Chapter 3

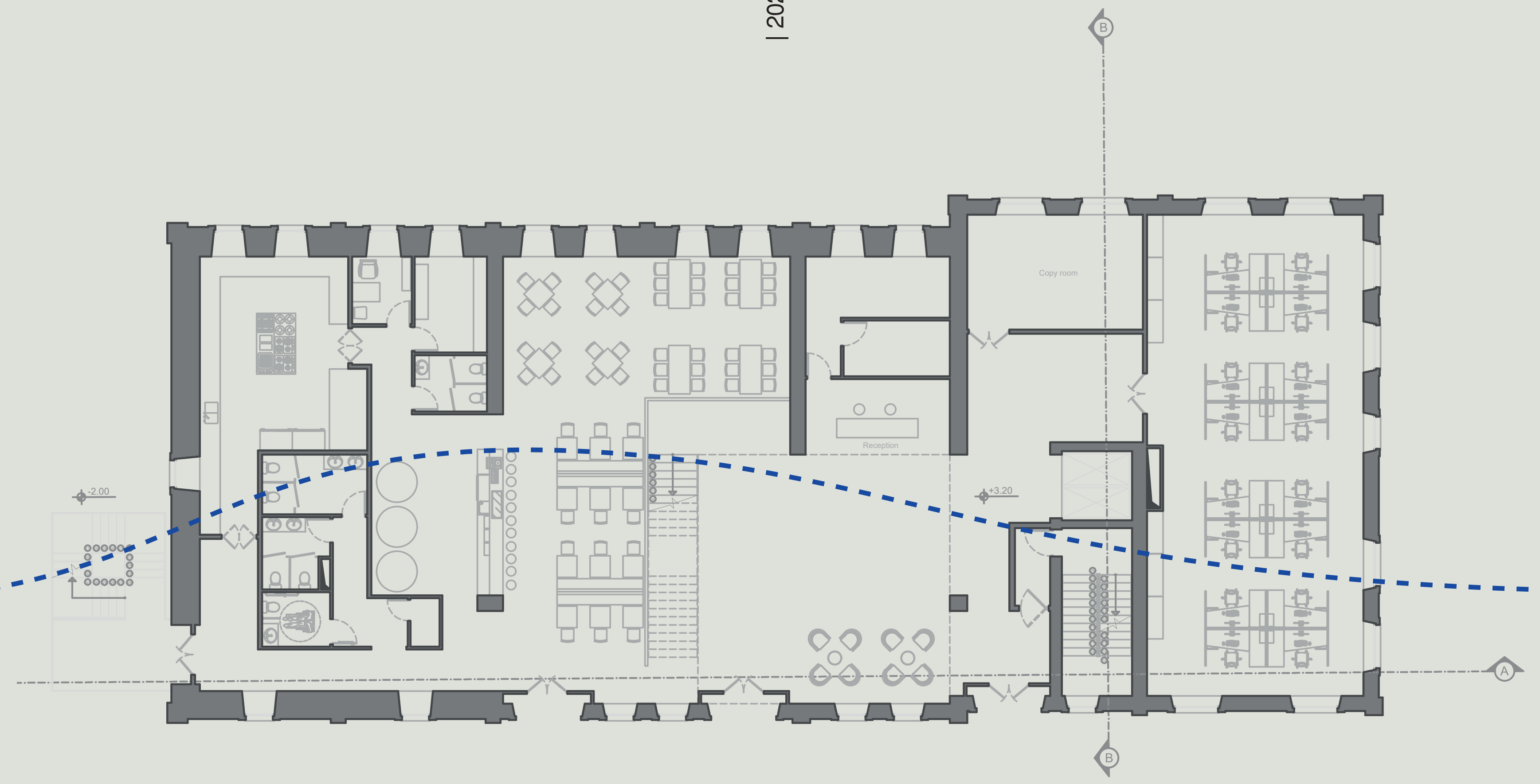
PROPOSAL



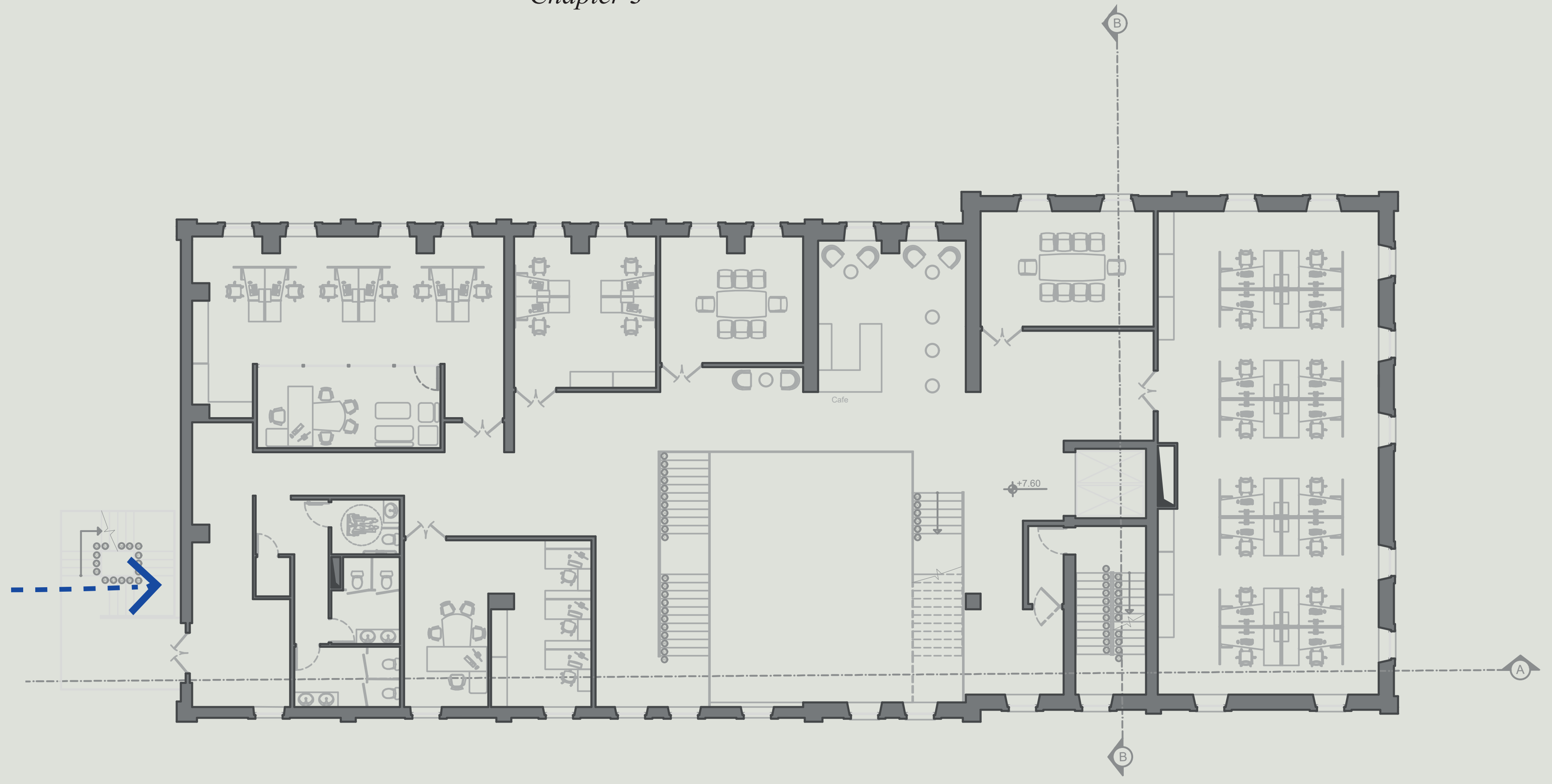


Basement plan
Scale: 1:200

Building section — Primary elevation — Secondary elevation — Information

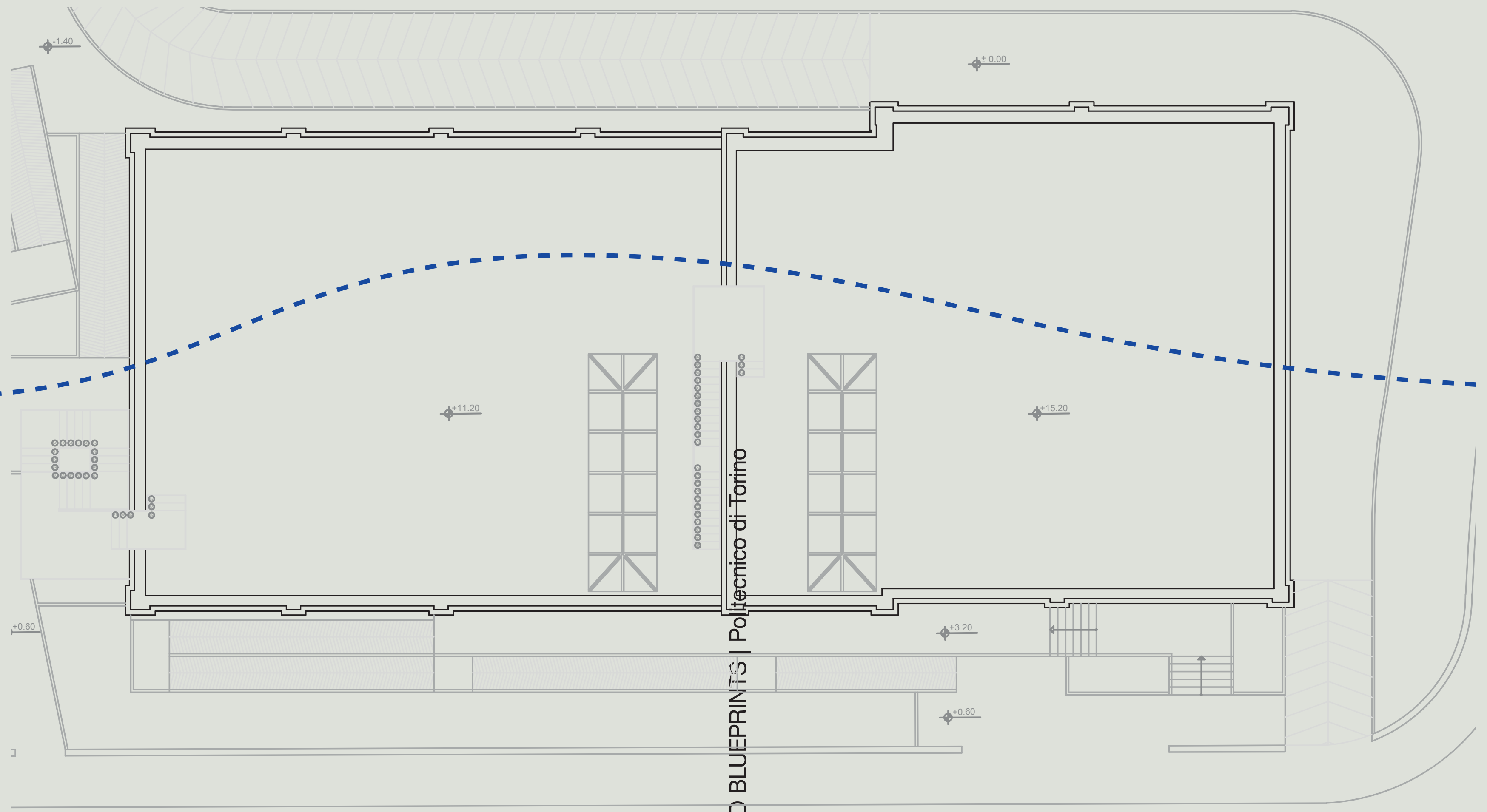


First level plan
Scale: 1:200

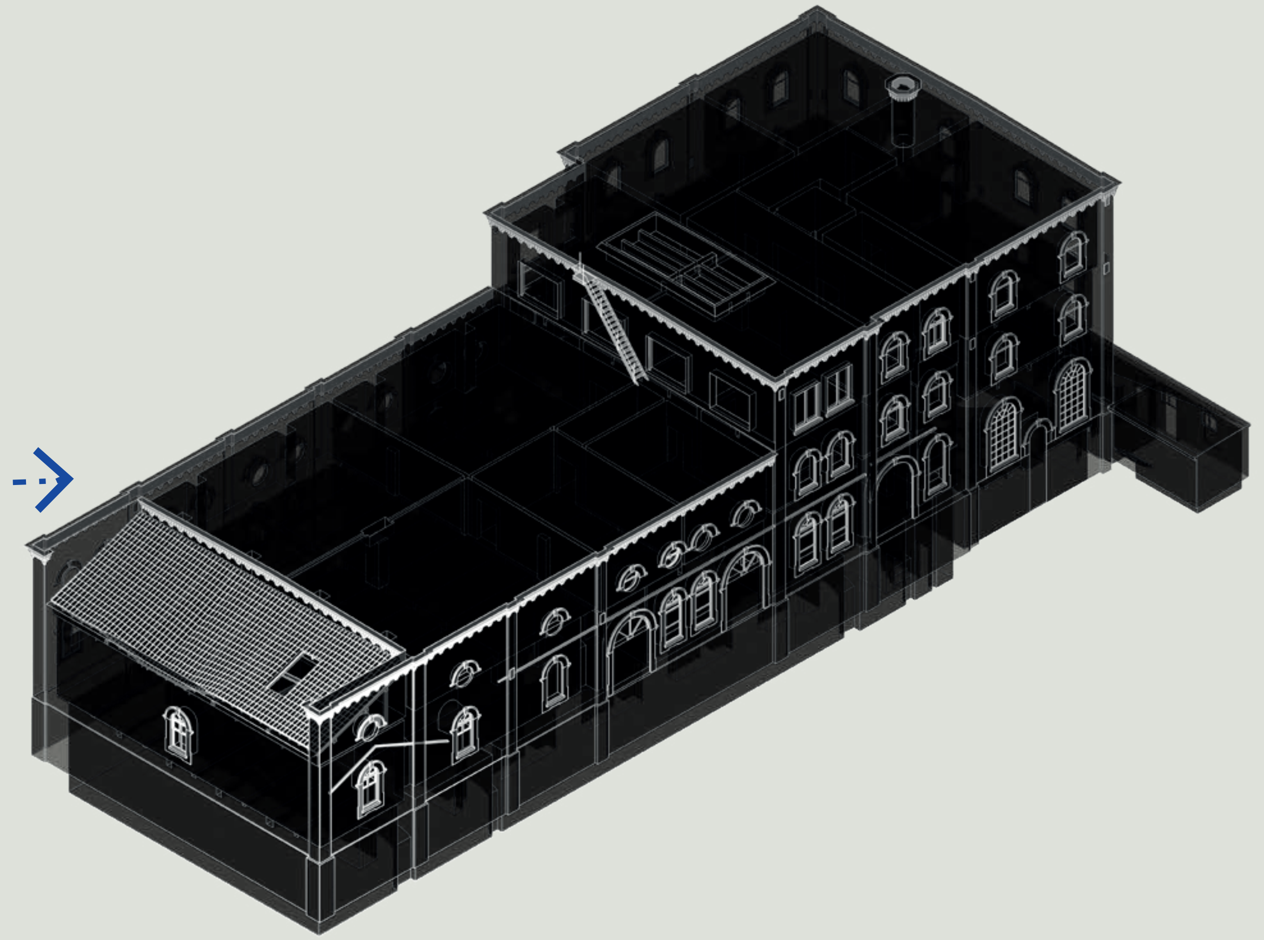


Second level plan
Scale: 1:200

Third level plan
Scale: 1:200

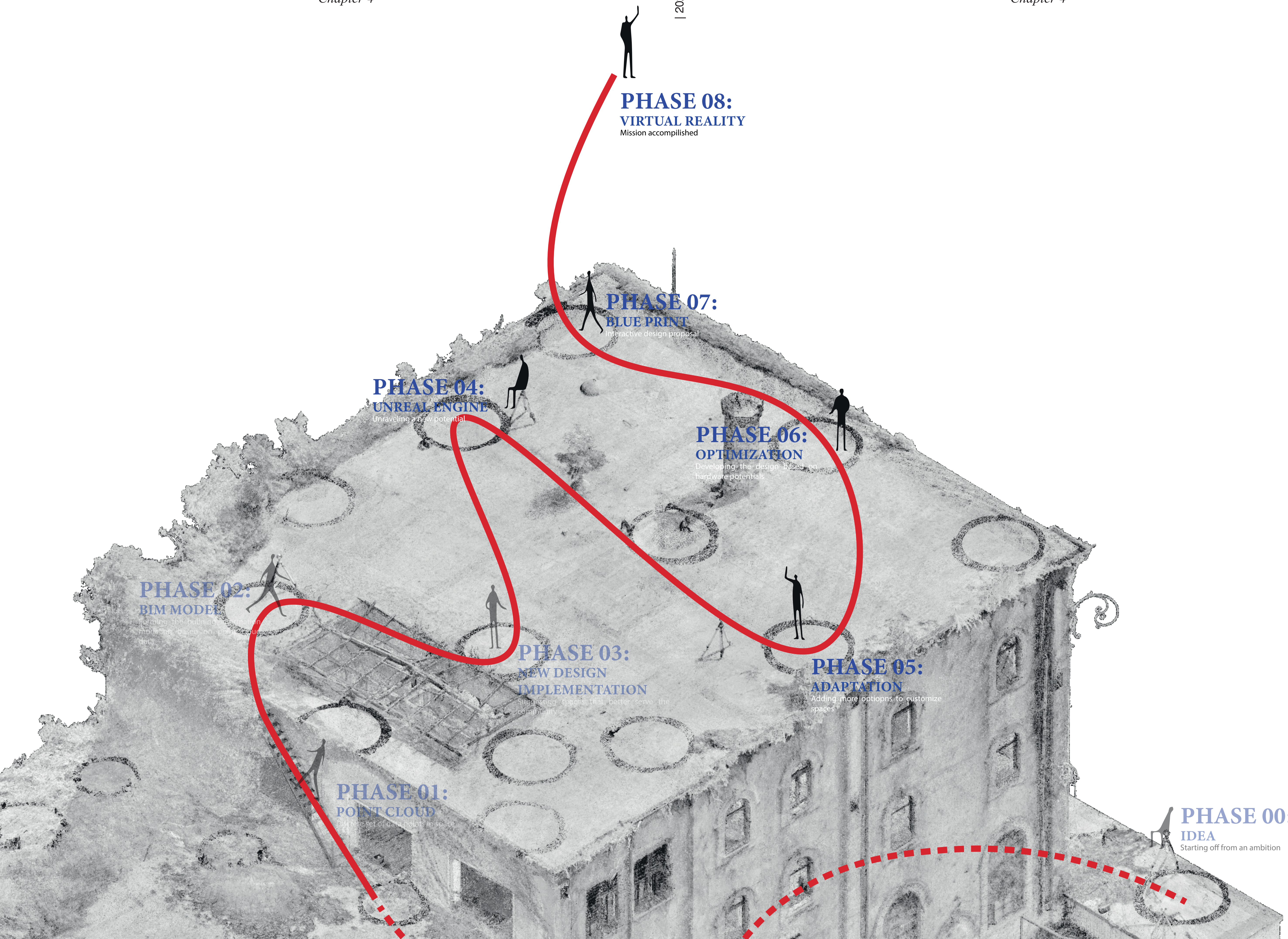


Roof plan
Scale: 1:200




AA
S
N


BB
W
E


PHASE 08:
VIRTUAL REALITY
Mission accompilished
PHASE 07:
BLUE PRINT
Interactive design proposal
PHASE 04:
UNREAL ENGINE
Unraveling a new potential
PHASE 06:
OPTIMIZATION
Developing the design based on hardware potentials
PHASE 02:
BIM MODEL
Forming the building information modeling based on point cloud data
PHASE 03:
NEW DESIGN IMPLEMENTATION
Suggesting spaces that better serve the community
PHASE 05:
ADAPTATION
Adding more optiopns to customize spaces
PHASE 01:
POINT CLOUD
Discrete set of data points in space
PHASE 00:
IDEA
Starting off from an ambition

4

Virtual Reality Implementation

4|

4. 1| Importing 3D Model to Unreal Engine:

A researcher, a student, or just someone who expresses interest in the subject can engage with 3D models and agents in a virtual world using virtual models, which are legitimate cognitive tools. According to Bruno et al. (2010), this technology may be used in the field of cultural heritage as a tool for recording, study, preservation, reconstruction, and promotion.

There are programs which allow the user to fly or walk through the building with a single click from the 3D-model- or BIM-software. And with a single click, the building is gamified. These simpler gamification programs have little flexibility when it comes to how much you can do inside the software. This is where Unreal Engine steps in. Made by Epic Games, Unreal Engine is a powerful game development tool that enables developers to create 3D models, animations, linear film and television, training and simulation and architectural visualization (Susi, 2022).

Seamless Transition to Unreal Engine:

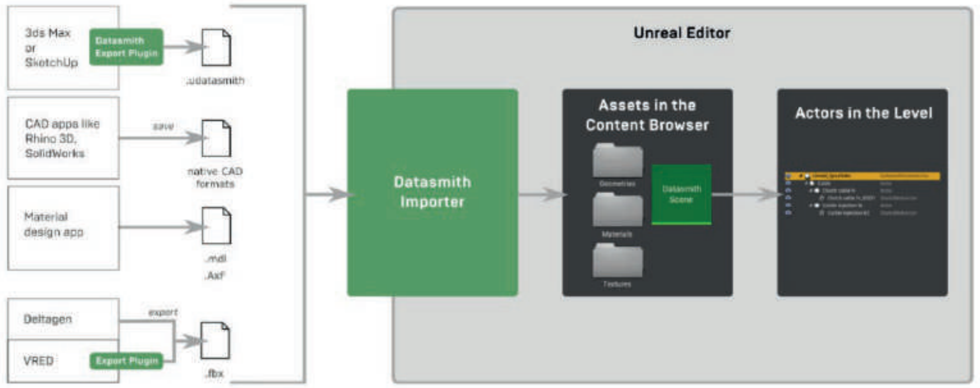
The process of importing the 3D model to Unreal Engine is a well-structured endeavour that facilitates the creation of an immersive virtual reality experience:

Step 1: Export from 3ds Max Using Datasmith:

The 3D model, perfected in 3ds Max with enhanced details and design changes, is exported using the Datasmith plug-in a powerful tool for streamlining the transfer of assets between 3ds Max and Unreal Engine. Datasmith ensures compatibility and a smooth transition of assets.

Datasmith import:

