Univerza *v Ljubljani*
Fakulteta *za gradbeništvo in geodezijo*

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ARCHITECTURALLY DRIVEN BIM PROCESSES WITH PRACTICAL EXPLORATIONS

BIM-VODENI ARHITEKTURNI PROCESI S PRAKTIČNIMI PRIMERI

BIM A+ European Master in Building Information Modelling

Master thesis No.:

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Ljubljana, 2023

Co-funded by the Erasmus+ Programme of the European Union

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BIBLIOGRAFSKO – DOKUMENTACIJSKA STRAN IN IZVLEČEK

UDK: **004.946:72(043.3)**

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Naslov: **BIM-vodeni arhitekturni procesi s praktičnimi primeri**

Tip dokumenta: **Magistrsko delo**

Obseg in oprema: **91 str., 48 sl., 0 pregl**

Ključne besede: **bim, arhitekturno načrtovanje, implementacija bim, vizualizacija, renderiranje, arhitekturni natečaj**

Izvleček:

Naloga raziskaije vlogo BIM v arhitekturni praksi, pri čemer poudarja njegovo identiteto kot metodologijo, ki se osredotoča na optimizacijo delovnih procesov bolj kot na ustvarjalni proces. Navkljub transformativnemu potencialu BIM ostaja velik izziv, kako narediti BIM bolj privlačen za arhitekte in druge projektante? Pri tem je pomembno, da presodimo in izboljšamo načrtovalska orodja. BIM vnaša korenite spremembe v arhitekturno načrtovanje z usmerjanjem delotokov, spodbujanjem nove ustvarjalnosti in k stalnemu napredku arhitekturne in inžeriske stroke ter izvedbe.

Za raziskovalne metode sem opravil participativno raziskavo v sodelovanju z Dekleva Gregorič arhitekti, priznanim slovenskim arhitekturnim birojem v Ljubljani, pri čemer sem raziskoval njihov prehod na BIM s študijami primerov realnih porjektov. Pomen teh primerov je relevanten tudi za druge arhitekturne prakse, vključno z implementacijo BIM, integracijo vizualizacije znotraj okolja BIM kot vizualne podpore odločanj in manjši arhitekturni natečaj sam.

Osnovni cilj raziskave je pokazati, kako lahko implementirani delotoki izboljšajo procese in rezultate načrtovanja ter hkrati obravnavajo izboljšave v prihodnosti. S temi izboljšavami bi bila orodja BIM bolj privlačna in izboljšali bi lahko lahko potek projektiranja. Ciljna skupina teh izboljšav vključuje arhitekturne biroje, arhitekte, uporabnike, razvijalce opreme BIM in študente. Končni cilj je preoblikovati pristop k arhitekturnemu načrtovanju z večjim izkoristkom zmogljivosti BIM, z višjo stopnjo optimizacije, racionalizacije in boljšim sodelovanjem pri arhitekturnem načrtovanju.

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BIBLIOGRAPHIC– DOKUMENTALISTIC INFORMATION AND ABSTRACT

UDC: **004.946:72(043.3)**

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Title: **Architecturally Driven BIM Processes with Practical Explorations**

Document type: **Master Thesis**

Scope and tools: **91 p., 48 fig., 0 tab.**

Keywords: **bim, architecture design and bim, bim implementation, bim and visualization, rendering, architectural competition**

Abstract:

This thesis explores the role of BIM in architectural practice, highlighting its identity as a methodology centered on optimizing work processes rather than a creative design approach. Despite its transformative potential, BIM faces challenges like ¿ how to make BIM more appealing to architects and designers? it is essential to address them to enhance its design tools. BIM's future entails revolutionizing architectural design by streamlining workflows, fostering creativity, and contributing to the ongoing advancement of the AEC industry.

For the exploratory methods, I did participatory research Collaborating with Dekleva Gregorič Architects, a renowned Slovenian architectural firm in Ljubljana, exploring their transition to BIM with real-world case studies, illustrating their relevance to any architectural practice, starting with BIM implementation, incorporation of BIM-embedded visualization as visual support within the authoring software, and a smaller-scale architectural competition on my own.

The primary aim of this research is to showcase how these workflows can enhance design processes and outcomes while addressing future challenges. These enhancements aim to make BIM a more appealing design tool, improve project development, and provide accessible software. The target audience for these improvements includes design studios, architects, users, software developers, and students. The ultimate goal is to transform how we approach architectural design by leveraging BIM's capabilities to optimize, streamline, and facilitate effective collaboration within the architectural design process.

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ACKNOWLEDGEMENTS

Over the past year, I've been a part of the BIM A+ European Master in Building Information Modelling in Portugal and Slovenia, and it's been an incredible and enriching experience that will stay with me forever. This journey has not only expanded my knowledge and skills but has also introduced me to new experiences and lifelong friends.

I'd like to express my heartfelt gratitude to my Parents, Brother, Grandma, Family, and Friends. Their unwavering support and unconditional love have been my constant motivation in achieving my goals.

A special thank you goes to Dekleva Gregorič Architects, especially Aljoša, Tina, and Lea, for their warm welcome and for generously sharing their knowledge and support throughout the development of this work. I hope your practice continues to thrive, bringing outstanding architecture to Slovenia

I'm also deeply appreciative of Aljoša Dekleva and Tomo Cerovšek for their guidance and wise supervision of my dissertation. Their valuable feedback and insights have greatly contributed to its improvement.

To the BIM A+ family, your friendship, help, and guidance have been invaluable throughout this master's journey. You've made every moment special and brought smiles and happiness when needed the most.

Thanks!

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1. INTRODUCTION

1.1 General Approach

This thesis primarily aims to illustrate the profound impact of implementing the BIM approach on architectural design practices. Embracing BIM represents a paradigm shift for architectural firms, allowing them to modernize their established processes through enhanced collaboration with stakeholders and specialized teams. This transformative approach streamlines workflows, rendering them more efficient, and automates tasks that were previously carried out manually, such as aligning floorplans with elevations or sections. For example, the utilization of extended projected lines serves as a valuable tool for achieving this alignment. Consequently, the incidence of errors is significantly reduced, as any modifications made to the model automatically propagate to all interconnected views. In stark contrast, traditional CAD tools, now viewed as outdated in the face of contemporary technology, were primarily designed for 2D line drawings and lacked coordination or integration with the building's environmental aspects, such as levels, elevations, and sections. BIM, on the other hand, offers a comprehensive digital representation of the entire building, transcending these limitations.

In the era before CAD, when architects, and indeed all engineers, relied on manual drafting, they were compelled to meticulously coordinate 3D aspects of their designs. These professionals, driven by their innate need for a robust 3D imagination, had to grasp the project's dimensions and intricacies to seek innovative solutions. Architectural excellence is not solely contingent on the act of drawing itself; it hinges on comprehending the multifaceted nature of a project and deftly coordinating its complexity into a whole.

Indeed, the dichotomy between 2D and 3D representation alone is a simplification of the broader architectural process. In addition to drawings, architects must consider a full number of elements, such as information tags, digital data flow, and real-time information exchange. These facets are integral to the contemporary architectural landscape, transcending the traditional boundaries of 2D versus 3D, and underscore the multifaceted nature of architectural design and construction. In essence, modern architectural practices necessitate a bigger approach that combines creative vision, technical expertise, and innovative utilization of digital tools and information flow to seamlessly unite the diverse elements of a project into a cohesive whole.

BIM empowers architects to create detailed 3D models, thereby facilitating better visualization, design exploration, and iterative decision-making. It also fosters seamless collaboration among project stakeholders, leading to improved coordination, communication, and interdisciplinary teamwork. Notably, clash detection and conflict resolution are significantly improved, reducing construction errors and rework that were previously difficult to identify in 2D environments. BIM enables accurate cost estimation, material optimization, and construction sequencing, resulting in better cost control and project scheduling. Furthermore, all aspects within the model are automatically and directly related, meaning that any changes made are reflected across the project. This integration eliminates the need for multiple processes, such as redrawing areas, obtaining numbers, transferring data to Excel, and performing calculations. In the realm of BIM, everything is integrated. Even when sharing the model with other parties, they can access the numbers directly or extract information from the architectural model stored in the cloud.

In addition, BIM incorporates sustainability analysis, simplifies documentation, and supports facility management, thereby contributing to the creation of more sustainable, efficient, and well-maintained buildings. Each element within the model possesses specific properties related to the building, including the assembly of materials. This enables the performance of analysis for high-performance and sustainable buildings.

BIM surpasses the capabilities of CAD, fundamentally transforming architectural processes through its comprehensive approach to design, collaboration, and information management.

1.2 Goals and Objective

The objective of this thesis is to illustrate how the practical implementation of the BIM methodology enhances workflows and processes in real-life architectural practice. It showcases case studies of significant architectural processes to highlight both the benefits and challenges of BIM in improving architectural creative processes. Addressing these challenges is essential for future improvements and making BIM more appealing to architects and designers within the creative process.

1.3 Methodology and structure

The BIM approach to architectural practice follows a structured framework, beginning with an exploration of the background context and generalities of BIM. This is followed by a literature review and investigation of previous articles and papers related to the subject. The thesis then proceeds to present three case studies that exemplify the various benefits of implementing the BIM methodology in architectural practice.

Aligned with the vision of the BIM Approach in architectural practice, the case studies undertaken in this thesis concentrate on implementing BIM, utilizing visualization tools with BIM, and participating in the HBIM Architectural Competition.

Eventually, I connected with Dekleva Gregoric Architects, who are interested and aware of the importance of improving their processes deeper into BIM, they are in the process of training / adopting the tool.

This presented an ideal opportunity for me to the specific topics of interest. I commenced working in-house with Dekleva Gregoric Architects, primarily focusing on BIM implementation and visualization. Furthermore, I undertook an independent study involving an architectural competition in Italy, where the entire project was developed using BIM.

BIM Implementation

-Examining the challenges and benefits of implementing BIM in architectural practice, with a focus on improving workflow, communication, and collaboration while maintaining quality and graphical standards.

-Design Efficiency: BIM enables architects to create detailed 3D models, enhancing the design process. It allows for better visualization, analysis, and exploration of design options. Architects can easily make changes, evaluate their impact, and iterate designs more efficiently.

-Collaboration and Coordination: BIM better collaboration among project stakeholders, including architects, engineers, contractors, and clients. It provides a centralized platform for sharing and integrating project information, reducing coordination errors and improving communication. This collaborative environment allows for real-time feedback, seamless information exchange, and coordinated decision-making.

-Documentation and Information Management: BIM streamlines the documentation process by automatically generating accurate and up-to-date construction drawings, schedules, and specifications from the model. It ensures that project information is consistent, reduces manual errors, and enhances the overall quality of documentation. BIM also provides a centralized database for managing and accessing project information throughout its lifecycle.

HBIM Architectural Design Competition

BIM provides an advantage in architectural design competitions by improving workflows and enabling faster creation of competition drawings. It facilitates enhanced visualization with customizable view styles, seamless collaboration with other specialties such as structural engineering, and efficient design iterations with team members working simultaneously on different parts of the design in a central file. BIM also enables the quick and accurate creation of plans, including elevations, sections, and details. Additionally, it can assist in cost estimation and sustainability analysis if required.

BIM Visualization

architects need to see a materialized model, as representing materials with a certain degree of accuracy is relevant information in any architectural process. BIM excels in this aspect by enhancing client engagement through realistic 3D visualizations and virtual walkthroughs. Clients can better understand the design intent, visualize the space, and provide feedback. This not only improves communication and client satisfaction but also facilitates better decision-making throughout the project.

Furthermore, this innovative approach represents a game-changing advancement in the rendering field. It simplifies and streamlines formerly intricate processes, making them remarkably user-friendly and accessible. This not only enhances the efficiency of architectural workflows but also opens up new possibilities for architects and designers to create stunning visual representations of their projects with ease, ultimately revolutionizing the way we approach architectural rendering.

2 BIM OVERVIEW

BIM is a digital approach that revolutionizes the way architectural and construction projects are planned, designed, and managed. It entails creating a comprehensive and dynamic 3D model of a building that not only visually represents its physical aspects but also integrates extensive data about its components and systems. BIM joins collaborative teamwork among architects, engineers, contractors, and other stakeholders by allowing them to work on a shared digital platform. This technology streamlines the design and construction processes, identifies and resolves conflicts before they become issues, enhances cost estimation accuracy, and can even simulate a building's energy efficiency. Ultimately, BIM is transforming the construction industry by offering a holistic and efficient approach to building development and management.

BIM emerged in the late 20th century, with its origins dating back to the 1970s. However, its widespread adoption and development gained momentum in the early 21st century.

BIM started primarily as a response to the inefficiencies and limitations of traditional 2D paper-based drafting and design methods in the construction and architectural industries. Architects, engineers, and contractors were seeking more effective ways to collaborate, reduce errors, and improve project management. BIM was conceived as a solution to these challenges.

The development of powerful computer hardware and software played a crucial role in the evolution of BIM. The availability of 3D modeling software, along with advancements in data management and visualization, made it possible to create digital representations of building projects that included not only geometry but also rich data about building components, materials, and systems.

The adoption of BIM was further accelerated by government initiatives and industry standards. Several countries and organizations recognized the potential benefits of BIM in terms of cost savings, sustainability, and efficiency in construction projects. They began mandating or promoting BIM usage in public infrastructure and building projects, encouraging its wider adoption across the construction industry.

In summary, BIM began as a response to the limitations of traditional design and construction methods, gained traction with technological advancements, and was further promoted by government and industry initiatives aiming to improve efficiency and collaboration in the construction sector.

BIM revolutionizes design and construction processes by embedding metadata within 3D geometries, fostering seamless collaboration among stakeholders within a shared model. BIM offers visualizations, integrated data, and comprehensive lifecycle management, empowering users with real-time data-driven decisions, efficient change management, and advanced analysis capabilities. In contrast, traditional CAD workflows often involve disconnected data, limited 2D representations, manual change management, and cannot support comprehensive analyses and simulations. BIM's impact extends beyond design to encompass the entire building lifecycle, from initial planning through construction and ongoing maintenance, making it a transformative technology for the architecture, engineering, and construction industry.

The history and progression of traditional design methods in civil engineering have witnessed significant changes. In the latter part of the 20th century, architects and engineers transitioned from conventional drawing and calculation tools to the utilization of CAD/CAE systems. Nonetheless, the next advancement in this evolution is the adoption of BIM.

Traditional approaches to design using CAD systems typically involve architects creating 3D element sketches, while civil engineers work with plans or detailed drawings. In this classical design method, each specialist focuses on their respective elements, working on tracing papers. These separate drawings are then overlaid during coordination meetings to identify any compatibility issues within the project. While CAD systems have modernized this process by introducing separate layers for each specialist, the designers still work on plans of the same structure, inevitably leading to interdisciplinary conflicts.

Specialized programs have been developed for installations, and the functionality of available AEC software is strong, encompassing compliance with industry standards. These programs enable comprehensive structural modeling, and their load pattern combination modules support a multitude of variations. The final analysis results can be easily transferred to CAD/BIM systems for adjustments to the 2D/3D model and the generation of drawings. Building Information Modelling or Building Information Management is “a digital representation of physical and functional characteristics of a facility...and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.” (BuildingSmart, n.d.)

The general benefits of BIM technology, include improved coordination and collaboration between specialists. BIM allows for comprehensive modeling of structures and results from analysis can be easily transferred to CAD/BIM systems for drawings.

2.1.1 Levels of BIM

The process involves different levels, starting from Level 0, which includes paper documentation, to Level 2, similar to Level 1 but with better library management and file-based collaboration. BIM promoters aim to use Level 3 - intelligent BIM - for all projects and expect the widespread use of BIM formats and ISO standards. BIM provides benefits by integrating different specialized documentation into one 3D model with a database, allowing for quick changes during interdisciplinary coordination. Collision detection uses algorithms developed in gaming and computer graphics and should be exact.

BIM systems use computer graphics procedures, good standards, and engineering practices to identify heavy, light, and technological collisions.

2.1.2 Dimensions of BIM

The dimensions represent the progressive integration of information and data into the BIM model, allowing for more comprehensive and informed decision-making at various stages of a construction project's lifecycle, refer to different aspects of the project data and its timeline.

- BIM 3D model has digital geometry models of objects in space.
- BIM 4D adds scheduling to the model, allowing for the division of the project into phases, visualization of phases, and simulation of the schedule of works.
- BIM 5D adds cost estimation to the model, enabling fast estimation of costs for conceptual designs and comparing the execution time and total costs of various alternatives.
- BIM 6D focuses on sustainability and allows for the integration of data related to environmental protection or energy consumption.
- BIM 7D Although less commonly used, 7D BIM extends the model into the operations and facility management phase. It includes data on facility operations, maintenance, and even decommissioning. It helps optimize the long-term performance of the built environment. (Czmoch & Pękala, 2014)

3 BIM ADOPTION AND IMPLEMENTATION IN ARCHITECTURAL PRACTICES

3.1 Current State of AEC regarding BIM

The systematic approach for implementing BIM in architectural SMEs at the organizational level. The approach uses a socio-technical view, incorporating people, processes, and technology equally, and is based on action research.

The AEC industry is under a transformation to improve productivity, efficiency, sustainability, infrastructure value, and quality while reducing costs, lead times, and duplications through better stakeholder collaboration. BIM is a process that seeks to integrate all aspects of the construction lifecycle. Recently, building owners have become more aware of BIM's potential to streamline and enhance the design, construction, and operation of buildings, resulting in increased pressure on architects, design professionals, construction managers, and companies to adopt BIM.

While BIM has been around, however, there are challenges to implementing BIM like in UK construction practice, such as overcoming resistance to change, adapting existing workflows, providing BIM training, understanding required hardware and networking resources, fostering collaboration between designers and engineers, and clarifying stakeholder responsibilities for construction lawyers and insurers.(Arayici et al., 2011)

3.2 Challenges and Obstacles of Practical Bim Implementation

According to the paper (Migilinskas et al., 2013), “*The AGC Contractors' Guide to BIM was published in 2007 and updated in 2010 to educate project participants about BIM and its benefits, tools, and applications. The guide also clarifies the responsibilities of each team member in the BIM process and identifies areas of risk management. Professionals in the AEC industry have provided their opinions on BIM implementation, highlighting its benefits in improving coordination, reducing errors and omissions, and saving resources. Their experiences over the years have also identified issues of BIM implementation such as:*

Challenges:

• Educating people about the potential of BIM and overcoming resistance to change from 2D drafting
•Adapting existing workflows to lean-oriented processes
•Providing BIM training to employees or finding those who already understand BIM
•Achieving collaboration, integration, and interoperability between different designers/engineers
• Implementing Virtual Project Development may lead to mistakes and require consulting with other practices

•Barriers to using BIM include fear of low success rates or big failures, high initial investment costs, and lack of support from senior leadership

Obstacles:

- *High cost of BIM implementation, especially for small and medium designing offices*
- *Accuracy in modeling is crucial from the beginning, and small mistakes can lead to major complications*
- *BIM requires learning new expressions, phrases, and nomenclature that may be unknown to those who worked with CAD software*
- *Technical building documentation must be prepared from a 3D model, which can require more designers in the first phase of designing*
- *Costs and benefits of BIM implementation should be defined realistically among all parties involved*
- *Lack of significant legal regulations regarding widespread application of BIM-based design can create confusion and legal issues"* (Arayici et al., 2011; Migilinskas et al., 2013)

Implementing BIM effectively requires significant changes in the construction industry, from workflow to staff training and responsibilities. Clear guidelines for BIM implementation could benefit the industry.