The most effective way to import a Revit-model to Unreal is through a tool called Datasmith. Datasmith is a collection of tools which helps you bring content into Unreal Engine 4 from other software. It works seamlessly across various industries such as architecture, engineering, and construction. In short, it is an importing tool for bringing the data from an external design software into Unreal Engine (Susi, 2022).



.Fig 23. *Datasmith import process (Unreal Engine documentation 2021)*

Step 2: Unreal Engine Integration:

The exported 3D model is seamlessly integrated into the Unreal Engine environment. Unreal Engine's robust capabilities for handling complex 3D assets make it an ideal platform for the virtual reality presentation.

Step 3: Asset Optimization:

Within Unreal Engine, architects and designers further optimize assets, taking advantage of Unreal Engine's capabilities for enhancing textures, materials, and object interactions to ensure optimal performance in the virtual reality environment.

Facilitating Immersive Experiences:

The process of importing the 3D model to Unreal Engine serves as a conduit to delivering immersive experiences and presentations:
Virtual Walk throughs: Unreal Engine enables the creation of virtual walk-throughs, allowing users to navigate and explore the renovated brewery in a highly immersive and interactive manner.

Cognitive walk-through is a method used to identify usability issues by focusing on specific tasks. The method involves taking a set of tasks and performing a task analysis for each one of them. If there are many ways to perform the task this should be included in the task analysis as well as the different steps involved in performing the task (Nilsson, & Wendt, 2010).

Real-Time Interaction: Users can interact with the virtual environment,

examine design details, and even make design choices within the virtual space, offering a unique and participatory experience.

Spatial Understanding: Unreal Engine's spatial mapping capabilities ensure that the virtual reality presentation aligns precisely with the physical conditions of the renovated brewery, enhancing the sense of presence.

Stakeholder Engagement: The immersive nature of the presentation fosters deep stakeholder engagement. Clients, community members, and other stakeholders can experience the project in a tangible and captivating way.

4. 2| User Interface and Navigation Design

A visit to a real building is an investigation and discovery experience, particularly for the first time visitor. Incorporating this routine procedure into a virtual reality walkthrough requires a high level of intuitiveness and usability to guarantee high user engagement.