3.3 Case Study Examples from Literature Review

A good practice study of BIM adoption for an architectural company in social housing identifies efficiency gains and recommends the adopted approach for other SME architectural companies.

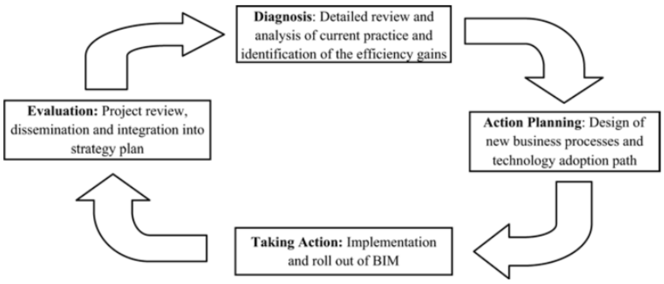
"*The research* (Arayici et al., 2011) *was conducted through a knowledge transfer partnership between the University of Salford and John McCall Architects. The study found that this approach led to capacity building and efficiency gains, providing competitive advantages for SMEs. This paper provides a roadmap for BIM adoption in SME companies.*

John McCall Architects in Liverpool specializes in social housing, regeneration, private housing, one-off homes, and large extensions. The company has used a 2D CAD tool for two decades, but it brings about inefficiencies and the company needs to improve its capacity for greater integration and collaboration with other disciplines in the production process. (Arayici et al., 2011)

Also provides a more effective business process, effective intelligent real-time response, and move into related building sectors.

Lean principles form the seven pillars of the BIM implementation strategy: eliminate waste, increase feedback, delay decisions, deliver fast, build integrity, empower the team, and see the whole". (Arayici et al., 2011)

The BIM implementation process is planned through four stages, including discovery, comparison, experimentation, and implementation.



Stage	Details
1. Detail review and analysis of current practice and identification of efficiency gains from BIM implementation	Production of current process flowcharts Soft system analysis Review of overall ICT systems in the company Stakeholder review and analysis Review of BIM tools for the company Identification of competitive advantages from BIM implementation
2. Design of new business processes and technology adoption path	2.1. Identification of lean efficiency gains 2.2. Production of detail strategies 2.3. Documentation of lean process and procedures 2.4. Development of the knowledge management database 2.5. Documentation of BIM implementation plan
3. Implementation and roll-out of BIM	3.1. Piloting BIM on different projects (past, current, and future) 3.2. Training the JMA staff and stakeholders 3.3. Devising, improving and documenting companywide capabilities and processes
4. Project review, dissemination	4.1. Sustaining new products and processing offerings 4.2. Evaluation and dissemination of the project

Figure 1: Action research process adopted and Detailed activities in the action research stages

(Arayici et al., 2011)

"Improve the design process at JMA by adopting a lean approach and implementing BIM technology. The project involved four stages: a review of current practice, design of new business processes and technology adoption path, implementation and roll-out of BIM, and project review and dissemination. The review of current practice involved producing process flowcharts and using the contextual design technique. Soft system analysis involved using the soft systems methodology (SSM) and storyboarding. The review of IT systems and BIM tool selection showed that the data used by the company was very fragmented, and the inefficiencies were mainly because the software tools used did not have bi-directional interoperability. The project aimed to address these inefficiencies by implementing BIM technology, piloting it on different projects, training staff and stakeholders, devising and improving company-wide capabilities and processes, and evaluating the project.

the importance of flexibility in outputting from BIM systems for external stakeholders while maintaining the quality of output compared to existing CAD systems. The use of BIM models can provide several advantages such as cost leadership, differentiation, cost focus, differential focus, and collaboration. SWOT analysis helped to identify the efficiency gains and (KPIs) to improve the organization's and project's performance through the adoption of lean principles and emerging technology. Rapid prototyping using 3D printers is also seen as a potential gain from BIM models". (Arayici et al., 2011)

"KPIs at the organizational and project level:

- *Project man hours*
- *Development speed*
- *Revenue per employee*
- *Architectural quality*
- *Product Quality*
- *Cost savings in travel, printing, and document shipping*
- *Bids won or win rate*
- *Client satisfaction and retention*
- *Employee skills and knowledge development*

JMA has also developed a relational database to store critical data that was previously dispersed across multiple formats. the development of an integrated knowledge database at JMA by normalizing data elements from different sources and creating a proposed data structure. This knowledge database allows for the retention and sharing of information internally and is accessible to all staff. It is also integrated with BIM project databases to enable bilateral information feeding. The text also discusses the documentation of the BIM implementation plan, including factors to consider such as the BIM adoption approach, scale, training and education, recruitment of BIM champions, and model analysis.

The problems during project implementation according to the article of (Arayici et al., 2011)depend on the contractual arrangements between the project team and client, which can either promote individual interests or common project goals and create an environment where individual interests are prioritized, leading to barriers to full-scale BIM implementation. On the other hand, integrated project delivery (IPD) contracts minimize problems and create the best environment for BIM methodology, providing the most benefits to the final user of the built environment. (Arayici et al., 2011)

During the "Taking action" stage of implementing BIM at JMA, past, current, and future projects were piloted to ensure they were representative of typical JMA projects. One past project and two current projects were selected, and object libraries were developed and implemented for JMA in its practice in housing and regeneration. Future projects will be identified once the initial core training for JMA staff has been completed via piloting. Training of JMA staff and stakeholders was conducted in four areas, *including basic operation skills and JMA modeling standards, to ensure successful change management. The report highlights the benefits of BIM adoption, including effective reuse of information, consistent information exchange, and a lean process of conceptual and detailed design development. JMA needs to develop linkages with other BIM-enabled organizations to realize the true benefits of BIM and become a market leader in the field. A tangible benefits log has been maintained throughout the project to evaluate the efficiency gains, and concludes that the BIM adoption has already improved JMA's practice and will continue to do so in the future, improving communication, streamlining processes, and providing collaborative practice. The approach emphasizes people and processes as much as technology, after 18 months, JMA has made significant progress in upskilling staff and improving infrastructure. (Arayici et al., 2011)*

Other Case studies to determine productivity and profitability gains and to learn from the experience of BIM implementation teams. They provide recommendations for BIM process planning in small companies with different software and methodologies. BIM implementation requires the development of reliable tools for information exchange and coordination between project participants using different software. The standardization of work methods and interoperability is necessary for successful BIM implementation. However, existing contractual arrangements and traditional project organization can constrain the effective and fast use of BIM technology.

The project delivery should prioritize searching for better solutions and alternatives that can benefit all parties involved. (Migilinskas et al., 2013)

For instance, according to the article (Czmoch & Pękala, 2014), An office complex in Warsaw was designed using BIM software in two phases, resulting in more than 30,000 sqm of office space. The design process prioritized sustainability, with lighting and air-conditioning designed for special certification. Ten designers used the REVIT system, resulting in a faster and more accurate design process than traditional methods. The construction site was provided with both paper documentation and a BIM model, with all collisions eliminated in the designing phase. BIM implementation reduced the total amount of time needed to produce documentation by approximately 30%. While BIM technology offers benefits such as better interdisciplinary cooperation and positive effects on clash detection, bill of quantities, and cost estimations. (Czmoch & Pękala, 2014)

BIM-based design can be effectively implemented by experienced designers and allows for the simplification of tasks and considerable savings in time and money. Successful implementation requires a skillful design team that follows BIM procedures. BIM is currently profitable mostly for large projects, but as software and hardware become cheaper, it will spread to smaller projects. BIM is a complete design tool that can radically change the designing process in the following years". (Czmoch & Pękala, 2014)

3.4 Impact of BIM Implementation on Architectural Practice

"The impact of BIM implementation on architectural practice from a practical point of view, based on real-life results, observations, and statistical data. Using the example of the study (Jasiński, 2021) evaluates a seven-year-long process of BIM implementation in a medium-sized architectural practice based in Poland over ten years, considering human, technological, and business factors, as well as financial factors. The findings suggest that the practical benefits of using BIM technology in architectural practice are significant, improving the quality of design, clash control functions, and coordination. However, the implementation of BIM also raises running costs, reduces profits, and increases liability.

The practical difficulties and complications during the implementation of BIM in architectural offices. The author provides insights from a case study of a practice that won a competition to design a large office building in Krakow and was required to use BIM technology to complete the project. The practice decided to implement BIM in stages, beginning with a Skanska project on which several architects were working. The process offered the practice benefits such as securing the financial side of operations, involvement in long-term projects, and a robust business environment. The practice incorporated the Integrated Design and Integrated Project Delivery processes, which enabled it to quickly overcome the technological and business barriers that prevent BIM from being implemented in architectural firms. However, the most challenging barrier to overcome was the human one, as it was necessary to train architects and project leaders to use new tools and methods. The decision to pursue a top-down strategy of BIM adoption on a project-by-project basis proved to be effective, with all projects moving past the conceptual phase being carried out using BIM software. (Jasiński, 2021)

The staffing policy has also changed, with potential new hires now required to have a good knowledge of BIM software.

The practice has also modernized its hardware and communication infrastructure, and the number of BIM seats has increased.

Between 2013 and 2019, the practice worked on 13 major projects for new buildings, but only three projects required the use of BIM at the design stage, and the clients of the other projects either refused to bear the additional costs or were uninterested. Architects who became proficient in using BIM Revit continued to use it, while those who were less advanced continued to use AutoCAD.

However, now all projects are carried out using BIM technology. The practice sometimes has to compete with architects who do not use BIM, and whose services are cheaper. An example was given where a BIM-based bid for a dormitory design for the Polish Air Force Academy was calculated at 1,361,000 PLN, but the tender was invalidated because the bid exceeded the client's design fee budget. A new *tender was announced without BIM, and the lowest non-BIM offer that was awarded the commission was over 100% lower than the practice's previous BIM-based offer.*

The adoption of BIM requires hiring highly qualified architects, designers, and consultants, as well as investing in training, hardware, and software. BIM-based projects are generally more skill-demanding and time-consuming, but they can lead to cost savings during the construction phase. However, the benefits of BIM are hard to quantify and depend on business factors and operator proficiency. In Poland, higher rates for architects using BIM are not yet commonly accepted, and the promise of using BIM throughout the whole building lifecycle is still a dream". (Jasiński, 2021)

3.4.1 Benefits

- *Properly prepared BIM models result in well-organized and fully-coordinated design documents, making it a key advantage for architectural practices compared to those using 2D software.*
- *The use of BIM technology enables interference checking and clash control detection, leading to an improvement in the quality of design.*
- *BIM models can be used for effective communication with clients and the creation of marketing materials.*
- *BIM models allow faster and more accurate quantity surveys, resulting in earlier cost estimations.*
- *BIM models enable construction processes to be planned, organized, and visualized more effectively.*
- *Additionally, Figure 1 shows that BIM adoption has occurred twice as quickly as CAD adoption.*
- *Obtaining as-built documents is easier with BIM models.*
- *BIM models have the potential for use in facility management.* (Jasiński, 2021)

3.4.2 Benefits of implementing BIM technology at the design stage

- Implementing BIM in an architectural firm can benefit clients and contractors by achieving precise and optimal design valuations, ensuring a smooth construction phase, and reducing and optimizing construction costs.

- Implementing BIM can also benefit architect employees by improving their skill level and increasing their rates. However, implementing BIM technology may require senior architects to change their habits and replace their 2D processes with new 3D skills and abilities. (Jasiński, 2021)

3.4.3 Benefits and risks of implementing BIM technology in a large or medium-sized architectural firm

- Strengthening the company’s market position and giving access to large-scale, potentially more prestigious, or profitable projects.
- Simplifying project control and cross-trade coordination, increasing documentation quality, and reducing the number of errors.
- Requiring the hiring of more highly qualified employees, which can increase labor costs.
- Generating higher investment and operating costs. (Jasiński, 2021)

3.5 Innovation in BIM Design Management

Collaboration and innovation are necessary for change, and BIM is seen as a perfect tool for achieving this according to (Elmualim & Gilder, 2014)

"The construction industry is criticized for its fragmentation and lack of collaboration between professionals and contractors. Facilities management is becoming more important, but it's challenging to incorporate it into the construction process. A well-designed building doesn't always require high specifications, but inefficiency and waste account for almost 30% of construction costs. The trend is moving away from fee competition towards a selection process based on quality and price balance. Collaboration throughout the construction process is very important to create and sustain appropriate built environments for users. Design management decisions should focus on the end product, and the industry should aim for committed leadership, customer focus, quality through innovation, reduced operational costs, and after-sales care.

Design management is an essential part of construction projects and involves coordinating the efforts of many individuals and organizations. It requires a common understanding of design and management and can be categorized by focusing on design actors, processes, and products. Collaboration during the design stage is taking new forms with emerging technologies. Innovation is crucial for sustained competitiveness and economic growth, but it is difficult to define and procedural in the construction industry. Innovation occurs when knowledge from different parts is combined in new ways, leading to a successful new product. The innovative practice relies on existing knowledge networks in an organization.

the use of BIM software benefits in terms of sustainability, accuracy, and time savings. However, the implementation of BIM as an everyday design method faces challenges. the relationship between design management, innovation, and BIM adoption. Respondents expressed varying views on innovation, with some seeing the project architect, design manager, or client as having the most influence.

BIM Implementation Evaluation: Regular evaluation and assessment of BIM implementation are important to identify areas of improvement and ensure that the adopted processes are meeting the desired objectives. This may involve conducting post-project reviews, gathering feedback from stakeholders, and refining BIM standards and workflows based on lessons learned.

BIM Support and Resources: Providing ongoing support and resources for BIM users is crucial. This includes having a dedicated BIM team or BIM manager to oversee implementation, troubleshoot issues, and provide guidance. Access to technical support, software updates, and relevant industry resources also contribute to successful BIM adoption.

Continuous Improvement and Innovation: BIM adoption should be viewed as an ongoing process of continuous improvement and innovation. Architectural practices should stay updated with the latest BIM trends, advancements, and best practices. Actively seeking feedback, sharing knowledge, and fostering a culture of innovation contribute to maximizing the benefits of BIM adoption".

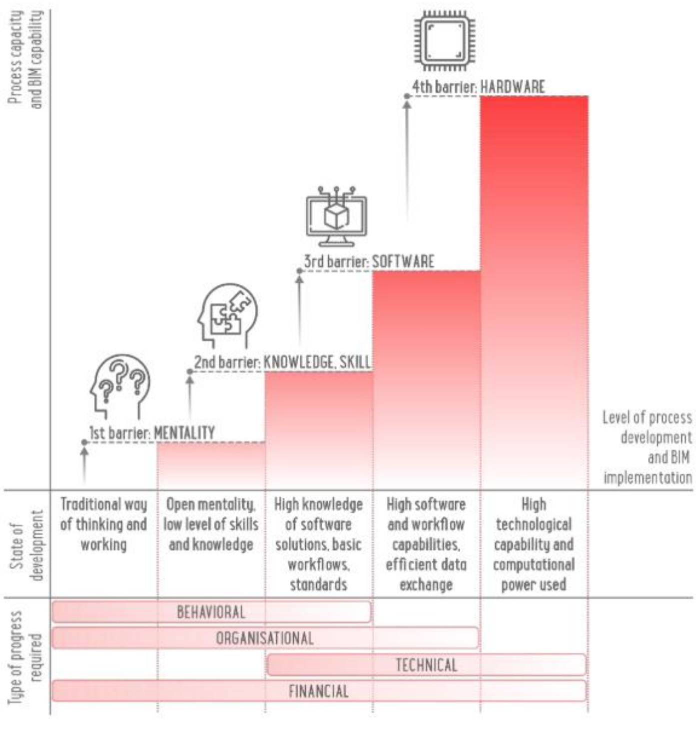


Figure 2: General barriers to process development and BIM implementation for design companies.

(Cesnik et al., 2019)

4 CASE STUDY: PROCESS OF IMPLEMENTATION IN AN ARCHITECTURAL PRACTICE

4.1 Architectural Practice - Dekleva Gregorič Architects

Contemporary architecture in Slovenia is characterized by a fusion of innovative design, sustainable practices, and a strong connection to the country's cultural and natural context. This architectural approach showcases a balance between innovation, sustainability, contextual sensitivity, and a commitment to preserving cultural heritage. Slovenian architects have gained recognition both nationally and internationally for their ability to create inspiring, functional, and socially responsible architecture. Their designs contribute to the country's cultural identity and enrich the built environment, reflecting a deep appreciation for the unique context of Slovenia.

One of the most notable firms is Dekleva Gregorič Architects, which describes their standing on architecture with the following text on their website: "*an architecture studio based in Ljubljana that was founded by Aljoša Dekleva and Tina Gregorič in 2003. Their design approach focuses on "research by design" and "design by research" across various aspects such as space, society, materials, history, and more. They aim to challenge the obvious and propose specific responses by understanding the constraints and conditions of each context. Their systematic design approach aims to create structured spaces and explore the primary nature of materials. The studio prioritizes the user's experience and participation in architecture, seeking to stimulate interactions and involve users in the design process to meet their specific needs.*

Dekleva Gregorič architects gained international recognition with their XXS house in Ljubljana, which received the European Architecture Award Luigi Cosenza and the WALLPAPER award. Their Metal recycling plant ODPAD was nominated and shortlisted for the Mies van den Rohe Award 2009 and won the Plečnik's Medal prize in Slovenia, among other accolades. Several other projects, including Housing Perovo, Compact Karst House, KSEVT - Cultural Centre of EU Space Technologies, and Slovenska street renovation, were also nominated for the Mies van den Rohe Award. The Clifftop house on Maui garnered attention and awards such as the AIT award, International Architecture Awards 2012, and an honorable mention at the American Architecture Prize 2016. The Compact Karst House won the WAN House of the Year 2015 Award, recognized by the AR House Award 2015, and recently won the first prize for building the Slovenian Pavilion for Osaka 2025.* (Dekleva Gregorič Architects, 2023)

In addition to their architectural practice, Aljoša Dekleva and Tina Gregorič are actively involved in reshaping architectural education. Aljoša serves as the Programme Head of AA nanotourism Visiting School at the Architectural Association in London, while Tina is a Professor of Architecture and Chair of the Research Unit Architectural Typology and Design at the Institute of Architecture at the University of Technology Vienna. They both hold the Frank Gehry International Visiting Chairs in Architectural

Design at Daniels, University of Toronto. They have lectured and exhibited extensively worldwide, questioning the role of architecture in improving society.

Both Aljoša and Tina graduated from the Faculty of Architecture, University of Ljubljana, and obtained their postgraduate Master's degrees in Architecture with Distinction from the Architectural Association in London. They researched participation, responsive environments, and mass customization, and co-authored the book "Negotiate My Boundary!" on these topics. They have also been leading a design research project called nano tourism since 2014, which offers a participatory and locally oriented alternative to conventional tourism. As curators of the Slovenian National Pavilion at the Venice Architecture Biennale 2016, they explored the concepts of home and dwelling through the "Home at Arsenale" exhibition, featuring a parametric site-specific wooden structure functioning as a curated library.

Through their innovative design approach, focus on user experience and participation, and contribution to sustainable and socially conscious architecture, Dekleva Gregorič architects have significantly enriched the contemporary architectural scene in Slovenia. Their projects serve as examples of the studio's commitment to pushing boundaries, engaging with context, and stimulating interactions between users and their built environment." (Dekleva Gregorič Architects, 2023)

4.2 Current State of the Practice

Dekleva Gregorič Architects, an established architectural firm, had traditionally CAD software for their architectural projects. Their typical workflow involved conceptualization in SketchUp and documentation in AutoCAD. However, a significant shift was necessitated when they secured a high-profile public project, the Science Centre of Ljubljana, which mandated the utilization of BIM methodologies. After a comprehensive evaluation of available options and consultation with industry peers, they opted for Autodesk Revit as their BIM software of choice.

This shift posed a considerable challenge to their team, as the majority of their architects were proficient in CAD-based workflows. Transitioning to BIM required a substantial adaptation of technical skills. The process involved intensive training for the entire team, acclimatizing to a new software environment, and managing intricate geometric aspects inherent to a large-scale project.

The intricacies of the BIM process were particularly daunting, especially considering their initial lack of familiarity with the software. As a result, the transition period was extended compared to their previous CAD-based projects, primarily attributable to the learning curve associated with Revit. The scope of the project encompassed highly detailed architectural plans, intricate installations, rigorous structural calculations, and various other intricate elements.

This transformation necessitated a methodical and incremental approach. It involved assembling a proficient team of architects well-versed in Revit, along with the establishment of Revit templates and predefined standards to facilitate a smoother transition process. This initial segment of the thesis is dedicated to exploring the nuances of this transitional journey within an architectural practice.

4.3 Adoption of BIM

Analyzing the office's current workflows, with a specific focus on identifying areas for improvement in BIM and architectural design, drawing from practical experience and collaboration within the team. The ongoing transition to BIM within the office has yielded positive outcomes with a positive effort and achieving the goals for any project, resulting successful design of beautiful projects to be built. However, this transition has not been without its challenges. Particularly, the move to BIM has required addressing various challenges associated with the adoption of this transformative tool.

Dekleva Gregorič Architects having experience working on larger projects with complex geometries, it has become evident that this paradigm shift involves more than just replacing or enhancing the traditional CAD workflow. It is about having confidence in utilizing an intuitive, user-friendly, and collaborative software platform that allows architects to spend less time grappling with technicalities and more time engaging in the creative design process. Having this we can provide valuable feedback and recommendations.

4.4 BIM Software and Tools

Having this in count, selecting and implementing the appropriate BIM software and tools is a crucial step. This involves evaluating different software options, considering the specific needs and requirements of the architectural practice, and training the staff to effectively use the chosen software and other tools for their effectiveness.

Several software applications were widely used in the field of BIM for architecture as is up to every user or practice how to combine them and what is their best workflow to effectively achieve their desired results. Here are some of the most commonly used software for architecture:

BIM Authoring Software: Autodesk Revit - Graphisoft ArchiCAD - Bentley Systems' AECOsim Building Designer

Customization and Parametric Design: Rhinoceros (Rhino) with Grasshopper - Dynamo (with Revit)

Multi-Purpose BIM Software: Nemetschek Allplan- Vectorworks Architect

Specialized BIM for Structural Integration: Tekla Structures.

IFC Viewers: Dalux – BimVision

IFC clash detection: Solibri - Revit (Built-In Clash Detection) - Tekla Structures - Trimble Connect - BIMcollab ZOOM

CDE: Bim 360 – Aconex – Trimble Connect

CAD: AutoCAD

No BIM - User-Friendly and Conceptual Design: Trimble SketchUp - Rhinoceros (Rhino)

CAD: Autocad

Figure 3: Bim Software Categories (Integrated Bim, n.d.)

4.5 BIM Standards and Guidelines

Establishing internal BIM standards and guidelines ensures consistency and uniformity across projects. This includes defining naming conventions, file organization, layering systems, and modeling guidelines to streamline collaboration and information exchange.

-BIM Project Planning: Developing a BIM project execution plan outlines the overall strategy for BIM implementation within the architectural practice. It includes defining project objectives, roles and responsibilities, project milestones, information exchange protocols, and quality control processes.

-BIM Training and Education: Providing training and education to the architectural staff is crucial for successful BIM adoption. Training programs should cover BIM software proficiency, modeling techniques, collaboration workflows, and project-specific requirements. Continuous professional development is also important to stay updated with the latest BIM advancements.

-BIM Integration with Workflows: Integrating BIM into existing architectural workflows is essential. This involves defining how BIM will be incorporated into the design, documentation, and construction processes. It may require redefining roles and responsibilities, establishing new coordination procedures, and adapting project workflows to accommodate BIM practices.

-Data and Information Management: BIM relies on effective data and information management. This includes defining data exchange standards, file formats, and protocols for information sharing among project stakeholders. It also involves establishing a centralized project information repository and implementing version control and revision management processes.

-**Structure the Project:** Properly structuring a project involves a systematic approach to maximize efficiency and collaboration. Begin with a clear understanding of project requirements and phases, have all the options of the software, and select which is better. Organize the model with precision, employing file linking for different disciplines. Establish worksets, enabling simultaneous collaboration while minimizing interference. Shared parameters maintain data consistency across linked models. Implement coordination workflows, regularly sync linked models, and use design options to explore variations.

-Collaboration and Coordination: BIM adoption emphasizes collaboration and coordination among project team members. This involves establishing communication channels, defining review and approval processes, and facilitating interdisciplinary coordination through regular meetings and BIM coordination sessions.

4.5.1 Revit Project Template

Revit Template is a base standard file to create projects from scratch in Revit achieving efficiencies in the production of easily readable drawings, information, and delivery projects with are set of clear instructions for the builder. As architects, we need to produce not only very clear drawings that express with detail the intention of design also we need beautiful graphic drawing output and imagery. This will help the methodology that focuses on the production of technical drawings and graphic output and the implementation of efficient workflows for the effective organization of drawing information, graphic tools, annotations, schedules, views, and sheets.

Create a Revit template specifically developed for Dekleva Gregorič Architects with a focus on crafted design output. It is designed to help you organize your drawings, sheets, and views more easily navigate the Revit browser. The template is fully set up with graphic features, annotations, and elements of the standard Dekleva Gregorič Architects drawings, ready to use simply start the project and do not spend time creating a lot of families or looking for the appropriate view template for the drawings.

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For this template, Dekleva Gregorič Architects required a straightforward base file to initiate new projects from scratch. They possessed a previous model project, the Science Centre, which served as the base. The concept involved taking this model and filtering all its components, including elements, families, annotations, drafting, title blocks, views, sheets, and more. After the selection and filtering process with Dekleva Gregorič Architects, the template was configured, involving modifications to various elements to align with the desired template.

Analysis And Planning

This involves thorough analysis and planning to ensure that the template meets the specific needs and standards of the practice. Here are the key steps and analyses that should be done before creating a Revit template:

1. Understand Practice Requirements: Gather input from architects, designers, drafters, and other team members to understand the specific needs of the practice. Identify the types of projects the practice works on, the common elements used, and any specific design or documentation requirements.

2. Review Existing Workflows: Analyze the current design and documentation workflows within the practice. Identify areas for improvement and opportunities for standardization.

3. Standardization Analysis: Determine which design elements, families, annotation styles, and views are used consistently across projects. Identify where standardization can lead to more efficiency and better collaboration.

4. Content Inventory: Take stock of existing Revit families, templates, and content libraries that the practice already uses. Evaluate the suitability of these resources for inclusion in the template. Review of past Revit projects and past templates of cad and then the selection and extraction of families and other elements relevant.

5. Regulatory and Industry Standards: Research and understand relevant regulatory and industry standards that the practice needs to adhere to. Ensure that the template supports compliance with these standards.

6. Company Branding and Guidelines: the practice's branding and graphic guidelines. Ensure that the template's graphical elements align with the practice's visual identity.

7. Worksharing Analysis: If the practice uses work sharing (collaboration among multiple users), determine how worksets and linked files should be structured in the template to facilitate smooth collaboration. (According to every project's needs this can be customized and according to the desired categories to improve the management)

8. Project Types and Phases: Different architectural projects may have distinct requirements based on their type (residential, commercial, institutional) and project phases (conceptual, design development, construction). (According to every project's needs this can be customized and according to the desired categories to improve the management)

9. Naming Conventions: Define consistent naming conventions for families, views, sheets, and other project elements. This ensures that everyone in the practice can easily locate and understand project components.

10. Annotation and Graphics Standards: Determine annotation styles, line weights, text sizes, and other graphics-related standards that should be included in the template for consistent documentation.

According to the base project, analysis of other projects in the practice, and CAD lines and colors, were applied to the template.

11. Coordination with Other Disciplines: Analyze how the architectural template should interact with templates from other disciplines, such as structural engineering or MEP (mechanical, electrical, plumbing) design.

12. Custom Parameters: Identify project-specific and shared parameters that need to be incorporated into the template for consistent data management and analysis.

13. Future Growth and Changes: Anticipate potential changes in the practice's projects and workflows. Create a template that is flexible enough to adapt to evolving needs.

14. Feedback from Users: Involve key users from different roles in the practice to provide input on the template's design and functionality. Incorporate their feedback to make the template more effective.

Creating the Revit Template File:

1. Setup and Configuration: Start by creating a new Revit project file and configuring it to include common settings, such as project units, levels, grids, and work-sharing settings. Browser Organization – Views, Sheets, Families, Annotations

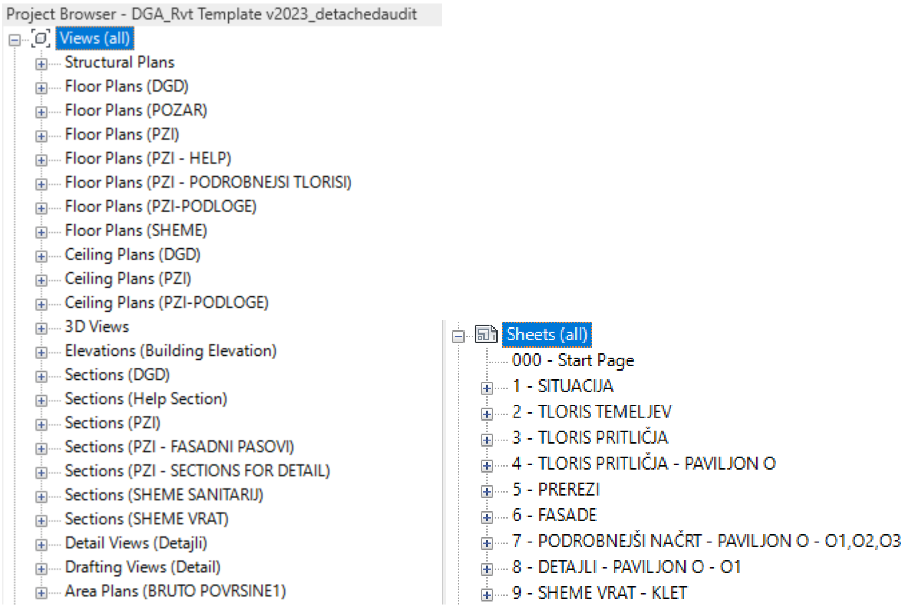

Figure 4: Preconfigured Views and Sheets Revit Template

2. Families and Content: Review of past Revit projects and past templates of cad and then the selection and extraction of families and other elements relevant. Adding standard families (components) and content that are frequently used in projects, such as doors, windows, walls, furniture, fixtures, etc.

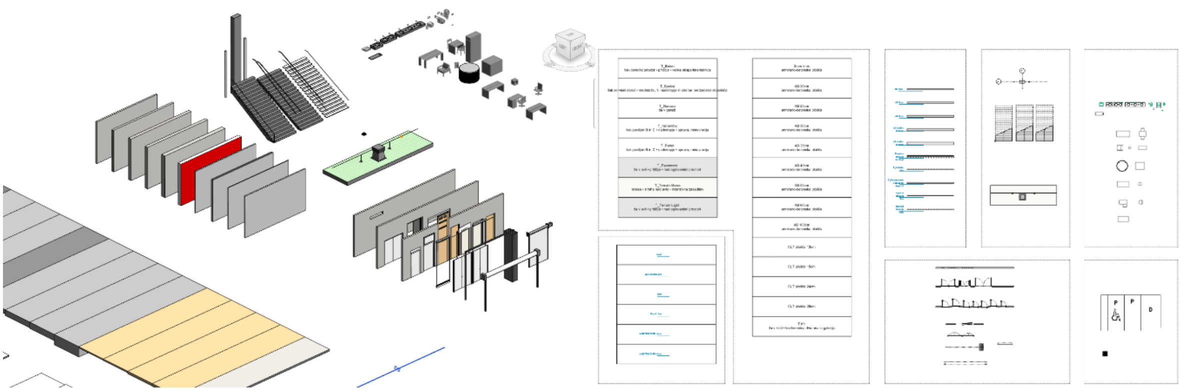

Figure 5: View of Families and Content in Revit

3. View Templates: Set up predefined view templates that control the appearance of various views like floor plans, sections, elevations, and 3D views. This ensures consistent graphics and annotations.
   Dekleva Gregorič Architects view templates – Predefined in Science Centre Project, used for this Revit template

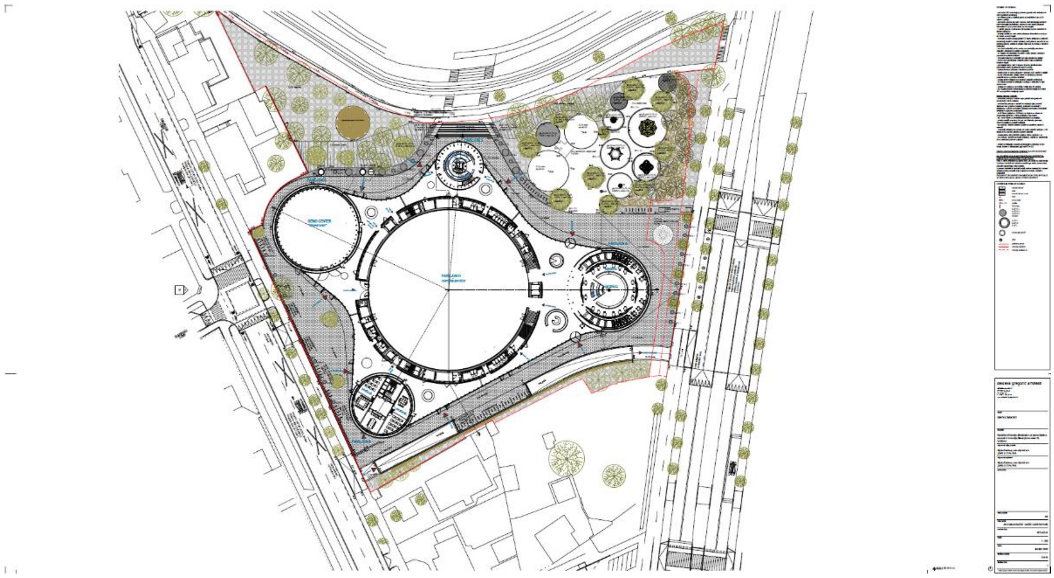

Figure 6: Situation Floorplan View Template - Dekleva Gregorič Architects

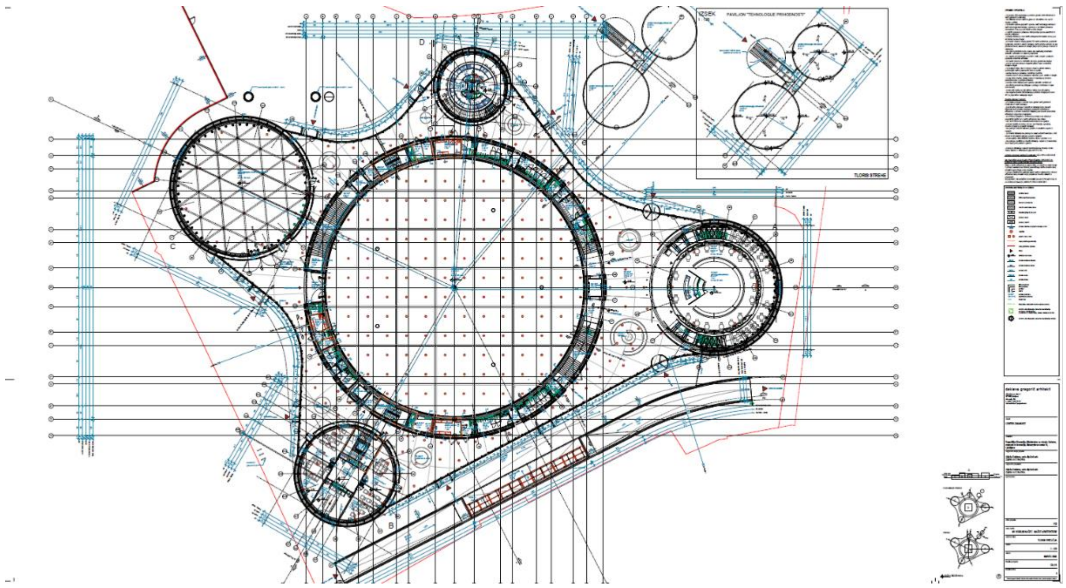

Figure 7: Ground Floorplan View Template - DEKLEVA GREGORIČ ARCHITECTS

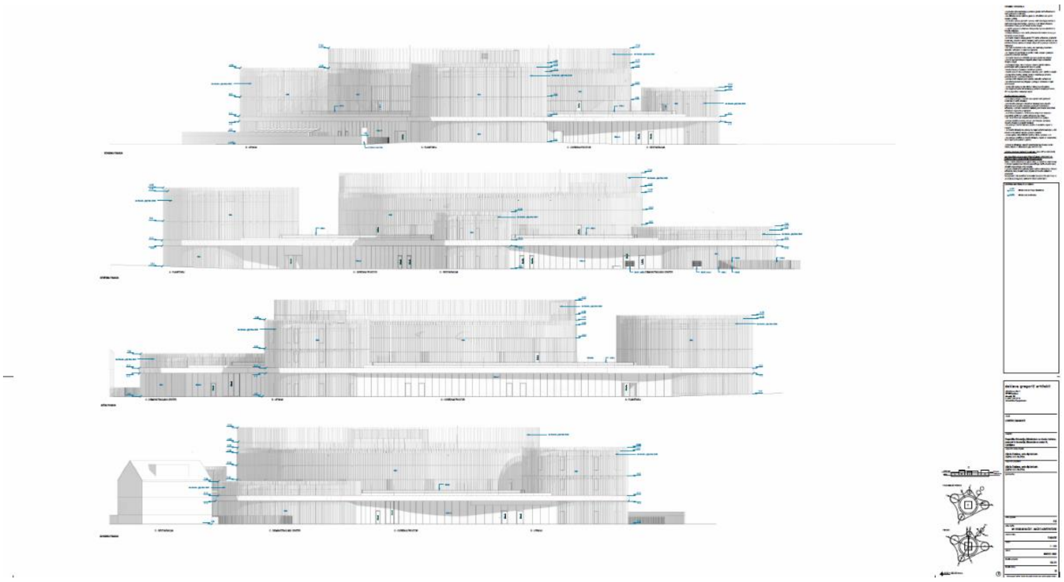

Figure 8: Elevations View Template - Dekleva Gregorič Architects

4. Title Blocks: Create standardized title blocks for sheets, containing company information, project details, and placeholders for sheet numbers, names, and dates. Welcome Page + Title Blocks Templates

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SI-1000 ljubljana
slovenija, EU
t: +386 1 430 25 70
www.dekleva-gregoric.com

objekt: CENTER ZNANOSTI

investitor: Republika Slovenija, Ministrstvo za visoko šolstvo, znanost in inovacije, Masarykova cesta 16, Ljubljana

datum: MAREC 2023

odgovorni vodja projekta: Aljoša Dekleva, univ.dipl.inž.arh. ZAPS 1117 PA PPA

odgovorni projektant: Aljoša Dekleva, univ.dipl.inž.arh. ZAPS 1117 PA PPA

spremembe

Vsakdo lahko dopolni to predlogo.