The literature on the study of how individuals explore environments highlights two ideas that characterize the two primary methods by which people see and comprehend their surroundings and chart paths across them. These techniques are wayfinding and navigation, with some scholars (Taylor et al., 2008) arguing that the former is a subset of the latter (Barneche-Naya & Hernández-Ibáñez, 2023). Bowman claims that the most ubiquitous and frequent interaction job in 3D UIs is navigation.

Usability is more important since the navigation process is secondary and frequently supports other tasks (Bowman et al. 2004). With travel and wayfinding components, navigation is a crucial user behaviour in virtual worlds (LaViola et al., 2017). (Barneche-Naya & Hernández-Ibáñez, 2023).

The physical component of navigation is travel; the cognitive component is wayfinding, which entails building mental models of the environment to categorize, arrange, and associate locations and places in order to determine the best course of action. These mental constructs can differ between individuals and rely on elements like perspective, size, and the spatial complexity of the surrounding world.

Additionally, this process may be influenced by prior experiences (Foo et al., 2005; Maguire et al., 2003; Barneche-Naya & Hernández-Ibáñez, 2023).

Using objects inside the area as references, such as landmarks, milestones, reference points, and even outside tools like maps, is the concept of navigation. Because of structural, cognitive, and visual aspects, such reference points are crucial in drawing the user's attention in any given direction (Balaban et al., 2017; Sorrows & Hirtle, 1999). Therefore, handling these hints correctly might help to enhance the wayfinding procedure. Research on navigation and wayfinding is becoming more and more in demand. In order to better understand wayfinding processes in the real world, several research (Walkowiak et al., 2015; Parsons & Rizzo, 2008; Waller et al., 1998; Wacher, 1995) concentrate on navigating in virtual settings.

According to Vilar et al. (2014), Burgit & Chittaro (2007), Parush & Berman (2004), and others, navigational aids are used to give visual information about the virtual environment so that the user can find their destination. 2D and 3D maps are used to help users better understand multi-story buildings (Li & Giudice, 2013). (Chittaro & Venkataraman, 2006).

Approaches now in use to help with navigation across virtual environments focus on creating intelligent camera control systems that compute partial pathways by taking certain limitations into account (Drucker & Zeltzer, 1994).