- Skladnost z uporabljenimi konvencijami o poimenovanju.
- Primeri najpogosteje uporabljenih vrst pogledov so na voljo v brskalniku projekta.
- Ko delate v osrednji datoteki, vedno odprite novo lokalno datoteko na zagonskem zaslonu Revit, tako da označite "naredi novo lokalno".
- Ko delate v osrednji datoteki, preverite svoj trenutni delovni niz.
- NE uporabljajte 'Import CAD' v projektu, vedno uporabite 'Link CAD'.
- Osnovne familije opreme se nahajajo v mapi: DELO (X:)/01 PROJEKTI/000 DELOVNE PODLOGE/17_REVIT/REVIT OPREMA
- Ko uvozite datoteko v model revit, takoj izklopite ravni te datoteke
- Ko uvožene datoteke ne potrebujete več, jo izbrišite
- Opravite revizijo modela vsakih 14 dni
- Oglejte si opozorila o modelih

REVIT TEMPLATE V 2023.0

Figure 9: Start Page Revit Template Dekleva Gregorič Architects

5. Schedules and Legends: Set up schedules, legends, and keynotes that are commonly used in projects. These can be filled with the necessary information.
6. Worksets: My recommendation for this is by categories of elements, Architecture, Furniture, and Structure… (when it's completely integrated as this project) if not as a link.
7. Parameters and Shared Parameters: Define project-specific parameters and shared parameters that allow consistent data to be associated with elements throughout the project.

8. Project Standards: Apply industry-specific standards and guidelines for naming conventions, layering, object styles, and more.

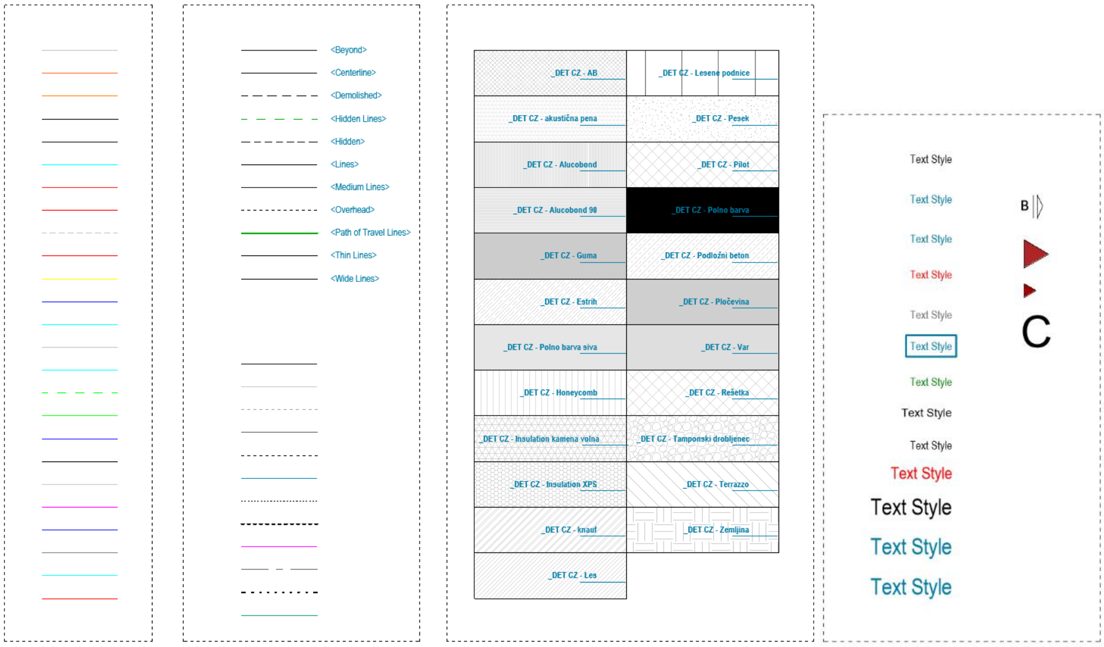

Figure 10: Drafting and Annotation Standards Revit Template Dekleva Gregorič Architects

Using a Revit Template File:

1. Create a New Project: When starting a new project, instead of creating a project from scratch, you choose to start from a template.
2. Choose a Template: Select the appropriate template file that matches the project type and company standards. This will automatically apply the predefined settings, families, and configurations to the new project.
3. Customize as Needed: Once the new project is created from the template, you can begin customizing it to match the specific requirements of the project. Add and modify elements, adjust views, and make any necessary changes.
4. Maintain Consistency: By using a template, you ensure consistency across projects within your organization. Design, documentation, and presentation standards are already set up, saving time and reducing errors.
5. Update Templates: Over time, you may update the template to include new standards, families, or best practices that have emerged in your industry.
6. Collaboration: If your architectural practice involves multiple team members working on the same project, categorize Revit's work-sharing capabilities.

7. Feedback and Improvement: Encourage feedback from your team members about the template's effectiveness. Use this feedback to make continuous improvements to the template, addressing any issues or areas for enhancement.
8. Documentation Standards: Ensure that the template includes standardized title blocks, annotation styles, and other documentation elements. This consistency helps maintain a professional appearance across all project documentation.
9. Ensure that modeling adheres to BIM standards, guaranteeing consistent implementation.
10. Reduction of Rework: avoid errors and costly rework, improving productivity.
11. Faster Production

4.5.2 Improve the Workflow

Please note that the adoption of BIM has been growing steadily over the years due to its benefits in terms of collaboration, data-rich models, and improved project outcomes. However, the choice between BIM and CAD workflows often depends on project complexity, stakeholder preferences, and available resources. To get the most up-to-date statistics on the adoption of BIM and CAD workflows, I recommend checking industry reports, surveys, and research conducted by organizations in the field of architecture and construction. CAD and BIM workflows are both essential in the field of architecture and construction, but they differ in their approach, objectives, and methodologies. Here are the main differences between CAD and BIM workflow.

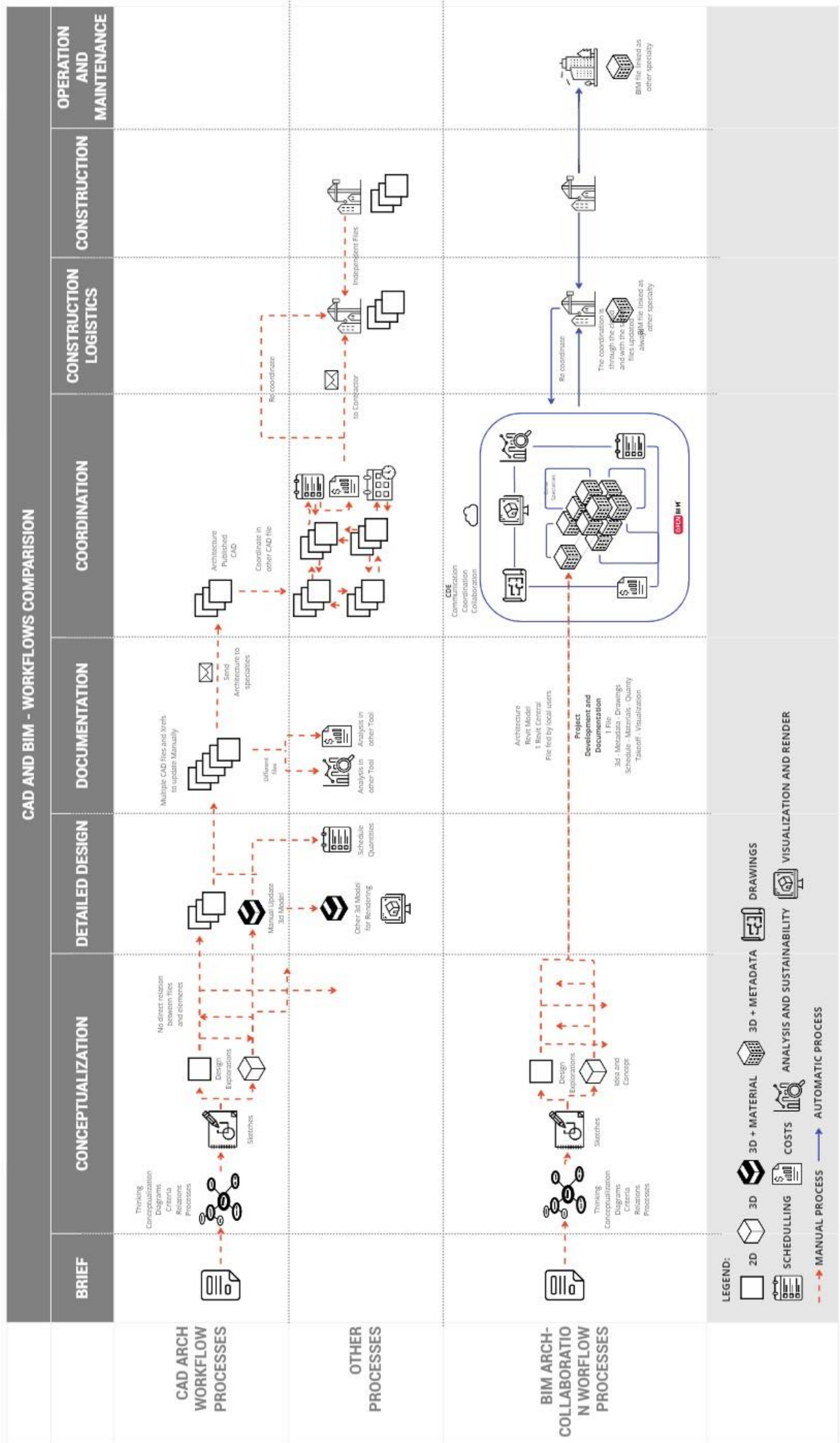

Figure 11: CAD and BIM Workflows

CAD Workflow:

- 2D Drafting: primarily involves 2D drafting, where architects create basic representations of building elements using lines and hatches.
- Limited Information: drawings lack comprehensive information and often require separate dimensions and annotations.
- Manual Updates: Changes require manual updates in all relevant drawings and documents, which can lead to inconsistencies.
- Less Collaborative: CAD workflows are less collaborative and lack 3D representation, making coordination and adjustments more challenging.

BIM Workflow

- Collaboration and Coordination: BIM emphasizes collaboration among project stakeholders and serves as a centralized hub for information sharing.
- 3D Modeling: BIM creates detailed 3D models representing entire buildings, including systems and components.
- Data-Rich: BIM models contain extensive data for analysis, simulations, clash detection, and informed decision-making.
- Efficiency and Consistency: BIM workflows improve efficiency, reduce errors, and maintain consistency across project documentation.
- Change Management: BIM facilitates accurate updates and modifications across the entire model, ensuring consistency throughout the project. According to these findings and experiences these are several differences of the 2 methodologies:

Representation	
CAD: focused on 2D and 3D geometric representations of objects. It provides precise drawings and models but lacks detailed information about the building's components, materials, and relationships.	**BIM:** Is with geometry that includes metadata about building elements. It represents objects as intelligent, parametric components with associated information, such as dimensions, materials, costs, and performance.
Collaboration	
CAD: workflows are often sequential, with limited collaboration capabilities. Multiple stakeholders may work on different versions of the same drawing simultaneously, leading to coordination challenges.	**BIM:** collaboration and coordination among all project stakeholders. Enabling real-time data sharing, allowing multiple disciplines to work on a single, coordinated model. Changes made by one discipline are reflected in real-time for others in a CDE.

Design and Analysis	
CAD: These tools are primarily for drafting and modeling. They lack built-in analysis capabilities for assessing aspects like energy performance, clash detection, and constructability.	**BIM:** allows to simulate and analyze various aspects of a building for the properties and data of the elements, including structural integrity, energy efficiency, and clash detection, leading to better-informed decisions.
Lifecycle Management	
CAD: It doesn't support the entire lifecycle of a building. For the clients is a big plus.	**BIM:** is lifecycle-oriented. From design, construction, and facilities management phases. (Operation and maintenance of the building).
Changes and Revisions	
CAD: can be time-consuming and require manual updates to multiple drawings and documents.	**BIM:** efficient change management. A single change can propagate throughout the model and associated documentation, reducing errors and saving time.
Quantification and Estimation	
CAD: can provide some basic geometric quantification, it requires manual input and calculations for estimating materials and costs.	**BIM:** automatic quantification and estimation based on the model's data. It can provide accurate material quantities and cost estimates, facilitating better project budgeting.
Documentation	
CAD: generates 2D drawings and 3D models that are typically used for documentation. These drawings may require manual updates as the project evolves.	**BIM:** generates documentation directly from the model. Changes to the model automatically update associated drawings, schedules, and other documentation.

4.6 FINDINGS

While CAD is valuable for precise drafting and modeling and has been a great tool over the years, creating lines and geometries, BIM is the next tool, which has all the 3D elements with metadata and real-life properties according to the type of object, being a digital twin, offering a comprehensive and collaborative approach that includes detailed data, lifecycle support, and better analysis capabilities. BIM is increasingly becoming the industry standard for architecture and construction projects due to its ability to improve efficiency, reduce errors, and support informed decision-making throughout a project's lifecycle, Although the timelines for project development have seen some improvements, the task of locating individuals with the skills remains not an easy task.

Even though the benefits and improvements are noticeable, the awareness of this way of working has a big learning curve in comparison to CAD work methodologies, which is simpler, with fewer clicks and processes, Consolidate all elements within a simplified, coordinated, and real-time environment, greatly alleviating the challenges associated with managing numerous files and communication issues., BIM adds a lot of new properties to elements but should be less rigid and more intuitive, BIM has transformed architectural design and construction processes in many positive ways, but it still faces challenges to overcome regarding architectural design.

5 BIM FOR ARCHITECTURAL COMPETITION

5.1 Overview

BIM can play a significant role in architectural design competitions by enhancing the quality of submissions, improving collaboration among design teams, and providing a comprehensive understanding of the proposed design. Here's how BIM can help in architectural design competitions:

- Visualization and Presentation: BIM models offer highly detailed and realistic visualizations of the proposed design. These visualizations can be used to create compelling presentations that effectively communicate the design concept to judges, stakeholders, and the public. BIM's ability to create photorealistic renderings and walkthroughs can help the jury understand the design's aesthetics and functionality.
- Data-Rich Design: BIM models contain extensive data beyond just the visual representation. This data can include information about materials, costs, quantities, energy performance, and more. Design competition submissions can leverage this data to support design decisions and showcase the feasibility of the proposed design in terms of construction, operation, and sustainability.
- Collaboration: Design competitions often involve multidisciplinary teams or collaborations between architects and engineers. BIM provides a platform for seamless collaboration, allowing team members to work together on a shared model. This leads to better integration of design elements and systems.
- Sustainability and Performance Analysis: BIM tools enable the analysis of energy performance, daylighting, thermal comfort, and other sustainable design aspects. Design competition submissions that incorporate these analyses can demonstrate a deep understanding of environmental considerations.
- Quantitative Analysis: BIM allows for accurate quantity take-offs and cost estimations. Competitors can showcase their ability to deliver a design that meets budgetary constraints without compromising quality.
- Dynamic Documentation: BIM models can generate construction documents, drawings, and specifications automatically from the model. This ensures consistency and accuracy in the documentation submitted for the competition.
- Post-Competition Benefits: Even after the competition, the BIM model can be used as a starting point for further design development, should the winning design be chosen for realization.

Incorporating BIM into architectural design competitions demonstrates not only a technological edge but also a comprehensive and thoughtful approach to design. It enhances the competitiveness of submissions by providing a holistic view of the proposed design's aesthetics, functionality, sustainability, and feasibility.

Architectural competitions have historically been essential for innovation and idea testing in the construction industry. However, challenges like clients' difficulties in understanding project functionality have raised uncertainty about their effectiveness. To address this, a preliminary study reviewed research on architectural competitions, revealing varying perceptions of BIM's impact.

Architectural competitions involve multiple actors, including building clients, architects, and consultants, and have evolved over time. They encompass elements like legitimacy, creativity, and efficiency, which can shift in focus. BIM's introduction as a new "actant" has promised accuracy and transparency, enabling detailed spatial and economic calculations. Architects have used BIM to enhance visualization and creativity.

However, there's a divergence in opinions about BIM's impact. Architects fear excessive effort on BIM models may detract from creativity, while clients emphasize buildability and detailed competition briefs.

This negotiation reflects power dynamics and the balance of legitimacy, creativity, and efficiency in competitions. BIM offers powerful simulation potential but requires structured data. But the creative part still needs more flexibility.

Technological advancements, including BIM, are responses to industry pressures. Architects emphasize quality through visualization, but clients demand more information, leading to larger competition programs.

In conclusion, the architectural competition landscape is evolving, with varying interpretations of BIM's role and competition purposes. This diversity indicates a fragmented network as actors hold differing views on competition functions and purposes, and ways to develop, which must be kept that way and be free to every practice to manage the best way they know.

BIM technology can offer more than visualization which will converge when BIM's role becomes clearer and accepted by a lot of practices towards efficiency and time. (Sørensen et al., 2015)

6 BIM AND ARCHITECTURAL COMPETITIONS CASE STUDY: REUSE ITALY – TORRE RINALDA

"Along the coastline of Puglia, in southern Italy, there are the ruins of an ancient system of fortification, the coastal towers. The towers were strategically placed along the coast, to provide visual signals to nearby towns and villages in case of sea invaders.

Torre Rinalda, located in the territory of Lecce, is a remarkable example of this architectural defensive apparatus. Built-in the 16th century with local limestone, the tower has a square base of over 10 meters on each side and a sloped body.

The competition asked the participants to design a second life for Torre Rinalda, turning it into a landmark with a restored territorial meaning, and turning the unused spaces into a public place for gathering and sighting. "(Reuse Italy Webpage, 2023)

This proposal didn't win but I'm pleased with the result and exercise regarding the design and process for this thesis about BIM and their Benefits for architectural design, in this case, related to the topic of HBIM.

6.1 Rules and Site Development

Organized by Reuse Italy in collaboration with the Municipality of Lecce, seeks to transform the deteriorated Torre Rinalda in Puglia's coastal region into a significant landmark and public square. Architects, engineers, and students are encouraged to participate by submitting their designs on a single A1 sheet by June 14, 2023. Winning projects will be exhibited in July 2023 in Lecce, with winners presenting their ideas publicly.

"Torre Rinalda, a 16th-century tower named after its location in Lecce, Puglia, once played a role in coastal defense. Despite its current ruins, it demonstrates a unique pyramid-like structure made from local stone blocks. Similar towers from that era are visible along the Puglia coast, forming a defensive network.

The challenge for participants lies in rejuvenating Torre Rinalda, both physically and conceptually. Architects, engineers, and students have the opportunity to reimagine the tower's purpose, connecting it with other towers in the area. The goal is to transform Torre Rinalda into a modern landmark, accessible to the public. The design can take the form of an art installation or an architectural addition, serving as a public space with accessible outdoor, interior, and upper levels.

The competition requires participants to establish a connection between the tower's second level and the ground floor, either internally or externally. The focus is on creating a space for people to gather, appreciate the landscape, and potentially accommodate other functions. The program excludes *considerations for external parking, private facilities, and surrounding buildings. In essence, the competition challenges participants to breathe new life into a historic military structure while fostering creativity, connectivity, and accessibility.*

The evaluation criteria for the design entries will be assessed by the jury based on specific categories, each assigned a maximum point value:

A. Territorial Scale Design Quality (max 10 points): Judges will evaluate how well the proposed design integrates the tower into the overall territory, including its relationship with other existing towers within the system.

B. Architectural Quality and Relation to the Ruin (max 15 points): The design's ability to engage with the existing ruin on an architectural level will be assessed, including precision in the approach and the conceptualization of the renovation project's monumental significance.

C. Adherence to Principles and Citizen Engagement (max 10 points): Judges will consider the design's alignment with the specified functions and objectives, as well as its capacity to unite the community". (Reuse Italy Webpage, 2023)

Documents and files are given to work on the proposal,

All competition materials for participants were available on the webpage. These include photographs, CAD drawings, 3D models, textual reports, and a BIM model. These documents have been compiled and organized by Reuse Italy exclusively for the Ideas Competition.

Figure 12: Aerial Photo Torre Rinalda - ReUse Italy

(Reuse Italy Webpage, 2023)

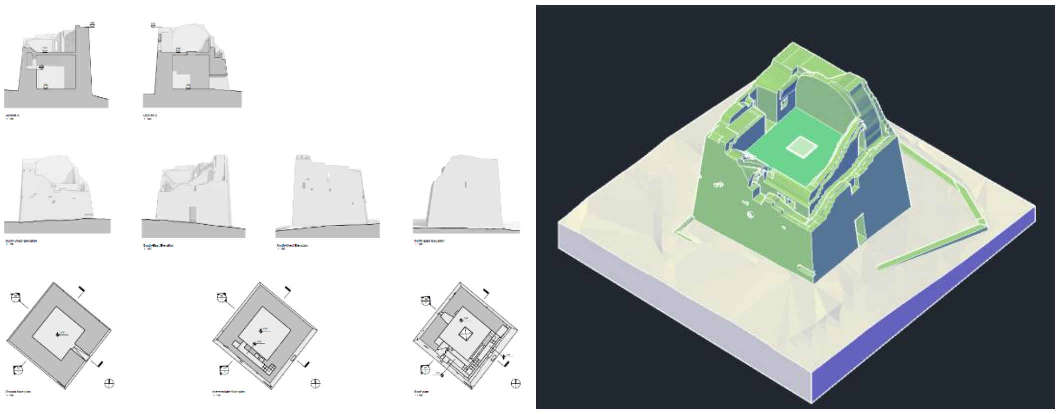

Figure 13: Cads and 3D model Torre Rinalda - ReUse Italy

(Reuse Italy Webpage, 2023)

6.2 Design Proposal

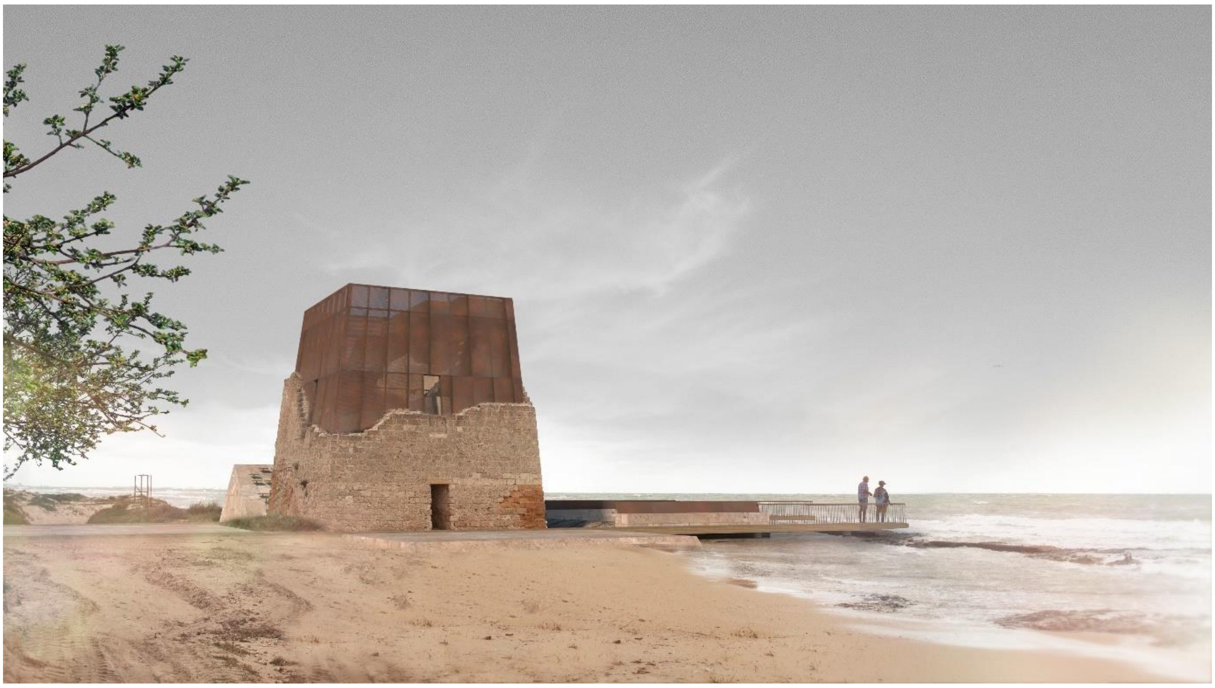

Figure 14: Exterior Render - Torre Rinalda Proposal

ATEMPORAL: Rinalda Tower Seafront

As a general concept, our aim was temporality, while preserving the essence of Rinalda Tower. Creating a public space that seamlessly integrates with the building and the surrounding landscape with a system that can be replicated with other coastal towers along the seafront. The effectiveness of a watch tower, particularly and most importantly its communication within the entire system.

In consideration of the existing tower's presence on the beach, we generated a public square by extending the building's sidelines from the beach to the city and connecting it to the sidewalk. This design follows the flow of pedestrians and the existing road, enhancing the space and incorporating limestone materials that blend harmoniously with the tower and sand.

Approaching the tower, two small squares unfold in reflection of its height. To the northwest, towards Specchiolla Tower, an external auditorium serves as a venue for events or even movie projection providing a vantage point for admiring the landscape. To the southeast, towards Chianca Tower, a welcoming space awaits visitors. Both squares face the sea and feature two piers for observation and boat docking, enhancing the area's usability for the local community.

The intervention at Rinalda Tower, based on the square design, involves connecting the levels from the ground floor to the intermediate floor using an internal Corten steel stair and a new top floor as an observation deck, generating a void between the two levels and the possibility of observing the ruin walls while going up the stairs. Respecting the original design, no external attached elements are added to the volume.

The tower's façade addition in the enclosure structure is made of perforated Corten steel. This design complements and extends the inclination of the existing walls, creating a noticeable distinction between the original surface and the restoration, evoking the missing part of the pyramid shape of the building with the use of the new material.

Conceived as a public observation tower, the Rinalda Tower invites people to enjoy the breathtaking views and learn about the coastal towers of the Kingdom of Naples. These towers served as sentinels for a complex defensive system constructed to protect ports and cities. The tower acts as a focal point for the community, capable of accommodating various scenarios for cultural activities within the space and the tower itself, linked between the sea and the city with simple guidelines to replicate among other towers.

6.2.1 Design Authoring Tool and Concept Development

To address these challenges, architects often employ a hybrid approach. They may start with traditional sketching and conceptualization techniques to explore ideas freely. Once the design direction becomes clearer, they can transition to BIM for more detailed and data-driven development. Additionally, some BIM software is evolving to better support early-stage design by providing more intuitive and flexible design tools. These tools aim to strike a balance between creativity and data-driven design from the outset of a project.

Comparing software like Revit, Rhino, and SketchUp in the context of architectural design, especially in the early stages, involves considering their strengths and weaknesses:

SketchUp - Trimble	**Rhino - Robert McNeel & Associates**	**Revit - Autodesk**
Strengths		
User-Friendly: SketchUp is known for its ease of use and quick learning curve, making it accessible to architects and designers.	Freeform Modeling: Rhino is known for its strong freeform modeling capabilities, making it ideal for creating complex, organic shapes and exploring innovative design concepts.	BIM-Centric: Revit is a powerful BIM software known for its data-driven approach, making it excellent for managing and documenting complex architectural projects.
Conceptual Design: It is well-suited for early-stage conceptualization and sketching, allowing architects to quickly visualize and iterate design ideas.	Flexibility: Architects can work with a high degree of flexibility and creative freedom in the early design stages.	Collaboration: It facilitates collaboration among architects, engineers, and other stakeholders by providing a centralized platform for design and data.
3D Warehouse and Plugins: provides a vast library to improve the modeling.	Plugin Library: Rhino's extensive plugin ecosystem allows architects to extend its functionality for specific design needs.	Construction Documentation: Revit excels in generating detailed construction documentation, making it suitable for later design phases.
Weaknesses		
Limited BIM: While SketchUp offers some BIM functionality through plugins, it is not a full-fledged BIM software, which can limit its usability in complex projects.	Limited BIM: While Rhino can work with BIM data through plugins, it is not inherently a BIM software, which may be a limitation in projects requiring strict BIM compliance.	Early Design Flexibility: Revit can be less flexible and intuitive in the early conceptualization phase compared to software designed primarily for freeform modeling and sketching.
Data Management: It may struggle with managing extensive project data and detailed documentation compared to BIM software like Revit.	Less Structured: It can be less structured and organized compared to BIM-focused software, which might pose challenges in later project phases.	Learning Curve: It has a steeper learning curve, and architects may find it challenging to quickly create and iterate design concepts.

I opted to use SketchUp for the early conceptualization stage primarily because it required fewer clicks, reduced the need to contemplate complex model operations, and maintained a simpler structure with fewer categories. SketchUp's user-friendly interface and intuitive tools allowed me to focus more on creative thinking and less on the technicalities of the software. Its straightforward approach minimized the hurdles in performing design options and changes, liberating my thought process and providing me with ample time to explore and refine my creative ideas without being bogged down by the intricacies of the tool. This workflow efficiency encouraged a more fluid and innovative approach to architectural design during the crucial early stages of the project.

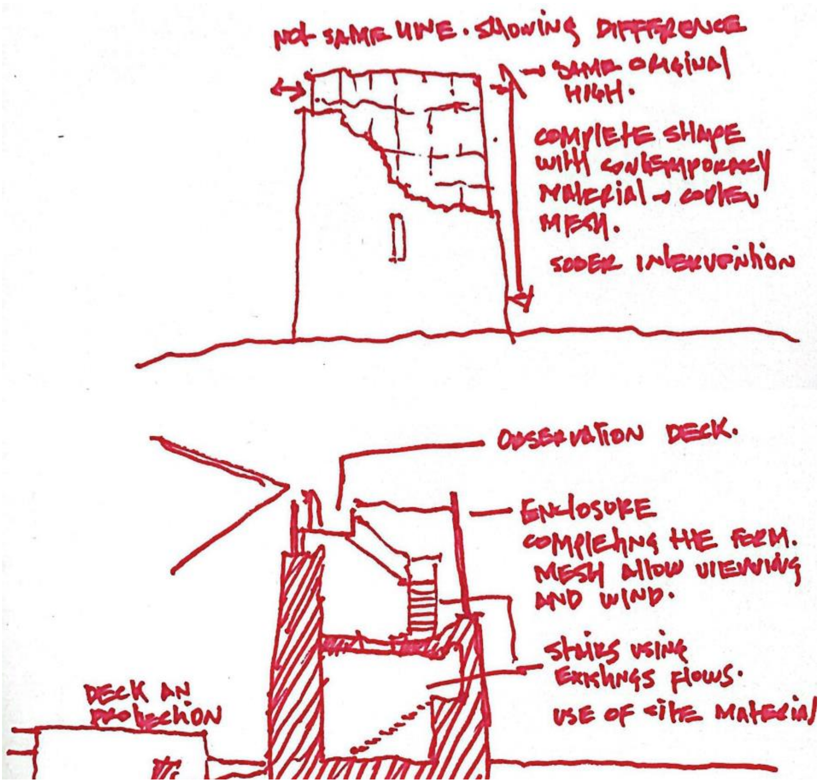

Figure 15: Sketches For Torre Rinalda Proposal

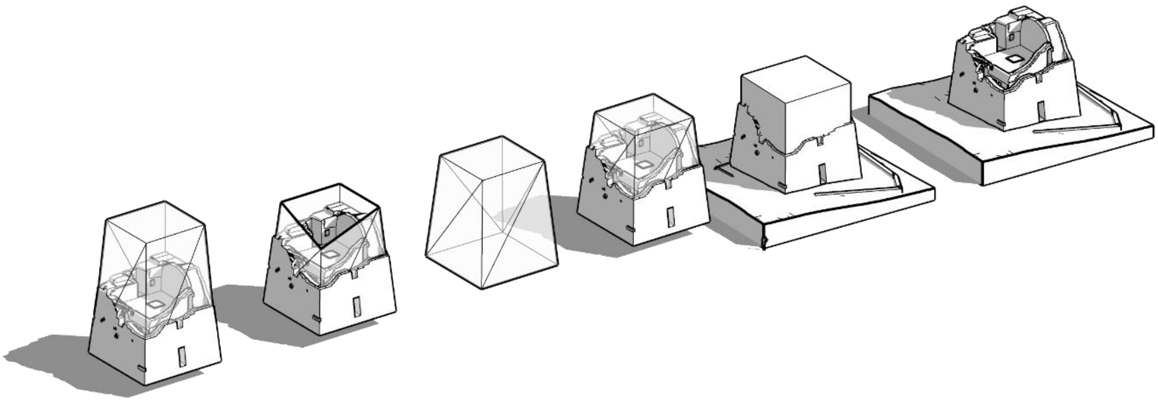

Figure 16: Explorations of Design in SketchUp

6.2.2 Context Modelling

For contextual modeling, Reuse Italy utilized CAD drawings depicting the current state of the surrounding area near the project site. With the help of Google Maps, it became possible to approximate the heights of neighboring buildings. This process involved incorporating site components into the model, using extrusions to represent it. Also, webpages like CadMapper help a lot with these situations.

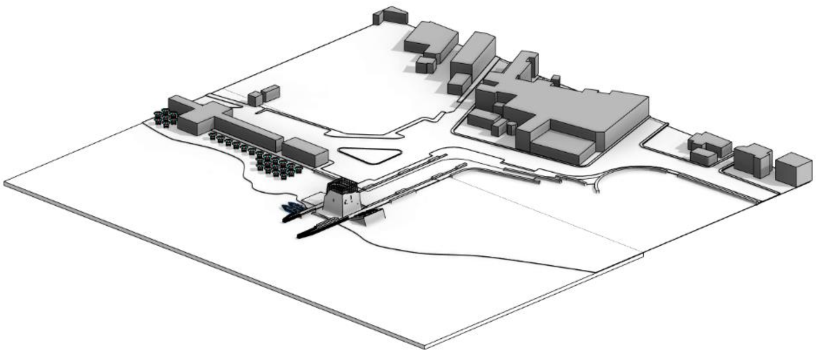

Figure 17: 3D model situation Revit - Torre Rinalda Proposal

6.2.3 Massing and Modelling

Drawing from my ten years of experience as an architectural designer, I've found that the best software for initiating any design should cater to the architect's preferences, offer exceptional flexibility, and allow for effortless management, modification, adjustment, adaptation, copying, stretching, and layer control. It should support a seamless creative process, devoid of excessive steps or rigidity, which can be encountered when using Revit's massing tools and solid creation interface. When the design concept is not firmly established, the software should remain intuitive and accommodating. In my case and previous offices I've worked for, software like SketchUp and Rhino has proven to be invaluable during the creative and conceptual phases of a project. These tools provide a more natural and unrestricted approach to design, particularly when the design direction is not yet fully defined.

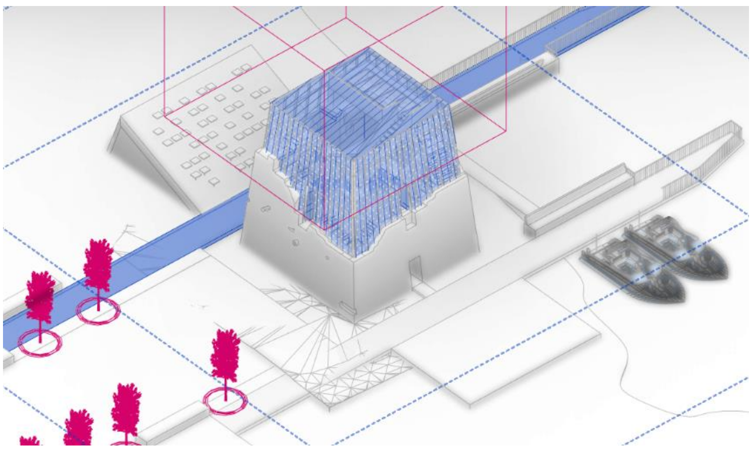

Figure 18: 3d Massing Revit - Torre Rinalda Proposal

6.3 Revit views and visual improvements with view templates

The creation of views and customized view templates in Revit helped me to manage the general appearance of the drawings, as I wanted to look very simple, in black and white with some shadows on to understand better the massing, as it is a competition the focus is to look the best as it can be and communicate the idea properly.

Then in one customized sheet with the requirements of the competition was easier to manage, change, and adjust, dimensions and scales. Afterwards, even though Revit gave me the look I wanted it could be improved with other elements in Photoshop, aerial views, trees, silhouettes, and drawings.