In contrast, others focus on the computational analysis of the space to extract the way to follow before presenting the virtual space to the visitor (Elmqvist, et al., 2007). Other approaches focus on avoiding collisions by tracing a path clear of obstacles (Andújar et al., 2004) or making the user move sequentially through a predefined sequence of viewpoints of particular interest (Chittaro et al., 2010). Those approaches have a common intention to provide the user with a path that takes them to specific viewpoints.

When facing the design of a museum installation, there are other essential aspects to consider related to the diverse user profile. Prior experience with virtual settings, such video games, can have a significant impact. Accordingly, a number of studies indicate that those who are used to playing computer games have a superior sense of direction inside the virtual environment (Green & Bavelier, 2006; Spence & Feng, 2010; Smith & Du'Mont, 2009; Murias et al., 2016).

NUI interaction for the architectural walkthrough:

Natural user interfaces, or NUIs, offer novel strategies for promoting imaginative and enjoyable engagement in addition to active participation, claims Price (2003). There are no specific technological or developmental skills needed to interact with these gadgets.

When it comes to NUIs used to disseminate architectural history, controlling the traversal inside virtual worlds without having to deal with physical interfaces has been a difficulty since the first virtual reality installations debuted decades ago.

Some authors, including Bowman et al. , 1998), have noted that interpreting users' natural gestures to infer their intentions might improve and simplify the design and implementation of interaction models inside these virtual environments.

Using depth cameras to detect user movements is standard practice. One of them is Kinect (Zhang, 2012), the well-known depth camera that Microsoft first introduced for the Xbox platform and has been extensively used in research on natural interaction. The Kinect camera measures each visible point in the scene's distance from the device by measuring the time it takes for light pulses to travel to their destination and be detected by a sensor.

With the advent of depth camera technology, developers no longer needed to employ ostensibly physical interfaces to understand the user's stance and motions.

As a result, depth cameras are being used in many other domains nowadays, including virtual museums, virtual archaeology, and architectural visualisation. The greatest solution for controlling user movement in virtual worlds is to employ depth cameras, which require little to no training and don't require physical touch or contact.

Reducing the amount of attention required to control movement is an essential part of the architectural walkthrough experience, as it allows the user to concentrate on appreciating the objects housed within the building, contemplating the building, and enjoying the surrounding scenery (Barneche-Naya & Hernández-Ibáñez, 2023).

4. 3| Realistic Lighting and Texturing

In Unreal Engine, a more complex lighting solution with moveable light sources was added, to make use of Unreal Engine's physically based rendering (PBR) system (Epic Games, 2021).

This means that the way images are rendered is modelled after the light fux in the real world. The result is more accurate and typically more natural-looking. Physically based Materials will work equally well in all lighting environments.

For the objects with Materials applied to them, the Material is used to calculate how light interacts with the surface of that object. The incoming data that is fed to the Material from a range of pictures (textures) and mathematical expressions, as well as from different property settings intrinsic to the Material itself, is used to do these computations (Lindner et al., 2021).

One of the most crucial aspects to master for creating a realistic setting is lighting. Built-in lighting from CPU-based or GPU-based light-masses produces the most lifelike lighting. A fully dynamic lighting setup is also an option, however it degrades the model's aesthetic appeal. On the other hand, if dynamic lighting is used, no additional illumination is required, and the amount of time required to notice lighting changes is negligible. Every modification takes effect right away.

4. 4| Interactive Elements and Dynamic Features

Plowman in his book called "3D Game Design with Unreal Engine 4 and Blender", 2016 expressing that "Blueprint is a visual scripting engine built into the Unreal game engine that allows artists and other non-programmers to program game mechanics and level events without ever looking at a line of code. Most of the basic programming that we will use as a level designer follows the same basic pattern: an Event causes a number of Actions to occur.

For example, to cause a door to open, the event might be that the player walks up to the door, and the actions would be to animate the door to the open position and then close it after a few seconds."

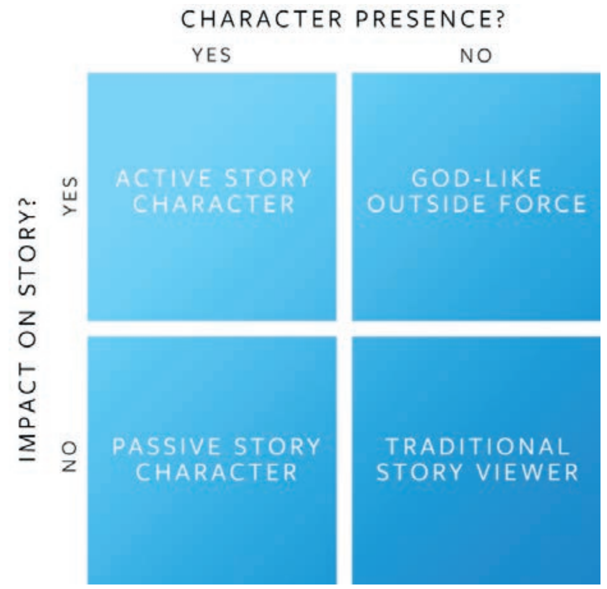
4. 5| User Experience and Interaction

Focusing on creating an immersive and engaging experience need both sensory elements and narrative integration.

Immersive Elements:

Immersive elements are integral to creating a compelling user experience within VR. The design incorporates sensory immersion to engage users on multiple levels (Bowman et al., 2014). Elements such as spatial audio and visual cues contribute to a heightened sense of presence (LaViola Jr et al., 2017). This aligns with principles outlined by Slater and Usoh (1994), emphasizing the importance of perceptual position for enhancing immersion.

The VR environment aims to captivate users visually, with carefully crafted elements that evoke a sense of wonder and interest (McMahan et al., 2012). These immersive elements contribute to a rich and memorable experience.



.Fig 24. *Impact on story (leap motion, 2016)*

Storytelling Elements:

Storytelling in VR tends to take one of four forms, based on whether or not the player exists within the story (embodied character vs. omniscient ghost), and whether they have any impact on the story as it unfolds.

As creators, we are responsible to our users in ways that can be therapeutic, awe-inspiring, or horrifying. We must also come to grips, Kahmke says, with a new approach to narrative. Storytelling has a beginning, middle, and end, but virtual reality involves a shift from time-based narration to spatial narration. From storytelling to world-building. Narrator to creator. Linear to non-linear (Leap motion, 2016).

4. 6| Technical Challenges and Solutions

Mesh count optimization:

Managing the 3D model's complexity, especially given its large mesh count from thorough modelling, was a major problem in the VR production cycle. Mesh count had to be carefully considered to ensure seamless interactivity inside the virtual environment due to Unreal Engine's real-time rendering capabilities, especially when navigating through intricate architectural details. Using the Nanite virtualized geometry technology in Unreal Engine proved to be a ground-breaking fix. Nanite eliminates the requirement for conventional LODs and enables the effective rendering of extremely detailed meshes. This technique guarantees optimal efficiency without sacrificing visual integrity by dynamically adjusting the amount of information dependent on the viewpoint of the user.

Visual quality and frame rate:

The complexity of the architectural layout and the need for a lifelike virtual reality experience frequently exceeded the hardware's full potential, which could cause performance problems during the presentation. As hierarchical instancing renders repetitive elements in the architectural design efficiently, mesh count is further optimized. This method preserved a high level of detail while greatly lowering the processing load.

Frequent testing was crucial for the development process. This required optimizing mesh counts, evaluating the effects of different methods of optimization on performance, and ensuring that the ratio between rendering speed and visual quality remained as ideal as it possibly could. It may be challenging to achieve a high level of visual fidelity in a virtual reality experience, particularly when attempting to strike a balance between the needs of fine details and the limits placed on the hardware.

Ensuring a seamless virtual reality experience requires maintaining a steady and elevated frame rate. The challenge is in balancing the demand for real-time rendering at the target frame rate with the requirement for realism in the visual features. Performance limitations were able to be identified throughout development via detailed analysis and constant frame rate monitoring. This iterative procedure made it easier to modify visual components to preserve optimal frame rates.

Utilizing texture streaming techniques helped optimize the use of high-resolution textures by loading them dynamically based on the viewer's location within the virtual environment. This improved overall performance in addition to the visual quality. Delivering a visually stunning experience across a range of devices without losing performance was challenging because to the disparities in end-user hardware capacity.

Collision:

The application of object collisions is essential to producing a realistic virtual reality experience. The issue is in creating a collision system that works sufficiently to keep virtual objects from colliding while also improving the users' overall perception of realism and immersion when they interact with the architectural space. Creating precise collision meshes that closely match the geometry of virtual objects is fundamental. This involves designing collision models with accuracy to ensure that interactions, such as grasping, pushing, or colliding with objects, align realistically with their visual representation.

Implementing dynamic collision responses based on user interactions enhances realism. For instance, defining how objects react when collided, such as simulating realistic physics interactions, adds a layer of authenticity to the VR environment. It is important to develop the logic for user-object interactions in the collision system. This includes specifying how user-input objects react, making sure that collisions result in the proper visual feedback, and establishing a smooth transition between the virtual and real worlds.

Extending collision considerations beyond object-object interactions to include environmental elements enhances realism. This involves defining how users interact with surfaces, walls, and architectural features to create a cohesive and immersive virtual experience. Utilizing real-time physics simulation engines within Unreal Engine contributes to realistic collision behaviours. This involves leveraging the engine's physics capabilities to calculate object movements, forces, and reactions dynamically based on user interactions.

Blueprint system in Unreal Engine:

Collaborative and interactive VR spaces require intricate handling of the Blueprint system in Unreal Engine. The challenge lies in designing a seamless and intuitive interactive experience for users within the virtual environment while ensuring that collaborative elements synchronize effectively among multiple participants.

In-depth knowledge of Blueprint scripting within Unreal Engine is essential. This involves creating custom scripts to enable interactive elements, define collaborative actions, and manage the synchronization of these actions in real-time. Integrating a user-friendly interface within the VR space enhances collaboration. Blueprint scripting allows the creation of interactive menus, tool-tips, and communication tools that facilitate seamless interaction among users navigating the virtual environment.

Blueprint scripting allows for the creation of dynamic object manipulation, enabling users to interact with and modify virtual elements collaboratively. This could include features like moving objects, adjusting parameters, or annotating specific areas of the architectural model. Continuous testing of the Blueprint scripts in a collaborative setting, coupled with feedback from users, enables refinement and improvement. This iterative process ensures that the collaborative and interactive elements meet user expectations and operate seamlessly.

Heuristic evaluation:

Heuristic Evaluation is a method which aims to identify weak design and usability problems in a specific user interface. It is beneficial to use heuristic evaluation several times during the design process since issues can be eliminated before each release making other issues easier to detect in the following evaluation.

A heuristic evaluation of the software should be done by more than one person, since persons often discovers different usability problems. Jakob Nielsen recommends that around three to four persons should perform the method as this provides the highest efficiency/cost ratio; with four evaluators it's estimated that 70% of the (Haik et al., 2002) problems are discovered. Due to this fact, heuristic evaluation is often considered a very cost effective way to discover usability problems.

Heuristic evaluation can be performed in two different ways. One way is

to have a single evaluator following an evaluation checklist and taking notes. The other is when a user experiments with the software under the supervision of an observer. The observer tries to identify potential problems during the testing session. The main difference between this method and the User interview method is that the user is allowed to ask questions. This is since, if the user's questions are answered, it will often grant an understanding of the user interface and save precious testing time.

The incoming data that is fed to the Material from a range of pictures (textures) and mathematical expressions, as well as from different property settings intrinsic to the Material itself, is used to do these computations (Lindner et al., 2021).

Jakob Nielsen's list of heuristics (Nielsen, 1995) is as follows:

Visibility of system status: The system must constantly update users on developments by providing pertinent feedback in a timely manner.

System-to-real world alignment: Instead of using terminology exclusive to the system, the system should communicate in terms that the user understands, using words, phrases, and concepts that they are acquainted with. Observe norms from the actual world and arrange the material in a logical and natural arrangement.

User control and freedom: When users inadvertently choose system functions, they will require a "emergency exit" that is clearly defined so they can quit the undesirable condition without enduring a protracted debate. In favour of undo and redo.

Recognition instead of recall: Reduce the amount of information the user must remember by making options, actions, and objects apparent. From one section of the chat to the next, the user shouldn't have to recall facts. The system's operating instructions need to be readily apparent or accessible when needed.

5 Comparative Analysis

5|

5. 1| VR vs. Traditional Architectural Presentations:

High-quality architectural renderings have served as an essential component of any effective presentation. However, new technologies are introduced and old ones get upgraded every year _ cutting costs, improving the quality and efficiency of work. In this case, virtual reality quickly emerged as one of the most potent immersive visual mediums available today. Entertainment industries were quick to adopt VR _ and regard it as their future. Similarly, other industries have taken notice of this incredible equipment, including architecture. The growing accessibility of virtual reality has created plenty of possibilities for project presentation.

High-Quality Architectural Renderings Vs. VR: Best Option For Presentations:

Cons:
Need To Hire Programmers To Produce VR Programs
While 3D models and scenes can be provided by architectural rendering companies, the virtual reality program actually is created by skilled programmers. It's far from an easy job, since they have to account for a lot of factors, such as person-object interactions and so on.

Long Production Time And High Costs:

This is the reason why, even for large teams of specialists, developing VR software can take several months. The expense is undeniable since a company must hire multiple outsourcing firms or maintain a large staff of programmers and 3D artists in-house to create virtual reality applications.

Pros:
Provides Unparalleled Immersion
Seeing objects on a screen is one thing, but being able to see them as if they were real, touch or fiddle around with your hands is something completely different. There is no way that a potential customer would ignore creative architectural and design concepts after such an encounter!

Showcases Goods In Any Environment:

Virtual reality programs can present experience of visiting a different place with different surroundings _ clients can literally feel how the environment fits in their life, thanks to the architectural presentation reinforced by VR. This amazing feature especially shines when shows both interior and exterior _ to provide a full understanding of the future house design.
High-Quality Architectural Renderings

Cons:
Companies Specialize In Different Object Visualization
When talking about different outsource 3D modelling and rendering services, there is no "one size fits all" principle. Every studio has a different area of expertise when it comes to objects and styles, and each render it creates has its own special characteristics. So employers have to be careful when looking for the right studio and always browse portfolios of potential contractors before choosing.

Actual Quality Depends On Professionalism Of Specialists
"High-quality architectural renderings" is a very wide definition. There are standards that any CGI studio has to adhere to, but results depend largely on how experienced 3D artists working on the projects are. Obviously, companies tend to pick the most professional specialists for important tasks _ but it's unlikely a mediocre company has a lot of outstanding staff to turn a project into an eye candy.

Pros:
Faster And Cheaper
Static CGI is much cheaper and faster to produce than advanced flexible models for VR. High-quality architectural renderings make any design look stunning because they are simpler to customize and enhance with effects.

Basic Animation Can Increase Effectiveness
For better effectiveness of project presentations, it's a good idea to combine static and animated high-quality architectural renderings. Virtual tours and 3D animations will make materials more informative and visually appealing, giving more opportunities to explore the design as if in real life.

Viewing Available On All Gadgets
To put it simply, high-quality architectural renderings are pictures that

can be purchased in any common file format, such as jpeg, png, pdf, etc. Such flexibility is quite useful _ everybody has gadgets, and they can download images at any time. So after a presentations on a large screen, clients can have a second viewing at home on their PCs or Macs or while commuting _ on their smartphones, inspecting constructions closely for themselves (Prus, 2018).

5. 2| Advantages and Limitations of VR Implementation:

Many generations of Architects were taught to work only with moodboards and drawings. Unfortunately, academic progress is never fully caught up with education. It is therefore not surprising that architects consider virtual reality to be a super-technological game. Very fun, but rather useless.

Meanwhile, VR can improve the work-flow and make the communication with client effective (Prus, 2017).

VR is a relatively new technology that has been used in a wide range of fields, such as education, design, and gaming, among other fields (Cipresso, 2018).

Application and benefits of VR in the design process:

VR is a visualization tool in the field of architecture (Woksepp, 2007). Virtual reality (VR) provides greater insight and information which promotes the design process, particularly in decision-making. Virtual reality is utilized in several stages of the design process. In contrast to more traditional methods of representation, technology is used in the early stages of the design process to inspect and better understand aspects like form and colour. (Bergman, 2017).

The same applies for later design stages where minor details are chosen. Currently, design concepts are also communicated to co-workers and other project participants through VR (Bergman, 2017). Using the technology during the design phase has a number of advantages. Gaining a deeper comprehension of the final product is one of them. Better decision-making is thus made possible, and time and money can be preserved (Bergman, 2017). In addition to providing depth perception and scale understanding, VR models are also easily modifiable (Zikic, 2007).

VR creating depth perception:

The basic way that VR devices create the illusion of depth is by having each eye see the same picture from a slightly different angle, this is called "stereoscopic display" (Jamiy et al., 2019). There are various ways to accomplish this, but the most common one _ which this study will look at _ is by using a head-mounted display, or HMD. Where two screens display different images to each eye while the viewer wears an eye-covering headset.

To make the screens larger, the headset also includes magnifying lenses. (Henry ,1992). Some of the cues for binocular vision are replicated by this method. However, this approach is not flawless since it does not faithfully replicate every visual cue and may cause discomfort for the user due to expertise (Jamiy et al., 2019).

Hardware and software requirements for using VR in architecture:

VR is a technology that allows for users to freely navigate a virtual three-dimensional environment and interact with virtual objects in real time (Woksepp, 2007). According to Woksepp (2007), a virtual environment (VE) can be experienced by using different methods that come with varying degrees of immersion.

This includes typical computer monitors, head-mounted displays for "fully immersive experiences," and a 3D stereoscopic display.

The HMD based VR systems incorporate a headset that functions as both an input and output device at the same time. Inputs for the headset include head motion tracking sensors, gyroscopes, and accelerometers (Renganayagalu et al., 2021).

The system also usually includes input devices such as gloves, or regular gaming controllers, and sensors that track the position of both the headset and the controllers. The simulation is ran by some type of computer that sends an output in the form of sounds and images to the two screens in the headset (Renganayagalu et al., 2021).