Figure 19: Site Situation Urban Scale - Revit View / Photoshoped Drawing - Torre Rinalda Proposal

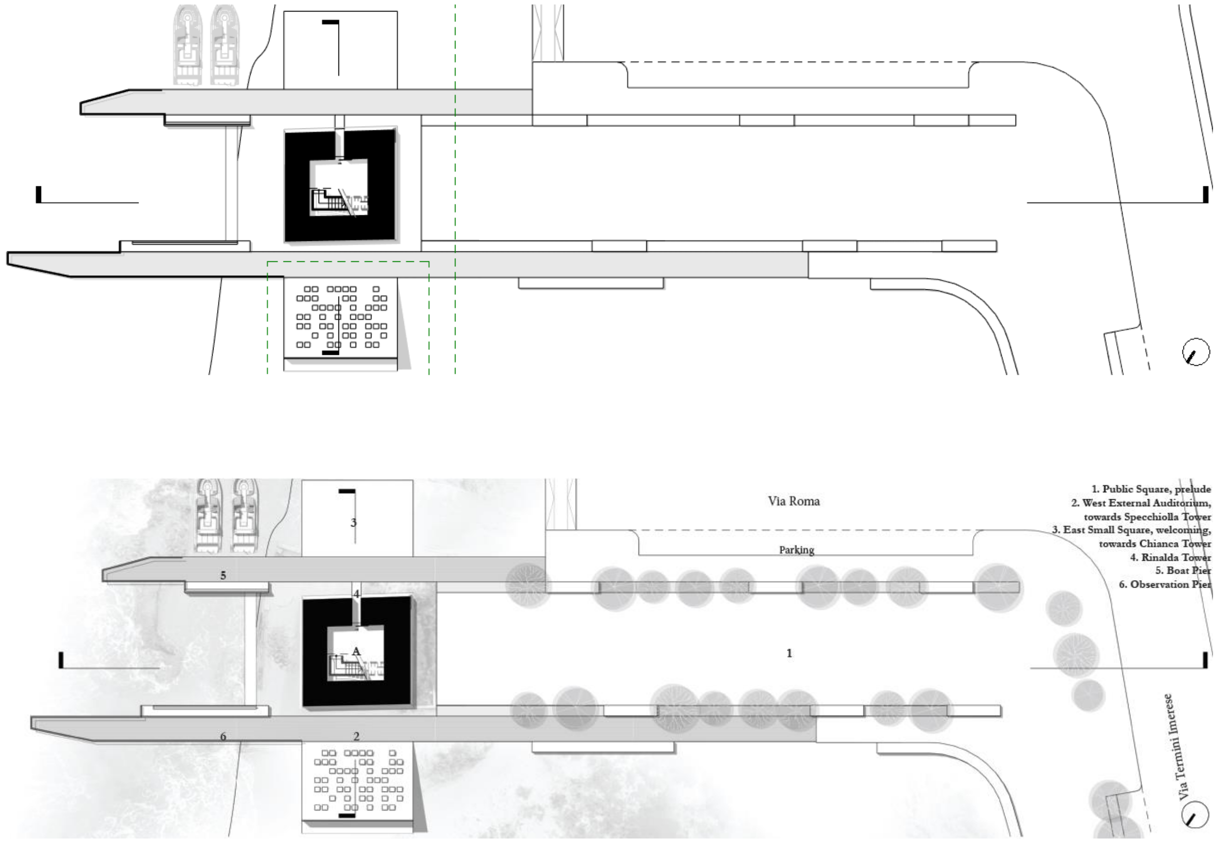

Figure 20: Site Situation Urban Scale - Revit View / Photoshoped Drawing - Torre Rinalda Proposal

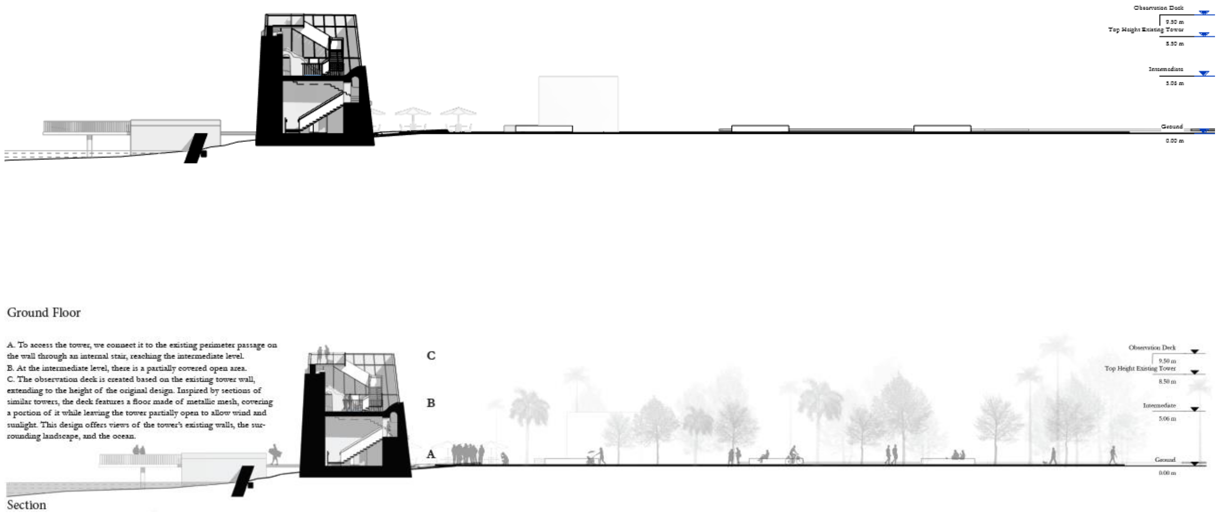

Figure 21: Section - Revit View / Photoshoped Drawing - Torre Rinalda Proposal

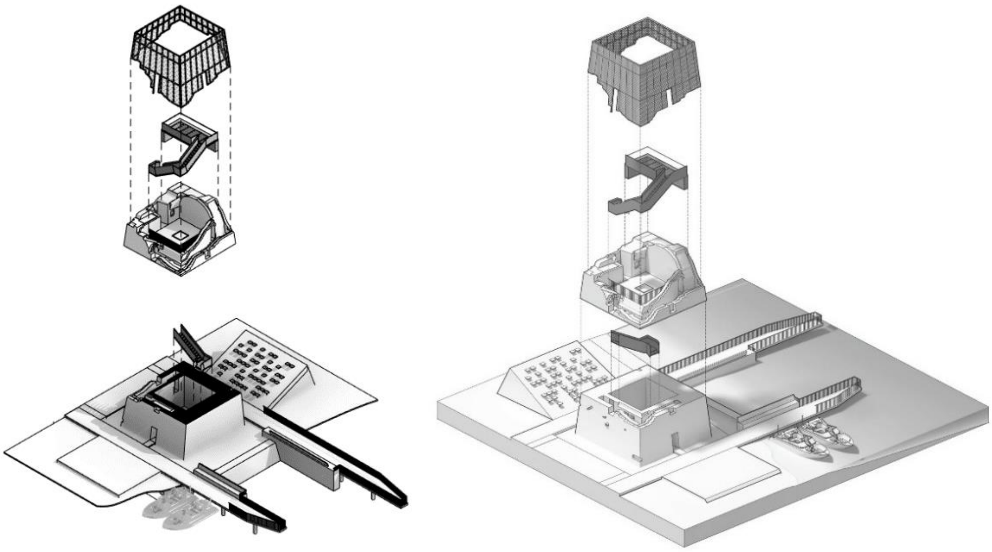

Figure 22: Displaced Axonometry - Revit View / Photoshoped Drawing - Torre Rinalda Proposal

6.4 Renderings

The renderings were made in Enscape and then Photoshopped for a better outcome, and also very important to adjust the photo match, that was required for the entry.

Figure 23: Aerial View Render - Torre Rinalda Proposal

Figure 24: Interior View Render - Torre Rinalda Proposal

Figure 25: Aerial View to the Beach - Torre Rinalda Proposal

6.5 Results and Workflow for the HBIM Competition Case Study

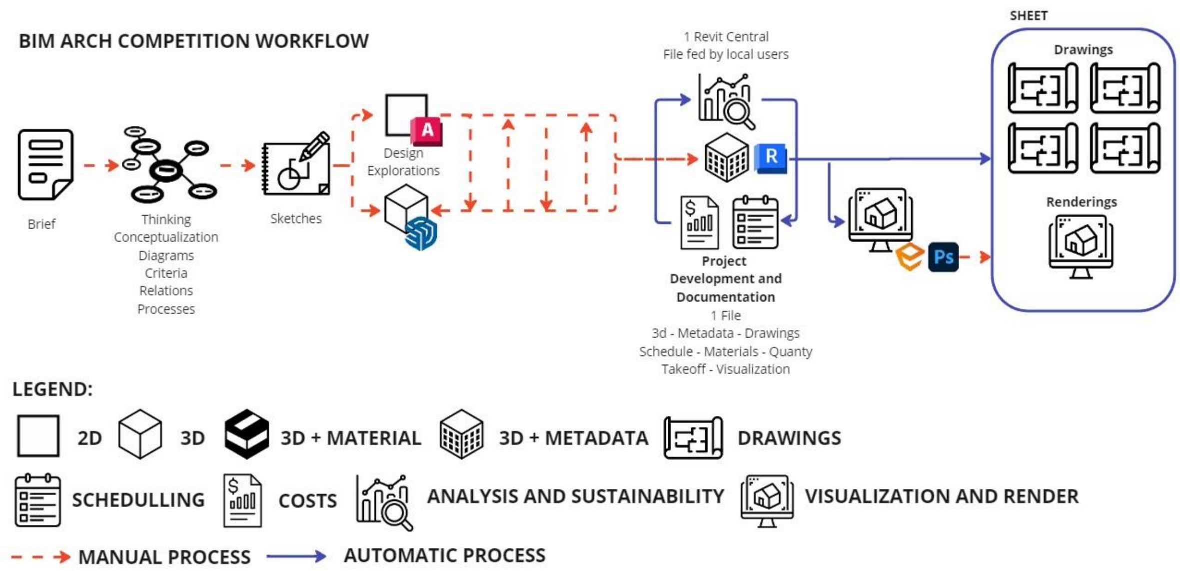

Figure 26: BIM Workflow used in Architectural Competition

This workflow shows the advantages of starting design explorations in user-friendly and intuitive software like SketchUp or Rhino. Once the design is well-defined and mature, transitioning to BIM software like Revit becomes seamless. In the BIM environment, the model can be developed with properties and information assigned, enabling analysis, scheduling, quantity takeoffs, and the creation of various views and visualizations. These elements can then be effortlessly incorporated into sheets with the required format, ensuring automatic updates across all related views in response to any changes made. This interconnected and automated approach streamlines the design process and enhances efficiency to finalize and take to the next level of graphical aesthetic which is crucial for any competition, with the help of Photoshop all drawings and rendering have postproduction.

View of the A1 poster entry for the competition. The view of the Revit sheet, and then added with the postproduction of drawings and renderings

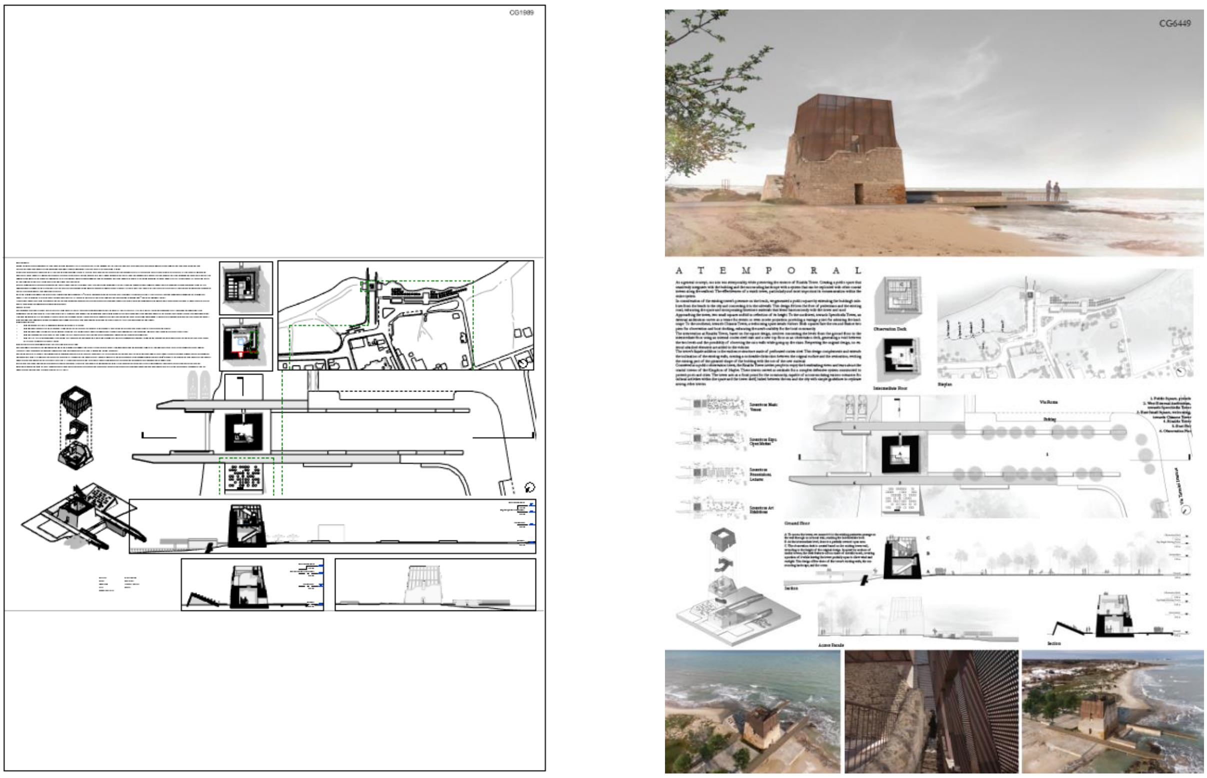

Figure 27: A1 Poster Competition Entry - Torre Rinalda Proposal

6.6 Findings

BIM software can sometimes be less flexible in the early stages of design, particularly during the conceptualization phase. Here are some challenges and considerations related to BIM in the early design stages:

Lack of Creativity: BIM software can sometimes restrict architects' creative freedom during the initial brainstorming and conceptualization stages, as it may emphasize precision and data over conceptual exploration.

Limited Sketching Capabilities: BIM software may not offer the same level of intuitive sketching and freeform design tools that traditional drawing or sketching mediums provide.

Data Overload: Early design phases are more focused on broad ideas and concepts. BIM's emphasis on detailed information may feel cumbersome and excessive at this stage.

Flexibility: Architects may need more flexibility to experiment with different design alternatives quickly. BIM can sometimes feel rigid in this regard, as changes may require substantial model adjustments.

Interoperability: Integrating BIM into early design phases can be challenging due to limited interoperability with other design tools and conceptualization techniques.

Integrating BIM software into early architectural design stages presents challenges such as limited creativity, sketching capabilities, data overload, inflexibility, and interoperability issues. Architects often adopt a hybrid approach, combining traditional methods with BIM.

Comparing SketchUp, Rhino, and Revit, SketchUp is user-friendly and suitable for early conceptual design, while Rhino offers flexibility, and Revit excels in BIM. Each has its limitations, so the choice should align with project needs and design preferences. As technology advances, architects can expect tools that better balance creativity and data-driven design.

BIM definitely enhances the architectural competition process by simplifying workflows and streamlining various aspects of design. In architectural offices, when preparing for competitions, efficiency, and accuracy are crucial. BIM offers several advantages:

- **Streamlined Workflow:** BIM software provides a centralized platform where architects can develop, visualize, and document their designs.
- **Automatic Updates:** BIM models are parametric, meaning that changes made in one part of the model automatically propagate throughout all related views and drawings. This eliminates the need for manual updates, reducing the risk of errors and saving valuable time.
- **3D Development:** BIM models are inherently 3D, allowing architects to work in a more immersive and realistic environment.
- **Data Integration:** BIM incorporates data into the design process. Architects can attach relevant information to building elements, such as materials, costs, and energy performance. This data-driven approach enables better decision-making and more accurate cost estimations, which are critical in competition submissions.
- **Collaboration:** BIM facilitates collaboration among team members, including architects, engineers, and consultants. Everyone can work on a single, centralized model, ensuring that all design aspects are coordinated and integrated seamlessly.
- **Visualization embed BIM**: software offers advanced visualization capabilities, allowing architects to create realistic 3D renderings and walkthroughs. These visuals are invaluable for presenting design concepts to clients and competition panels, helping them better understand and appreciate the design.

In essence, BIM simplifies and accelerates the design process, enhances collaboration, and improves the quality of design presentations—all of which are highly advantageous in the fast-paced and competitive world of architectural competitions.

7 BIM INTEGRATED VISUALIZATION

The shift from traditional 2D drawings to 3D BIM in the architecture, engineering, and construction industries. BIMs serve as repositories of detailed information supporting various applications throughout the design and construction processes. Real-time visualizations using BIMs facilitate communication and collaboration among stakeholders. However, large and detailed BIMs present challenges for real-time rendering in existing BIM viewers. The paper presents findings from analyzing four popular BIM viewers in terms of real-time rendering performance and identifies their limitations in handling complex models. To address these limitations, the paper introduces a prototype BIM viewer with modern algorithms for real-time rendering of large 3D models, aiming to provide both accuracy and interactivity. The paper concludes with a review of related work, methodology, findings, and implementation details of the prototype viewer. (Johansson et al., 2015)

7.1 Background BIM and Real-time Visualization

With the widespread adoption of BIM in the AEC industries, real-time 3D visualization has become more accessible. However, the increasing size and complexity of BIMs pose challenges for real-time rendering. Many existing BIM viewers fail to handle large and detailed models, leading to performance issues. Some workarounds involve breaking down the main model into sub-models, but this approach requires additional modeling work and restricts visualization sessions.

Despite the recognition of the challenge, there are uncertainties in the research literature. Studies often lack specific details about the size of the models and the hardware and software used. The current problem space mainly revolves around model size and computing power, neglecting potential limitations in software efficiency.

While real-time visualization of large 3D data is a research topic, there has been limited attention to the specific case of large BIMs. Some efforts have been made to leverage cloud computing and game engines for real-time visualization, but they often face limitations in image quality, real-time performance, or lack real-life project representations.

In this study, the authors address this gap in the research literature by providing an in-depth analysis of the rendering capacity of commonly used BIM viewers and by evaluating and implementing efficient real-time rendering algorithms in a prototype BIM viewer. The goal is to provide insights into the current state of real-time visualization of large BIMs using recent technological advancements. The study's metric for real-time performance is the frame rate. (Johansson et al., 2015)

This type of software requires high computer specifications such as a good video card, processor, and memory. The frame rate is a crucial factor in real-time rendering systems. Various applications have shown that a frame rate of around 15 Hz is the minimum acceptable level for maintaining user performance and comfort. Below 15 Hz, tasks like navigation and interaction become significantly degraded. However, 30 or 60 Hz is often preferred for a better user experience. For interactive visualizations, 30 Hz is considered the minimum satisfactory level, ensuring smooth and responsive experiences. Modern 3D computer games also target 30 Hz for smooth gameplay. In this study, the authors define the minimum, satisfactory, and optimal frame rates as 15, 30, and 60 Hz, respectively, to evaluate the interactivity and real-time performance of their prototype BIM viewer.

The performance of CPUs and GPUs has significantly improved in recent years, but there is still a limit to the amount of 3D data that can be interactively managed by a system out-of-the-box. However, there are acceleration techniques that can go beyond this limit. These techniques can be categorized into three groups: pipeline optimizations, LOD, and visibility culling.

Pipeline optimizations focus on effectively utilizing available hardware to feed the GPU with data and rendering tasks at a high rate. This involves storing geometry data directly in GPU memory using buffer objects, batching geometry from multiple objects to reduce draw calls, sorting objects by material properties to minimize rendering state changes, and using hardware-accelerated geometry instancing for scenes with replicated objects.

While these optimizations are efficient, they do not reduce the amount of data processed by the GPU for every frame, making them not indefinitely scalable. Further techniques such as LOD and visibility culling are necessary to handle larger and more complex 3D scenes. (Huang et al., 2017; Johansson et al., 2015)

Visibility culling is another acceleration technique aimed at enhancing rendering performance by processing only potentially visible geometry. It includes view-frustum culling, back-face culling, and occlusion culling. View-frustum culling rejects objects outside the camera's view, back-face culling discards polygons facing away from the viewer, and occlusion culling rejects objects hidden by other objects. Occlusion culling is more complex and involves tests against proxy geometry to determine visibility.

In some non-conservative culling approaches, like contribution culling, small objects with a minimal visual contribution are discarded to improve performance. Drop-culling takes into account object priority, frame rate, and heuristics to drop low-priority objects, but it can cause distracting visual artifacts.

Overall, these acceleration techniques can be combined to efficiently manage large and complex 3D scenes, improving real-time rendering performance for building models and other interactive applications.