Current challenges facing VR in architecture:

Dashti & Vasques (2020) state that organizational and financial issues prevail in the VR industry's challenges in architecture and, in general, the AEC sector. Managers generally don't know much about virtual reality (VR) and think the technology is too expensive. Additionally, feel that the technology is still too immature to be widely applied in those sectors (Dashti & Vasques, 2020).

VR implementation necessitates the purchase of new hardware and software because it is an emerging technology. This includes a computer strong enough to run virtual reality software in addition to the headset, controllers, and tracker (Norlund & Rask, 2016). Motion sickness is another issue, as is the need for employees to receive VR usage training. The strength and occurrence rate of motion sickness depends partially on the screens refresh rate and screen resolution (Norlund & Rask, 2016) (Al-Falahi, 2022).

The Future of Virtual Reality:

Virtual reality and enhanced reality platforms have an infinite future. The development and application of this technology are still in their infancy. VR technologies will soon be on level with office email communication.

This technology will be a crucial part of the design process, not just a tool for the project. Beyond just the design aspect, this technology will help to improve quality control parameters, collaborate more effectively, accelerate construction, and give a more seamless overall client experience.

VR has the potential to either greatly enhance or completely replace your current marketing strategies. While it may be an option now, virtual reality will soon be necessary.

VR allows designers and end users to collaborate in a way that was previously impossible. VR is also increasing rapidly in architecture design. Virtual reality can alter the design of buildings by architects and how better they "take" customers (Sahu, 2021).

5. 3| Summary of Achievements:

Throughout the course of this thesis project, significant milestones were achieved, marking a pioneering exploration into the realms of architectural restoration and immersive virtual reality (VR) experiences. The adaptation of advanced technologies, including point cloud scanning, 3D modelling, and VR visualization, culminated in a transformable process that redefined the conventional boundaries of architectural presentation. The primary achievement lies in successfully merging point cloud survey data into a Building Information Modelling (BIM) format, employing Unreal Engine to craft a dynamic and interactive VR presentation of an abandoned brewery in Pordenone as a case study.

The utilization of Unreal Engine's powerful capabilities allowed for the creation of a VR file that serves as the centrepiece of the architectural restoration journey. This achievement showcases the current state of the project, also incorporates proposed design changes, enabling stakeholders to immerse themselves in a virtual space where architectural concepts come to life. The careful attention to detail in optimizing the scene based on hardware capacities, coding interactive elements using the Blueprint section, and implementing real-time synchronization of BIM data represents a commendable technical feat.

Furthermore, the project's academic foundation is solidified by an extensive review of relevant literature, incorporating insights from studies on immersive virtual reality, mixed reality displays, and the application of VR in architecture, engineering, and construction. The synthesis of theoretical knowledge with practical application reinforces the scholarly contribution of this thesis.

5. 4| Closing Remarks:

In conclusion, this thesis stands as a testament to the potential of VR technologies in reshaping architectural practices and presentations. The fusion of point cloud data acquisition survey, BIM modelling, and VR visualization not only provides a cutting-edge approach to architectural documentation but also offers a novel avenue for engaging stakeholders. The case study of the abandoned brewery serves as a tangible demonstration of the project's outcomes, illustrating the power of VR in conveying design ideas and facilitating immersive experiences.

As we reflect on the challenges overcome, from mesh optimization to collaborative Blueprint scripting, it becomes evident that this endeavour has not only contributed to the field of architecture but has also pushed the boundaries of what is achievable in virtual reality. The synthesis of academic research with hands-on application has resulted in a comprehensive exploration that addresses both theoretical underpinnings and practical considerations in the realm of VR-based architectural restoration.

This thesis serves as a stepping stone for future research endeavours in the intersection of technology and architecture. The innovative use of Unreal Engine, coupled with advancements in point cloud survey techniques, opens avenues for further exploration and refinement of VR applications in architectural design and restoration. In essence, this project marks not just the culmination of a thesis but the beginning of a transformable journey into the immersive and dynamic future of architectural visualization.

6

Refrences:

Bibliography:

Advisory Excellence. (2023, July 20). *Virtual Reality: Unraveling the Boundaries of the Future.* Retrieved August 25, 2023, from https://www.advisoryexcellence.com/virtual-reality-unravelling-the-boundaries-of-the-future/.
Al-Falahi, A. (2022). Virtual Reality in Architecture: Technical limitations, solutions and future use.

Al-Kodmany, K. (2002). *Visualization tools and methods in community planning: from freehand sketches to virtual reality*. Journal of planning Literature, 17(2), 189-211.

Andújar, C., Vázquez, P., & Fairén, M. (2004, September). *Way-finder: Guided tours through complex walkthrough models*. In Computer Graphics Forum (Vol. 23, No. 3, pp. 499-508). Oxford, UK and Boston, USA: Blackwell Publishing, Inc.

Balaban, C. Z., Karimpur, H., Röser, F., & Hamburger, K. (2017). *Turn left where you felt unhappy: How affect influences landmark-based wayfinding*. Cognitive processing, 18, 135-144.

Barneche-Naya, V., & Hernández-Ibáñez, L. A. (2023). *Assisted navigation for digital architectural walkthroughs in Natural User Interface-based installations*. Universal Access in the Information Society, 1-15.

Berg, L. P., & Vance, J. M. (2017). *An industry case study: investigating early design decision making in virtual reality.* Journal of Computing and Information Science in Engineering, 17(1), 011001.

Bergman, E. (2019). *Framtidens teknik för arkitekter: En studie om hur VR kan integreras på arkitektkontoret.*

Boton, C. (2018). *Supporting constructibility analysis meetings with Immersive Virtual Reality-based collaborative BIM 4D simulation*. Automation in Construction, 96, 1-15.

Bowman, D. A., Koller, D., & Hodges, L. F. (1998). *A methodology for the evaluation of travel techniques for immersive virtual environments.* Virtual reality, 3(2), 120-131.

Bruno, F., Bruno, S., De Sensi, G., Luchi, M. L., Mancuso, S., & Muzzupappa, M. (2010). *From 3D reconstruction to virtual reality: A complete* *methodology for digital archaeological exhibition.* Journal of Cultural Heritage, 11(1), 42-49.

Burigat, S., & Chittaro, L. (2007). *Navigation in 3D virtual environments: Effects of user experience and location-pointing navigation aids.* International Journal of Human-Computer Studies, 65(11), 945-958.

Caterina Tiazzoldi. (n.d.). *Toolbox.* ArchDaily. Retrieved from https://www.archdaily.com/81630/toolbox-caterina-tiazzoldi

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). *The past, present, and future of virtual and augmented reality research: a network and cluster analysis of the literature.* Frontiers in psychology, 2086.

Dashti, B., & Viljevac-Vasquez, R. (2020). *Exploring Use and Perception of Augmented-and Virtual Reality in the Swedish AEC Industry.*

d'Cruz, M., Patel, H., Lewis, L., Cobb, S., Bues, M., Stefani, O., ... & Cappitelli, M. (2014, March). VR-HYPERSPACE _ *The innovative use of virtual reality to increase comfort by changing the perception of self and space.* In 2014 IEEE Virtual Reality (VR) (pp. 167-168). IEEE.

De Paolis, L. T., Bourdot, P., & Mongelli, A. (Eds.). (2017). *Augmented Reality, Virtual Reality, and Computer Graphics*: 4th International Conference, AVR 2017, Ugento, Italy, June 12-15, 2017, Proceedings, Part I (Vol. 10324). Springer.

Delgado, J. M. D., Oyedele, L., Demian, P., & Beach, T. (2020). *A research agenda for augmented and virtual reality in architecture, engineering and construction.* Advanced Engineering Informatics, 45, 101122.

Drucker, S. M., & Zeltzer, D. (1994, May). *Intelligent camera control in a virtual environment.* In Graphics Interface (pp. 190-190). Canadian Information Processing Society.

Dunston, P. S., Arns, L. L., Mcglothlin, J. D., Lasker, G. C., & Kushner, A. G. (2011). *An immersive virtual reality mock-up for design review of hospital patient rooms.* Collaborative design in virtual environments, 167-176.

El Jamiy, F., & Marsh, R. (2019). *Survey on depth perception in head mounted displays:* distance estimation in virtual reality, augmented reality, and mixed reality. IET Image Processing, 13(5), 707-712.

Elmqvist, N., Tudoreanu, M. E., & Tsigas, P. (2007, November). *Tour generation for exploration of 3d virtual environments.* In Proceedings of the 2007 ACM symposium on Virtual reality software and technology (pp. 207-210).

Epic Games (2021) *Unreal Engine API 4.26 Documentation.* https:// docs.unrealengine.com/4.26/en-US/API/.

Festini-Wendorff, M. A., & Shiguihara-Juárez, P. N. (2016, October). *Developing a videogame using unreal engine based on a four stages methodology.* In 2016 IEEE ANDESCON (pp. 1-4). IEEE.

Foo, P., Warren, W. H., Duchon, A., & Tarr, M. J. (2005). *Do humans integrate routes into a cognitive map? Map-versus landmark-based navigation of novel shortcuts.* Journal of Experimental Psychology: Learning, Memory, and Cognition, 31(2), 195.