BIM and rendering visualization are two interconnected aspects of architectural practice that contribute to the design and presentation of building projects.

BIM provides a comprehensive digital representation of a building, incorporating geometric information, spatial relationships, material properties, and other relevant data. It enables architects and designers to create intelligent 3D models that serve as a centralized database for project information. This information and 3D model form the foundation for various processes, including rendering visualization. Involves the creation of realistic and immersive visual representations of architectural designs. It brings the BIM model to life by applying materials, textures, lighting, and other visual elements to simulate the appearance of the building.

Rendering techniques aim to produce high-quality images or animations that accurately portray the intended design intent, allowing stakeholders to visualize and experience the project before construction begins.

By integrating BIM with rendering visualization, architects can have detailed information in the model to improve the quality and realism of visualizations. The model has a reliable source of data, including material properties, lighting parameters, and camera viewpoints, which can be directly utilized in the rendering process, just as it was designed, every element has their information and the rendering will show this.

The integration streamlines the visualization workflow and ensures consistency between the BIM model and the rendered images or animations. (Johansson et al., 2015)

7.1.1 Integrated rendering in BIM software advantages

- Data Synchronization: As the rendering is performed within the same BIM software, there is automatic synchronization between the 3D model and the rendering environment. Any changes made to the BIM model are reflected in the rendering in real time, ensuring accuracy and eliminating the need for manual updates.
- Material and Lighting Libraries: BIM software with integrated rendering typically provides preloaded libraries of materials, textures, and lighting options. These libraries offer a wide range of choices to customize the appearance of the rendered scene, making it easier and faster to create realistic visualizations.

- Seamless Workflow: Users can seamlessly switch between modeling and rendering modes within the same software, reducing the need for exporting models to separate rendering software. This saves time, eliminates data loss, and allows more design iterations.
- Control over materials, lighting, and camera settings. This enables precise adjustments to achieve desired visual effects and simulate various lighting conditions.
- Real-Time Visualization: Some BIM software provides real-time rendering capabilities, allowing them to see immediate visual feedback as they make changes to the model. This enables quick design exploration.

7.2 Tools

I have to say that integrated rendering in BIM software can produce high-quality visualizations but not as good as specialized standalone rendering software, it offers more advanced features and greater control over the rendering process. In complex projects requiring photorealistic renderings or advanced lighting simulations, architects may choose to use dedicated rendering software for more advanced results.

7.2.1 Rendering Integrated Directly in BIM Software

Several BIM software include rendering visualization integrated with their platforms. These are some popular software tools known for their integrated rendering features:

- Autodesk Revit: offers built-in rendering capabilities through its "Autodesk Raytracer" engine. It allows users to create “realistic” renderings directly within the software, utilizing materials, lighting, and camera settings from the BIM model.

- Graphisoft Archicad: incorporates the CineRender engine. It offers advanced features such as global illumination and physically-based materials.

- Bentley AECOsim Building Designer, developed by Bentley Systems.

- Vectorworks Architect: includes an integrated rendering engine called "Renderworks.

These are just a few examples of BIM software that offer integrated rendering capabilities. It's important to note that the rendering features and capabilities may vary across different software versions and editions. However, in my opinion, while these integrated features are included in the software, they may not be sufficient for producing high-quality renderings. The rendering engines provided are often basic, resulting in subpar results. Additionally, companies may prioritize adding more clients to their other software, such as Revit for modeling, and rely on separate rendering software like 3ds Max with Mental Ray, V-Ray, or Corona for more advanced rendering options, including advanced lighting, materials, and rendering settings. Consequently, if you want to create impressive imagery, you may need licenses for Revit, 3ds Max, and the dedicated rendering engine.

This is where standalone rendering software comes into play. Positioned between being fully integrated within the BIM software and being entirely separate, these rendering software options establish a direct connection to the Revit model through a plugin, allowing for live synchronization and data acquisition from the objects. Notable examples of such software include Lumion, Enscape, Twinmotion, and V-Ray (as a plugin in Revit). It's important to note that while they enable the creation of highly realistic renderings and visualizations, the results may not be equivalent to those achieved with V-Ray for 3ds Max.

7.2.2 Rendering with Integrated Plugin in BIM Software

A plugin, also known as an add-in or extension, is a software component that enhances the functionality of an existing software application, such as Revit, which is the software I'm using. It is designed to work in conjunction with the host software, extending its capabilities or adding new features that are not included in the base program.

In the context of Revit, a plugin is a separate software module developed by a third-party provider that integrates with Revit's architecture and extends its functionality. Plugins are typically developed to address specific needs or provide specialized tools and workflows with specific user requirements and are added to the interface as new panel buttons.

The best Rendering plugins are Enscape and V-Ray are the most advanced and popular, offering additional rendering options and advanced visualizations integrated into Autodesk Revit. Here's an overview of these plugins and their functionalities:

Enscape: Enscape is a real-time rendering and visualization plugin that seamlessly integrates with Revit. to quickly create high-quality visualizations directly from Revit.

- Real-time Rendering: instant feedback, in a newly opened window only for Enscape, allowing users to visualize changes in real-time as they navigate the model in the Enscape window or the Revit window.
- Easy-to-use Interface: The friendly interface makes it easy to orbit, pan or walk.
- Virtual Reality Experience: allows to export their Revit models to VR devices, to experience the design in an immersive environment with special goggles or the cellphone.
- Lighting and Material Controls: adjust lighting conditions, apply materials, and modify settings such as reflections and shadows to achieve desired visual effects more easily than complex engines.

- Photorealistic Rendering: high-quality and photorealistic rendering output, allowing the production of realistic visualizations of the designs, customizable skies, shadows, wind, bloom glare, and other options. (<i>EnscapeTM - Real-Time Rendering and Virtual Reality | Enscape</i>, n.d.)

V-Ray: is a renowned brand that could be named the top rendering plugin used in various design industries, including architecture.

V-Ray was originally designed for 3ds Max excels in flexibility, versatility, and advanced rendering capabilities, making it ideal for complex visualizations across different industries. V-Ray for Revit, as an emphasis on integration with Revit workflow, with efficient rendering solutions focused on architectural visualization.

Even though the version for 3dsmax is the best with more versions and fixes, you have more options and flexibility for materials, lights, and render configuration.

When integrated with Revit, is less advanced but still provides advanced rendering capabilities and fine-grained control over lighting, materials, and visual effects(*Revit Vray vs 3DS Max Vray - General Discussions - CGarchitect Forums*, n.d.)

- High-Quality Rendering: highly realistic and visually stunning renderings, with options for global illumination, advanced shading, and accurate light simulation.
- Material Editor: This allows to creation and manipulation of complex materials, including realistic textures, reflections, and transparencies.
- Lighting Control: offers precise control over lighting parameters, including the ability to simulate natural lighting conditions and adjust artificial light sources.
- Distributed Rendering: supports distributed rendering, enabling multiple machines or networked computers to accelerate the rendering process.
- Post-processing Effects: includes a range of post-processing effects and image adjustments similar to Photoshop in the same window that can be applied to renderings, improving their visual impact. (*V-Ray 3D Rendering Software | Chaos*, n.d.)

Both Enscape and V-Ray plugins enhance the rendering and visualization capabilities of Revit, providing architects with more advanced options for creating compelling and realistic visual representations of their designs. These plugins offer a level of control and realism beyond the built-in rendering features of Revit, allowing architects to produce high-quality renderings, interactive experiences, and immersive VR walkthroughs to effectively communicate their design intent to clients and stakeholders.

8 CASE STUDY: SCIENCE CENTRE - DEKLEVA GREGORIČ ARCHITECTS, LJUBLJANA SLOVENIA

For this case study we are using Enscape, the software selected by Dekleva Gregorič Architects.

Enscape was first introduced as a plugin for Revit in 2014, offering real-time rendering and visualization capabilities directly in Revit. Since its release, Enscape has gained popularity among architects, designers, and visualization professionals for its ease of use, real-time rendering speed, and high-quality results.

Quickly gained recognition in the architectural industry due to its ability to provide instant visual feedback, allowing users to see the impact of design changes in real-time. This real-time rendering capability revolutionized the workflow for many architects, as they could make quick design decisions and communicate their ideas effectively with clients and stakeholders.

A real-time rendering and visualization software developed by Enscape GmbH, a company based in Karlsruhe, Germany. Here's an overview of the history of Enscape:

- 2014: Initially released as a plugin for the architectural software Revit. The plugin provided real-time rendering capabilities directly with Revit
- 2015: Expanded its compatibility and released plugins for other popular architectural software, including SketchUp and Rhino.
- 2017: launched its standalone version, Enscape 2.0, which enabled them to directly import their 3D models and create real-time renderings without the need for separate architectural software.
- 2018: Introduced virtual reality support. enabling them to provide their clients with interactive walkthroughs of their projects.
- 2019: Expanded its compatibility by releasing plugins for additional software, including ArchiCAD and Vectorworks.
- 2023: Enscape and Chaos (Software company of Vray) have announced their merger, with plans to form a newly combined company where both parties will join as equal partners. The headquarters of the new company will be in Karlsruhe, Germany. Enscape will continue as a product brand, and the development of Enscape will be prioritized with plans for future enhancements, including the release of Enscape 3.3 and the first version of Enscape for Mac. The merger aims to leverage the strengths and technologies of both companies to provide users with improved visualization solutions and services. (Enscape and Chaos Merger: Your Questions Answered, n.d.)

8.1 Science Centre Project

The project for this case study for BIM visualization and rendering is the Science Science Centre in Ljubljana, Slovenia, designed by Dekleva Gregoric Architects. Where I was working in-house developing the process by hand with the team of architects as a BIM Master Intern.

"Slovenia recognizes the importance of science as a driver of progress and aims to establish a "Science Center" to promote and popularize science in the country. The center will serve as a hub for science, education, economy, and culture, fostering collaboration and showcasing scientific and economic achievements. It will offer interactive programs, including do-it-yourself experiments, to encourage research, critical thinking, and creativity among young people. The center will also present scientific findings and innovations simply and interactively. Additionally, it will serve as a test ground for learning and further development of technologies, facilitating the transfer of knowledge into practice and promoting the use of new technologies.

The idea of establishing a comprehensive "Science Center" that integrates science promotion with education, culture, and the economy has guided the project from its inception. To ensure a well-rounded approach, the Ministry formed an interdepartmental project group comprising representatives from various ministries and external stakeholders. To gather the best program starting points, the Ministry invited expressions of interest and formed a program group consisting of research institutes, universities, and technology parks. An analysis of science centers worldwide was conducted to inform the program's content.

Based on these activities, key program areas were identified, including a central space with interactive exhibits, a demonstration center showcasing economic innovations, a virtual junction for collaboration, a Fablab for research and development, laboratory classrooms, a gallery for temporary exhibitions, meeting rooms, a conference hall, a media center, and various other spaces.

For this project The Ministry launched an international architectural competition, in collaboration with the Chamber of Architecture and Space of Slovenia, to obtain the most suitable architectural solution for the "Science Center." The winning solution, designed by Dekleva Gregorič architects, features circular pavilions connected in a shared public space, reflecting the universal and self-organizing forms found in nature. The "Science Center" will occupy an area of approximately 10,000 m2". (*Izgradnja Centra Znanosti Kot Demonstracijskega Objekta | GOV.SI*, n.d.)

"The project aims to construct and establish the "Science Center," which will serve as both a technical-technological demonstration facility and a venue for various programs related to science promotion and communication in connection with education, culture, and the economy." (Dekleva Gregorič Architects, 2020)

Location

The designated site for the "Science Center" is situated in the central part of Ljubljana, specifically in Trnovo. It is conveniently located within the motorway ring, near the city center. The site is characterized by a wedge shape, bordered by Barjanska Cesta to the west, Riharjeva Street to the east, and connected to existing park areas along the Gradaščica River on the northern edge.

Figure 28: Science Centre Project - Location

(*Izgradnja Centra Znanosti Kot Demonstracijskega Objekta | GOV.SI*, n.d.)

8.2 Program Concept

"The Ministry assigned Institute 404 and subcontractors to develop the program concept and equipment design for the "Science Center" through a public contract. A large number of experts participated in the preparation, representing diverse fields of expertise. The program concept aims to emphasize the message that science is all-encompassing, for everyone, and a continuous process. The program covers various scientific topics, with a particular focus on Space and Life on Earth. The Planetarium will present the universe, while the Central Space will focus on Life on Earth, divided into Life itself and the Conditions for Life. The Conditions for Life are further categorized into Planet Earth, Climate Change, Energy, and Information. The Central Communicator serves as the main area for scientific presentations, surrounded by content related to Fundamental Theories of Physics. Each section of the circle features an Attractor exhibit that highlights scientific fields within the Central Space. The edge ring of the Central Space is designated for temporary exhibitions, showcasing current scientific research and sustainability solutions for approximately two years. The program concept allows for future development and incorporation of new content within the "Science Center."

The Science Centre is envisioned as a cluster of circular pavilions nestled within a park, connected by a shared green roof. It will be located in the Trnovo neighborhood, specifically in the green corridor between Barjanska Cesta and Riharjeva Cesta. The establishment of the Science Centre will play a significant role in the development of the southern part of Ljubljana. By integrating the pavilions into the park, the design preserves the open and green nature of the area while enhancing it with the Centre's program and aesthetics. The circular pavilions, enveloped by lush surroundings, serve as a visual representation of the harmonious coexistence between science and nature. Moreover, the Science Centre acts as a catalyst for community engagement, connecting existing programs in the neighborhood and creating a new urban identity for the southern gateway to the city center. The design of the Centre was carefully crafted to fulfill these vital roles. (Dekleva Gregorič Architects, 2020, 2023; *Izgradnja Centra Znanosti Kot Demonstracijskega Objekta | GOV.SI*, n.d.)

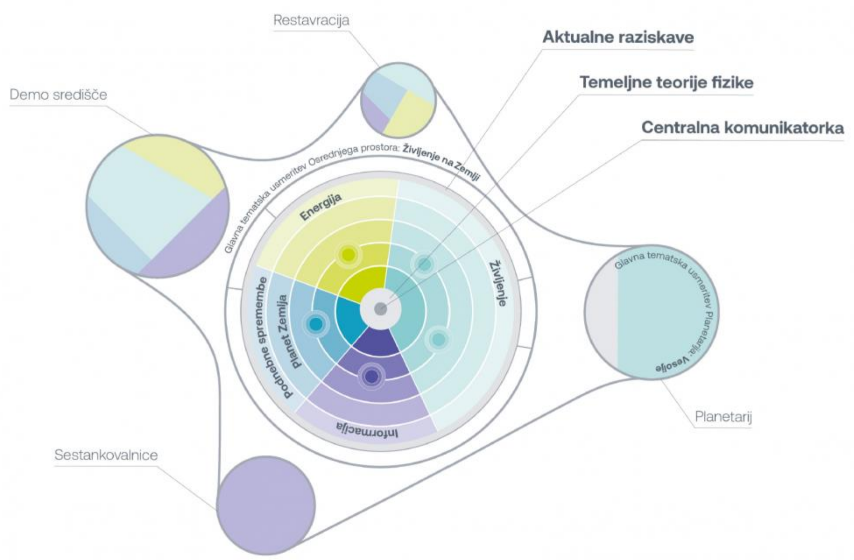

Figure 29: Science Centre Project – General Areas

(*Izgradnja Centra Znanosti Kot Demonstracijskega Objekta | GOV.SI*, n.d.)

The Science Centre caters to various target groups with its activities. Its primary mission is to inspire curiosity and foster scientific creativity and enthusiasm among children, young people, kindergartens, schools, educators, and families. Additionally, the Centre's attractions make it appealing to tourists and organized groups from societies, institutes, and companies.

The expanded program, which includes laboratories, a fab lab, a demonstration center, a gallery, and conference spaces, targets students, researchers, professors, the business community (companies and young entrepreneurs), as well as designers and creators.

Moreover, the Science Centre accommodates companies, and public and private institutes in research, education, economy, and culture, allowing them to utilize or rent premises for promoting their activities and research. The gallery and conference spaces are designed to cater to the professional public as well. (Izgradnja Centra Znanosti Kot Demonstracijskega Objekta | GOV.SI, n.d.)

8.3 Time Frame of The Project

All the project documentation: The PZI and PZR phases are completed, and the Ministry has concluded the call for information on the latest technological solutions for the construction of the Science Center.

(Dekleva Gregorič Architects, 2020, 2023; *Izgradnja Centra Znanosti Kot Demonstracijskega Objekta | GOV.SI*, n.d.)

Currently, the project requires an update of all its images. The renders currently in use were created during the 2019 competition, and it is now important to create new images within a tight timeline. These new visuals must meticulously capture every detail, showcasing the design objectives and reflecting the designers' vision as a complete process that integrates all the insights gained during the entire process.

The meticulousness of the process undertaken by Dekleva Gregorič Architects was to ensure no aspect was overlooked. The new images needed to show all aspects such as including spaces, materials, look and feel, angles, shapes, diverse individuals, vegetation, updated specialty designs, even the desaturated colors, the whitish look, and the kind of people.

This even extended to newly modeled furniture, intended for the ongoing contract. The clear objective was to effectively communicate ideas through these images, as they will be widely circulated across Slovenia. Their significance extends to stakeholders such as the general public, the Ministry, investors, sponsors, and potential clients. The Dekleva Gregorič Architects team engaged in a thorough review of every detail.

The Revit model served as the foundation, meticulously modeled in the Revit platform. The project reached the PZI stage, which signifies the comprehensive documentation of the architectural project, translating into the construction project.

The project is public and requires the development of a BIM model utilizing open BIM principles, as specified in the contract

they recognized that, moving forward, especially with public projects, BIM would become obligatory. The image development process commenced in Enscape, utilizing a licensed plugin known for delivering efficient and satisfactory outcomes. However, considerable effort was invested in fine-tuning materials, presets, and post-production to attain the desired results.

8.4 Revit Project Model and General Settings

The Science Centre project model was created using Revit Architecture software. It was initially structured as the primary model having both architectural and structural elements. Typically, the structural part should be an external link, but due to the close relationship between the structural and architectural aspects and the complexity it would introduce, it was decided to keep them integrated. This decision was made because modeling the cylindrical elements with attaching elements and radius points would have been challenging.

Models from external specialists such as structural engineers and planetarium contractors were received and coordinated with the Revit model. Various formats like Revit links, IFC, or generic model families were used for this purpose. The team evaluated and incorporated these models when information became available.

Other models necessary for the rendering process included lighting, HVAC, plumbing, special structures, furniture, Enscape vegetation, and landscape. All of these models were carefully coordinated and integrated into the drawings. Significant effort was put into creating view templates to ensure proper visualization in the drawings, considering that these models were initially developed in different offices.

Due to the extensive level of detail, the model size became quite large, which affected its performance. To address this, simplifications were made to objects, primarily within families. Some models were also temporarily turned off during work and then enabled specifically for Enscape rendering to optimize performance.

The models coordinated and needed for this process: Lighting, HVAC, Plumbing, Special Structures, furniture, Enscape Vegetation, and Landscape.