Guo, Y., Wang, H., Hu, Q., Liu, H., Liu, L., & Bennamoun, M. (2020). *Deep learning for 3d point clouds: A survey.* IEEE transactions on pattern analysis and machine intelligence, 43(12), 4338-4364.

Haik, E., Barker, T., Sapsford, J., & Trainis, S. (2002, February). *Investigation into effective navigation in desktop virtual interfaces.* In Proceedings of the seventh international conference on 3D Web technology (pp. 59-66).

Henry, D., & Furness, T. (1993, September). *Spatial perception in virtual environments: Evaluating an architectural application.* In Proceedings of IEEE virtual reality annual international symposium (pp. 33-40). IEEE.

Hilfert, T., & König, M. (2016). *Low-cost virtual reality environment for engineering and construction.* Visualization in Engineering, 4(1), 1-18.

James Leslie, *What is Point Cloud survey*: accessed June 19, 2023, from https://dronesurveyservices.com/what-is-a-point-cloud/

Jayawardena, A. N., & Perera, I. (2016, September). *A framework for mixed reality application development: a case study on Yapahuwa archaeological site.* In 2016 Sixteenth International Conference on Advances in ICT for Emerging Regions (ICTer) (pp. 186-192). IEEE.

Juan, Y. K., Chen, H. H., & Chi, H. Y. (2018). *Developing and evaluating* *a virtual reality-based navigation system for pre-sale housing sales*. Applied Sciences, 8(6), 952.

Kini, V. G., & Sunil, S. (2019, November). *Design and realization of sustainable rural housing using immersive virtual reality platform.* In Proceedings of the 25th ACM Symposium on Virtual Reality Software and Technology (pp. 1-11).

Kjems, E. (2005). VR applications in an architectural competition: *Case: House of Music in Aalborg.* In Realitat Virtual a l'Arquitectura i la Construcció: Taller 2 (pp. 47-58). Khora II.

Kose, A., Petlenkov, E., Tepljakov, A., & Vassiljeva, K. (2017). *Virtual reality meets intelligence in large scale architecture.* In Augmented Reality, Virtual Reality, and Computer Graphics: 4th International Conference, AVR 2017, Ugento, Italy, June 12-15, 2017, Proceedings, Part II 4 (pp. 297-309). Springer International Publishing.

LaViola Jr, J. J., Kruijff, E., McMahan, R. P., Bowman, D., & Poupyrev, I. P. (2017). *3D user interfaces: theory and practice*. Addison-Wesley Professional.

Li, H., & Giudice, N. A. (2013, November). *The effects of 2D and 3D maps on learning virtual multi-level indoor environments*. In Proceedings of the 1st ACM SIGSPATIAL International Workshop on MapInteraction (pp. 7-12).

Lin, Y. C., Chen, Y. P., Yien, H. W., Huang, C. Y., & Su, Y. C. (2018). *Integrated BIM, game engine and VR technologies for healthcare design: A case study in cancer hospital*. Advanced Engineering Informatics, 36, 130-145.

Liu, F., & Kang, J. (2018). *Relationship between street scale and subjective assessment of audio-visual environment comfort based on 3D virtual reality and dual-channel acoustic tests*. Building and Environment, 129, 35-45.

James Leslie, *What is Point Cloud survey*: accessed June 19, 2023, from https://dronesurveyservices.com/what-is-a-point-cloud/
Juan, Y. K., Chen, H. H., & Chi, H. Y. (2018). *Developing and evaluating a virtual reality-based navigation system for pre-sale housing sales*. Applied Sciences, 8(6), 952.

Chapter 7
| 2023-24

MTC, 2017. *VR, AR and MR discovery project*.

Maguire, E. A., Spiers, H. J., Good, C. D., Hartley, T., Frackowiak, R. S., & Burgess, N. (2003). *Navigation expertise and the human hippocampus: a structural brain imaging analysis*. Hippocampus, 13(2), 250-259.

Manikas, K., & Hansen, K. M. (2013). *Software ecosystems-A systematic literature review*. Journal of Systems and Software, 86(5), 1294-1306.

Martin, S. (2013). *Archeologia industriale a Pordenone : il caso dell'ex birreria Società Anonima Pordenone : un edificio, una storia, un progetto: tesi magistrale in Architettura*. Università degli studi.

Matilde. (n.d.). Retrieved from https://matilde.it/?fbclid=IwAR3mO74slj _ OeVHrAoYrkFjvTY3-gJwFcCoidcfbHISsaL0W0O3z8aaetFs

McMahan, R. P., Bowman, D. A., Zielinski, D. J., & Brady, R. B. (2012). *Evaluating display fidelity and interaction fidelity in a virtual reality game*. IEEE transactions on visualization and computer graphics, 18(4), 626-633.

Meines, S. (2023). LuminaCity: *a Real-Time Daylight Analysis Tool for Architectural and Urban Development Using Unreal Engine*.

Milgram, P., & Colquhoun, H. (1999). *A taxonomy of real and virtual world display integration*. Mixed reality: Merging real and virtual worlds, 1(1999), 1-26.

Motamedi, A., Wang, Z., Yabuki, N., Fukuda, T., & Michikawa, T. (2017). *Signage visibility analysis and optimization system using BIM-enabled virtual reality (VR) environments*. Advanced Engineering Informatics, 32, 248-262.

Natephra, W., Motamedi, A., Fukuda, T., & Yabuki, N. (2017). *Integrating building information modelling and virtual reality development engines for building indoor lighting design*. Visualization in Engineering, 5(1), 1-21.

Ng, A., & Huang, Q. (2010). *Multiple phase wireless capsule endoscopic image frames reconstruction*. Signal Processing, 90(4), 1212-1222.

Nguyen, M. T., Nguyen, H. K., Vo-Lam, K. D., Nguyen, X. G., & Tran, M.

T. (2016). *Applying virtual reality in city planning. In Virtual, Augmented and Mixed Reality*: 8th International Conference, VAMR 2016, Held as Part of HCI International 2016, Toronto, Canada, July 17-22, 2016. Proceedings 8 (pp. 724-735). Springer International Publishing.

Nilsson, M., & Wendt, F. (2010). *Virtual Reality Application User Interface-Design and Implementation of controls for navigation in a Virtual Reality application.*

Nielsen, J., & Molich, R. (1990, March). *Heuristic evaluation of user interfaces.* In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 249-256).

Nielsen, J. (1995). *How to conduct a heuristic evaluation.* Nielsen Norman Group, 1(1), 8.

Nilsson, M., & Wendt, F. (2010). V*irtual Reality Application User Interface-Design and Implementation of controls for navigation in a Virtual Reality application.*

Parsons, T. D., & Rizzo, A. A. (2008). *Initial validation of a virtual environment for assessment of memory functioning: virtual reality cognitive performance assessment test.* CyberPsychology & Behaviour, 11(1), 17-25.

Parush, A., & Berman, D. (2004). *Navigation and orientation in 3D user interfaces: the impact of navigation aids and landmarks.* International journal of human-computer studies, 61(3), 375-395.

Parsons, T. D., & Rizzo, A. A. (2008). I*nitial validation of a virtual environment for assessment of memory functioning: virtual reality cognitive performance assessment test*. CyberPsychology & Behaviour, 11(1), 17-25.

Price, S., Rogers, Y., Scaife, M., Stanton, D., & Neale, H. (2003). *Using 'tangibles' to promote novel forms of playful learning.* Interacting with computers, 15(2), 169-185.

Prus, I. (2017, April 20). *VR for Architecture Presentation*. Retrieved from https://archicgi.com/architecture/vr-for-architecture-presentation/

Prus, I. (2018, May 24). *High-Quality Architectural Renderings vs. Vr: Which Will Dominate Presentations In The Future?*

Plowman, J. (2016). *3D Game Design with Unreal Engine 4 and Blender*. Packt Publishing Ltd.

Raj, T., Hanim Hashim, F., Baseri Huddin, A., Ibrahim, M. F., & Hussain, A. (2020). *A survey on LiDAR scanning mechanisms*. Electronics, 9(5), 741.

Renganayagalu, S. K., Mallam, S. C., & Nazir, S. (2021). *Effectiveness of VR head mounted displays in professional training: A systematic review.* Technology, Knowledge and Learning, 1-43.

Roach, D. M., & Demirkiran, I. (2017, September). *Computer-aided drafting virtual reality interface*. In 2017 IEEE/AIAA 36th Digital Avionics Systems Conference (DASC) (pp. 1-13). IEEE.

Rowen, A., Grabowski, M., Rancy, J. P., & Crane, A. (2019). *Impacts of Wearable Augmented Reality Displays on operator performance, Situation Awareness, and communication in safety-critical systems*. Applied ergonomics, 80, 17-27.

Sanchez, G. M. E., Van Renterghem, T., Sun, K., De Coensel, B., & Botteldooren, D. (2017). *Using Virtual Reality for assessing the role of noise in the audio-visual design of an urban public space*. Landscape and Urban Planning, 167, 98-107.

Sanchez-Vives, M. V., & Slater, M. (2016). *Enhancing our lives with immersive virtual reality*. Frontiers in Robotics and AI, 3, 74.

Sahu, M. (2021, July 15). *Virtual Reality in Architecture: Role and Benefits*. Retrieved from https://www.analyticssteps.com/blogs/virtual-reality-architecture-role-and-benefits/

Smith, S. P., & Du'Mont, S. (2009, March). *Measuring the effect of gaming experience on virtual environment navigation tasks*. In 2009 IEEE symposium on 3D user interfaces (pp. 3-10). IEEE.

Sorrows, M. E., & Hirtle, S. C. (1999). *The nature of landmarks for real and electronic spaces. In Spatial Information Theory*. Cognitive and Computational Foundations of Geographic Information Science: International Conference COSIT'99 Stade, Germany, August 25-29, 1999 Proceedings 4 (pp. 37-50). Springer Berlin Heidelberg.

Spence, I., & Feng, J. (2010). *Video games and spatial cognition*. Review of general psychology, 14(2), 92-104.

Sun, L., Tan, W., Ren, Y., Ji, X., Wang, Z., & Li, P. (2020). R*esearch on visual comfort of underground commercial streets' pavement in China on the basis of virtual simulation.* International Journal of Pattern Recognition and Artificial Intelligence, 34(03), 2050005.

Susi, J. (2022). *Interactive Architectural Visualization using Unreal Engine.*

Taylor, H. A., Brunyé, T. T., & Taylor, S. T. (2008). Spatial mental representation: implications for navigation system design. Reviews of human factors and ergonomics, 4(1), 1-40.

Torres-Ferreyros, C. M., Festini-Wendorff, M. A., & Shiguihara-Juárez, P. N. (2016, October). *Developing a videogame using unreal engine based on a four stages methodology*. In 2016 IEEE ANDESCON (pp. 1-4). IEEE.

Virtual Reality: Unraveling the Boundaries of the Future. (2023, July 20). Advisory Excellence. Retrieved August 25, 2023, from https://www.advisoryexcellence.com/virtual-reality-unravelling-the-boundaries-of-the-future/.

Vilar, E., Rebelo, F., & Noriega, P. (2014). *Indoor human wayfinding performance using vertical and horizontal signage in virtual reality*. Human Factors and Ergonomics in Manufacturing & Service Industries, 24(6), 601-615.

Walkowiak, S., Foulsham, T., & Eardley, A. F. (2015). *Individual differences and personality correlates of navigational performance in the virtual route learning task*. Computers in Human Behaviour, 45, 402-410.

Waller, D., Hunt, E., & Knapp, D. (1998). *The transfer of spatial knowledge in virtual environment training*. Presence, 7(2), 129-143.

Walmsley, A. P., & Kersten, T. P. (2020). *The IMPERIAL Cathedral in Königslutter (Germany) as an immersive experience in virtual reality with integrated 360 panoramic photography*. Applied Sciences, 10(4), 1517.
Wang, R. (2013). *3D building modelling using images and LiDAR: A review.* International Journal of Image and Data Fusion, 4(4), 273-292.

Wang, R., Peethambaran, J., & Chen, D. (2018). *LiDAR point clouds to 3-D urban models $: $ A review*. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 11(2), 606-627.

Wigmore, I. (2016, August). *Immersive Virtual Reality (Immersive VR). TechTarget*. Retrieved from https://www.techtarget.com/whatis/definition/immersive-virtual-reality-immersive-VR

Willett, W., Jansen, Y., & Dragicevic, P. (2016). *Embedded data representations*. IEEE transactions on visualization and computer graphics, 23(1), 461-470.

Witmer, B. G., Bailey, J. H., Knerr, B. W., & Abel, K. (1995). *Training dismounted soldiers in virtual environments: Route learning and transfer.* Army Research Institute Technical Report, 1022.

Woksepp, S. (2007). Virtual reality in construction: tools, methods, and processes (Doctoral dissertation, Luleå tekniska universitet).

Xia, S. A. (2013). *Design and implementation of campus 3D virtual walkthrough system-take Hunan Science and Technology University as an example*. Applied Mechanics and Materials, 268, 1926-1929.

Xiao, A., Huang, J., Guan, D., Cui, K., Lu, S., & Shao, L. (2022). *Polarmix: A general data augmentation technique for LiDAR point clouds*. Advances in Neural Information Processing Systems, 35, 11035-11048.

Zhang, Z. (2012). *Microsoft Kinect sensor and its effect*. IEEE multimedia, 19(2), 4-10.

Zikic, N. (2007). *Evaluating relative impact of VR components screen size, stereoscopy and field of view on spatial comprehension and presence in architecture*.

Image Credits

Fig. 01. *Augmented Reality - Architectural Presentations*. Uniqueat. https://uniqueat.com/augmented-reality/
Fig. 02. Delgado, J. M. D., Oyedele, L., Demian, P., & Beach, T. (2020). *AR and VR cases in the AEC sectors and their estimated levels of adoption (see Section 4.2). The plots indicate the level of adoption in projects*

for the given use-case (1 = not used, 2 = early testing, 3 = basic implementation, 4 = partially used, 5 = fully implemented). Advanced Engineering Informatics, 45, 101122.
Fig. 03. Delgado, J. M. D., Oyedele, L., Demian, P., & Beach, T. (2020). *AR and VR general levels of adoption, expertise, implementation levels and future investment.* Advanced Engineering Informatics, 45, 101122.
Fig. 04. Delgado, J. M. D., Oyedele, L., Demian, P., & Beach, T. (2020). *Levels of adoption of Virtual Reality for the six use-cases defined in the AEC sector. Note that "fully implemented" only was recorded for design support and training.* Advanced Engineering Informatics, 45, 101122.
Fig. 05. Kose, A., Petlenkov, E., Tepljakov, A., & Vassiljeva, K. (2017). Process of the application. In Augmented Reality, Virtual Reality, and Computer Graphics: 4th International Conference, AVR 2017, Ugento, Italy, June 12-15, 2017, Proceedings, Part II (p. 300). Springer International Publishing.
Fig. 06. (n.d.). *Different components of Unreal Engine.*
Fig. 07. Unreal Engine. (n.d.). *Realistic Physical Lighting in Unreal.* Retrieved from https://www.unrealengine.com/en-US/explainers/ray-tracing/what-is-real-time-ray-tracing
Fig. 08. Akenine-Moöller, T., Haines, E., & Hoffman, N. (2018). *A Shot from Forza Motorsport 7.* In Real-Time Rendering, Fourth Edition. A K Peters/CRC Press. https://doi.org/10.1201/b22086
Fig. 09. Akenine-Moöller, T., Haines, E., & Hoffman, N. (2018). *The city of Beauclair rendered in The Witcher 3. (CD PROJEKT® , The Witcher® are registered trademarks of CD PROJEKT Capital Group. The Witcher game © CD PROJEKT S.A. Developed by CD PROJEKT S.A. All rights reserved.* In Real-Time Rendering, Fourth Edition. A K Peters/CRC Press. https://doi.org/10.1201/b22086
Fig. 10. Eckop. (n.d.). Light Detection and Ranging. Retrieved from https://www.eckop.com/applications/light-source-measurement/
Fig. 11. Archivio Storico Comunale di Pordenone. (Invalid date). Archival Image from Faldone.
Fig. 12. Google. (2023). *Google Map of 33170 Pordenone, PN.* Google Earth. Retrieved from https://www.google.it/maps/@45.963745,12.663432,224m/data=!3m1!1e3?entry=ttu
Fig. 13. Archivio Storico Comunale di Pordenone. *Brewery Image back in 1939* (1939). Archival Image from Faldone 02.1117, Category 8.4.
Fig. 14. Archivio Storico Comunale di Pordenone. *Brewery Image back in 1939* (1939). Archival Image from Faldone 02.1117, Category 8.4.
Fig. 15. Tonero, M., Zamborlini, B., & D'Annunzio, S. (2023). *Postcard 1989, taken from the report by Studio Raffin.*
Fig. 16. *Brewery position map date back in 1940/1970.* Archivio Storico

Comunale di Pordenone. (Invalid date)
Fig. 17. *Brewery position map date back in 1940/1970.* Archivio Storico Comunale di Pordenone. (Invalid date)
Fig. 18. Mehdizadeh, M. (*2023*), *Current situation of the brewery _ July 10th 2023*.
Fig. 19. Mehdizadeh, M. (*2023*), *Point cloud dataset of the brewery.*
Fig. 20. Mehdizadeh, M. (*2023*), *Mesh generation of the brewery.*
Fig. 21. Toolbox Coworking. (n.d.). Graphic from Explore Toolbox. Retrieved from https://toolboxcoworking.com/en/explore-toolbox
Fig. 22. Edit Brewing. (n.d.). Retrieved from https://www.editbrewing.com/
Fig. 23. *Unreal Engine. (2021). Datasmith Import Process. Retrieved from Unreal Engine documentation.*
Fig. 24. Leap Motion. (2016). Impact on Story. Retrieved from Leap Motion documentation or source.

At the End, I thank all the ones who helped me throughout this journey!

Sina Mehdizadeh

02.12.2023