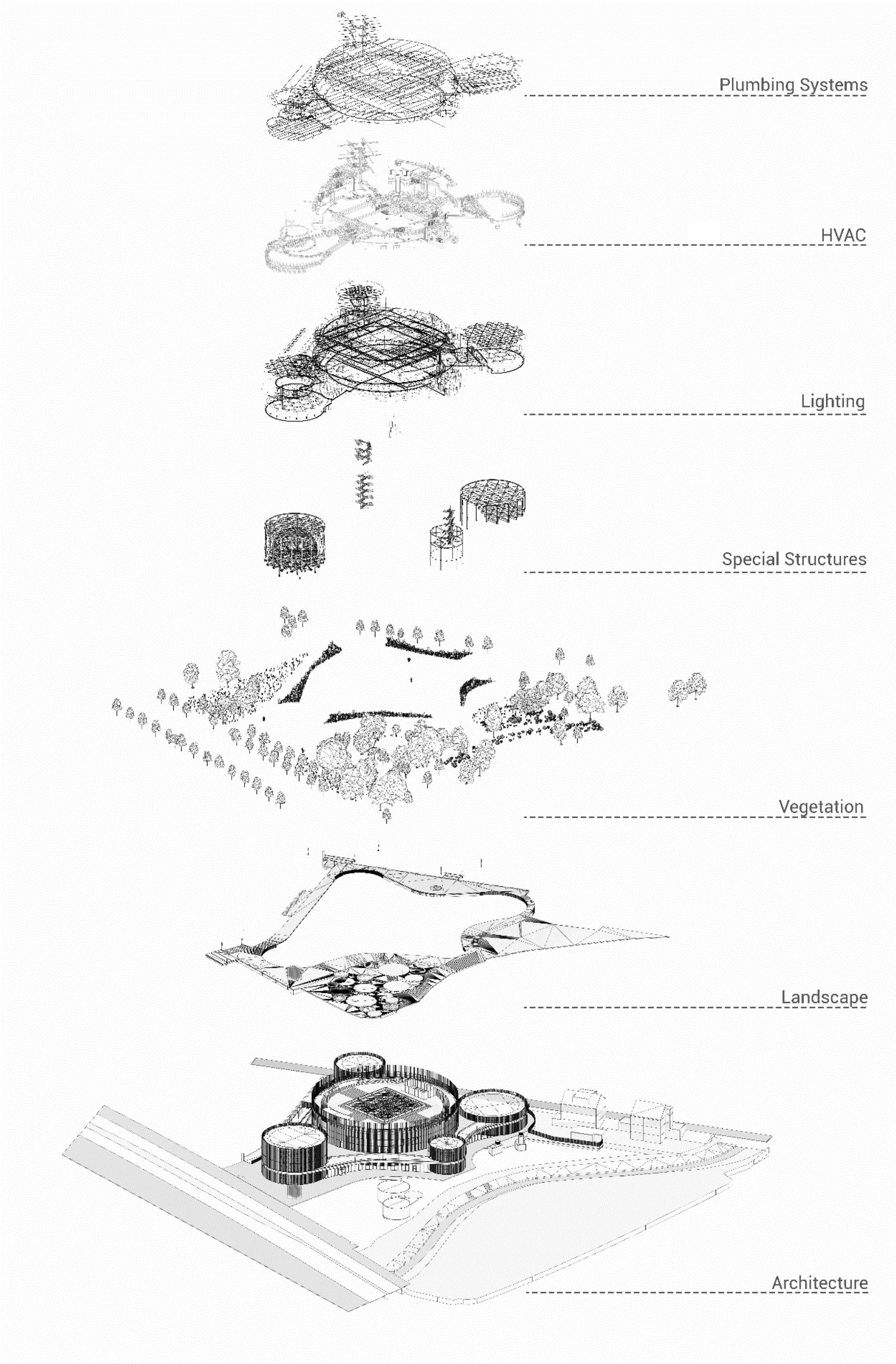

Figure 30: Displaced Axonometry of Revit Models Science Centre- Dekleva Gregorič Architects

All of these models were essential to create the final image, with particular emphasis on the vegetation and lighting components. The vegetation model was quite substantial, filled with numerous family proxies' assets. To handle this efficiently, it was linked as an external Revit model, which proved to be an excellent choice.

The lighting model played a critical role since it allowed for the control of turning lights on or off according to the lighting requirements of Enscape. Additionally, being a part of the BIM, each lighting fixture contained information about its intensity, light quality, and color.

The model coordinates were ready and set in the model, and then as verification, the location was set according to the georeferencing and also the location and site tool of the software. Setting the correct location in Revit for Enscape is crucial as it ensures realistic lighting, shadows, and seasonal variations in architectural renderings.

Figure 31: Location Setup Revit - Science Centre Dekleva Gregorič Architects

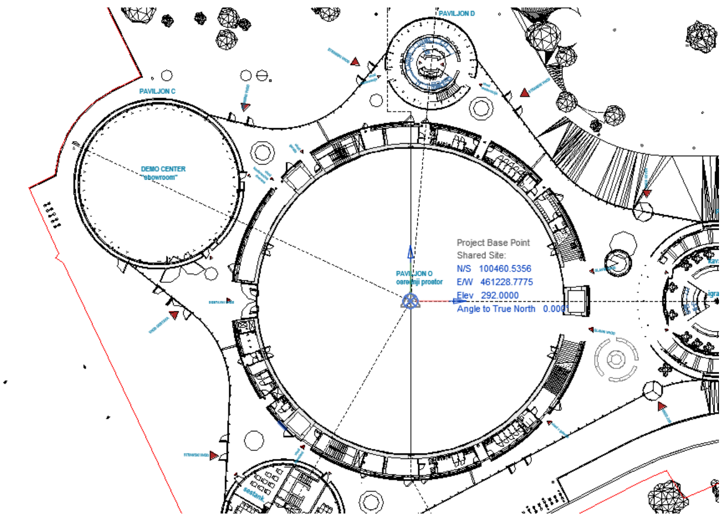

Figure 32: Setup for Project and Survey Point- Dekleva Gregorič Architects

8.4.1 Revit and Enscape Settings

Enscape as a plugin of Revit is installed in the software as another tool with its options. There is a Revit Interface:

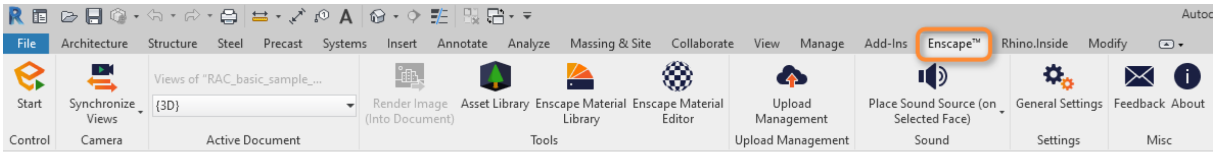

Figure 33: Revit Enscape Toolbar

(<i>EnscapeTM - Real-Time Rendering and Virtual Reality | Enscape</i>, n.d.)

Initiating Enscape within Revit

Upon starting Enscape in Revit, you may initially observe that certain buttons are inactive. This occurs because you need to complete the following steps beforehand:

1. Open the 3D view in your project.
2. Create and designate a valid 3D View in Revit. This action activates the Start button within the Enscape ribbon bar, rendering it no longer grayed out.
3. Select the Start button located in the Enscape ribbon.

The view's associated phasing and design options are automatically applied to Enscape's view. You can seamlessly continue using Enscape while making any desired modifications in Revit, such as adjusting cross-sections, materials, or geometric changes in the model. These adjustments will be instantly reflected in Enscape.

Additionally, for materials and assets, it is often more convenient to manage them through the Enscape interface. The option to pause and synchronize views is particularly valuable, especially in complex projects with numerous elements and links. It allows for a smoother workflow by pausing, making changes in Revit, and then resuming, as each Revit modification is promptly loaded into the Enscape interface, saving time.

Enscape Interface: the Enscape window offers a dynamic, real-time rendering of your Revit model, allowing you to explore the model using standard keyboard and mouse controls. However, for larger and more intricate projects, even high-spec computers may experience a reduction in performance due to the complexity of the geometry and real-time synchronization. On the other hand, with smaller projects, performance remains smooth without any issues.

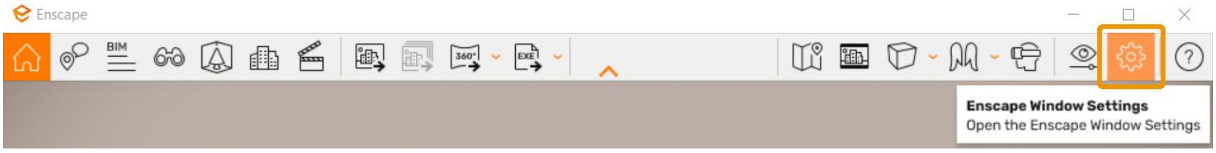

Figure 34: Enscape Interface

(<i>EnscapeTM - Real-Time Rendering and Virtual Reality | Enscape</i>, n.d.)

Enscape Window: When you launch Enscape from within Revit, it opens a separate window that becomes the Enscape interface.

Live Rendering: offers a dynamic, real-time rendering of your Revit model, allowing you to explore the model using standard keyboard and mouse controls. However, for larger and more intricate projects, even high-spec computers may experience a reduction in performance due to the complexity of the geometry and real-time synchronization. On the other hand, with smaller projects, performance remains smooth without any issues.

Settings Panel: On the left side of window, there's a Settings panel where you can adjust various rendering settings, including lighting, materials, and environment. All these options were customized for the general look of the images, having all the best results and according to the look that the office wanted to reflect. This can be saved as a preset and applied to the other images.

Visual Effects: a range of visual effects and styles that you can apply to your model in real time. You can access these through the Style dropdown menu.

Assets Library: an extensive library of 3D assets like trees, furniture, and people, which you can add to your Revit model from within the Enscape window. This option is better to use inside the Enscape interface, once there are applied, it's possible to see immediately how it looks.

Screenshot and Video Capture: This is the button to render the image, and export it in the format of choose and will not take as much time as rendering in another software, this is less than a minute! That's what is incredible about this software the preview is immediate and the rendering is so fast.

Viewpoints: You can save and manage viewpoints (camera positions) and it's better to set them here instead of Revit, because this interface is just how you save it, also the field of view is different.

VR Integration: Enscape Virtual Reality mode.

The Enscape interface is focused on rendering and visualization settings, with a live rendering window that allows you to explore your Revit model in a more immersive and realistic way.

Enscape's assets appear as simplified low-poly meshes within Revit. This approach is designed to optimize the model by reducing the polygon count, resulting in smoother performance when viewing and managing the file.

LOD is a scalable approach to improving rendering performance by reducing the complexity of 3D objects when they are far from the viewpoint. This involves simplifying objects by reducing the number of triangles or using textures instead of geometric details. For CPU-bound scenarios, HLOD is more suitable, where spatially coherent objects are simplified together to reduce draw calls and object complexity.

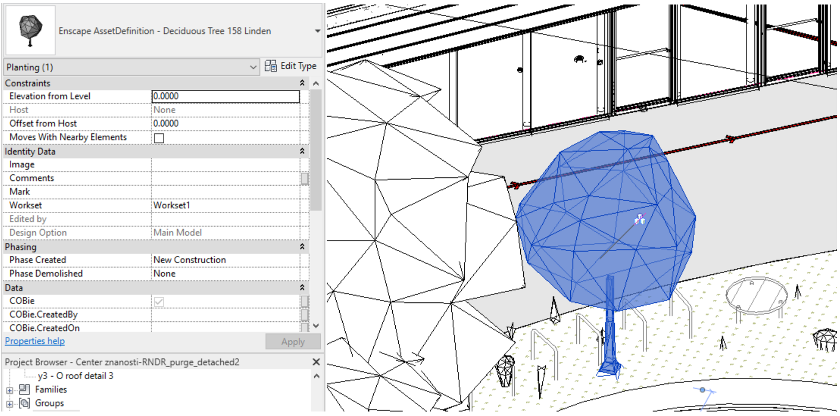

Figure 35: View of Enscape Assets in Revit Families

Materials

The Revit material browser functions similarly to when the software did not yet have the Enscape plugin. This continuity is highly advantageous as it seamlessly integrates with Enscape. Moreover, it allows for the incorporation of additional properties or attributes into materials, which Enscape can interpret, resulting in the precise visualization of materials as intended. Additionally, the material names are cross-referenced by the program. For instance, "grass" is distinguished from "wild grass," and this distinction is reflected in the rendered image.

Following Enscape's recommendation, it is advisable to create a dedicated project materials folder that contains all the images and textures used. These resources can then be easily added by configuring the paths within the options settings under rendering and appearance

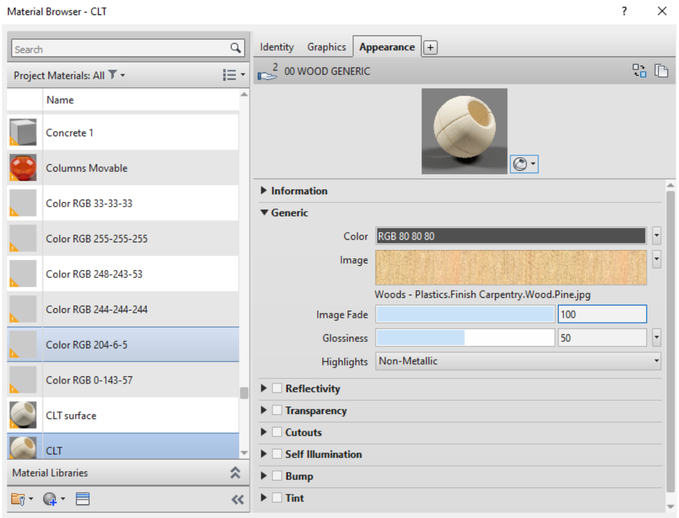

Figure 36: Revit Material Editor

The Enscape material editor is seamlessly integrated into the Revit toolbar, providing a convenient platform for managing created materials within Revit. This integration also offers the option to enhance materials in Revit with more advanced features. Additionally, Enscape provides a library of ready-to-use materials that can be easily added to the project. These materials come equipped with all the necessary properties and settings to enhance realism in your visualizations.

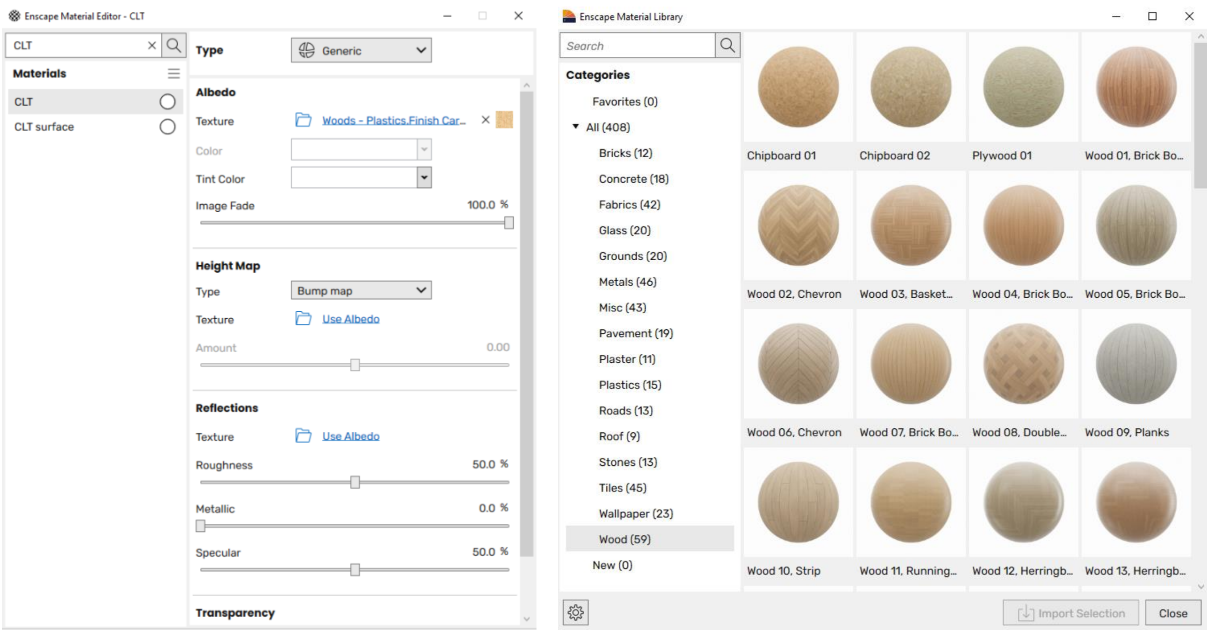

Figure 37: Enscape Material Editor and Library in Revit

As mentioned earlier, effective management of Revit links plays a crucial role in smoothing your workflow and making project creation, modeling, and manipulation more efficient. In this specific case, where a multitude of Enscape assets such as vegetation, trees, bushes, and plants are involved, it's advantageous to save them as external links to simplify the process.

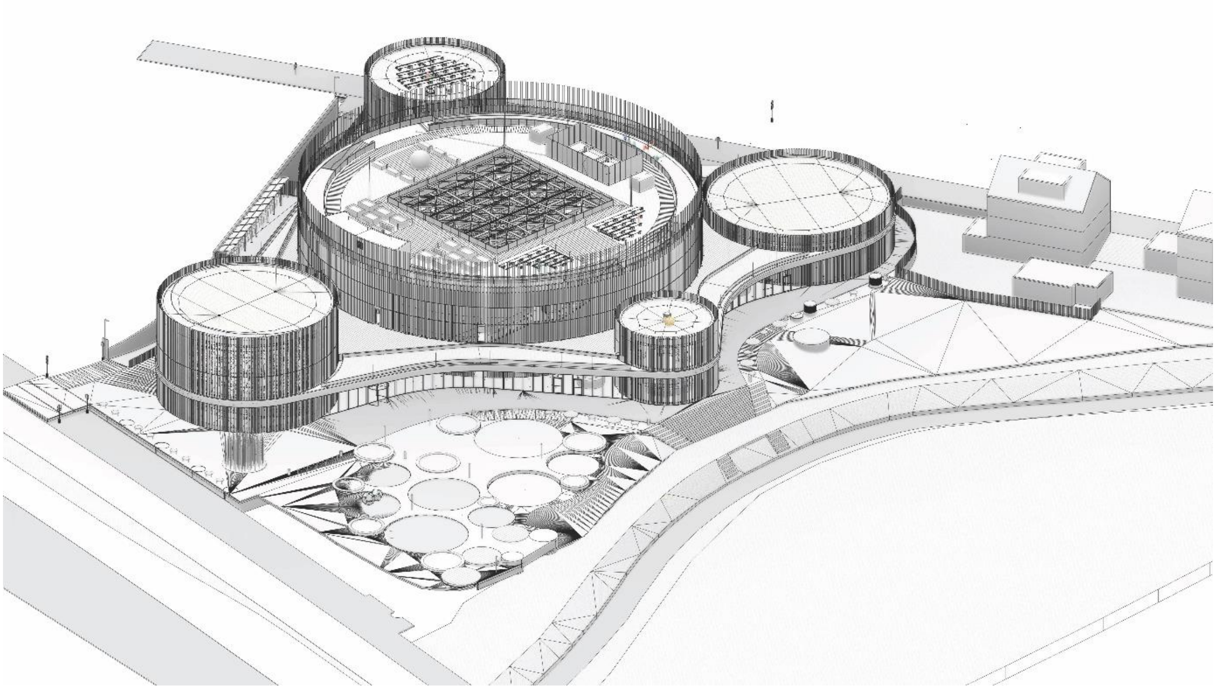

Figure 38: 3D view of the Revit model of Science Centre

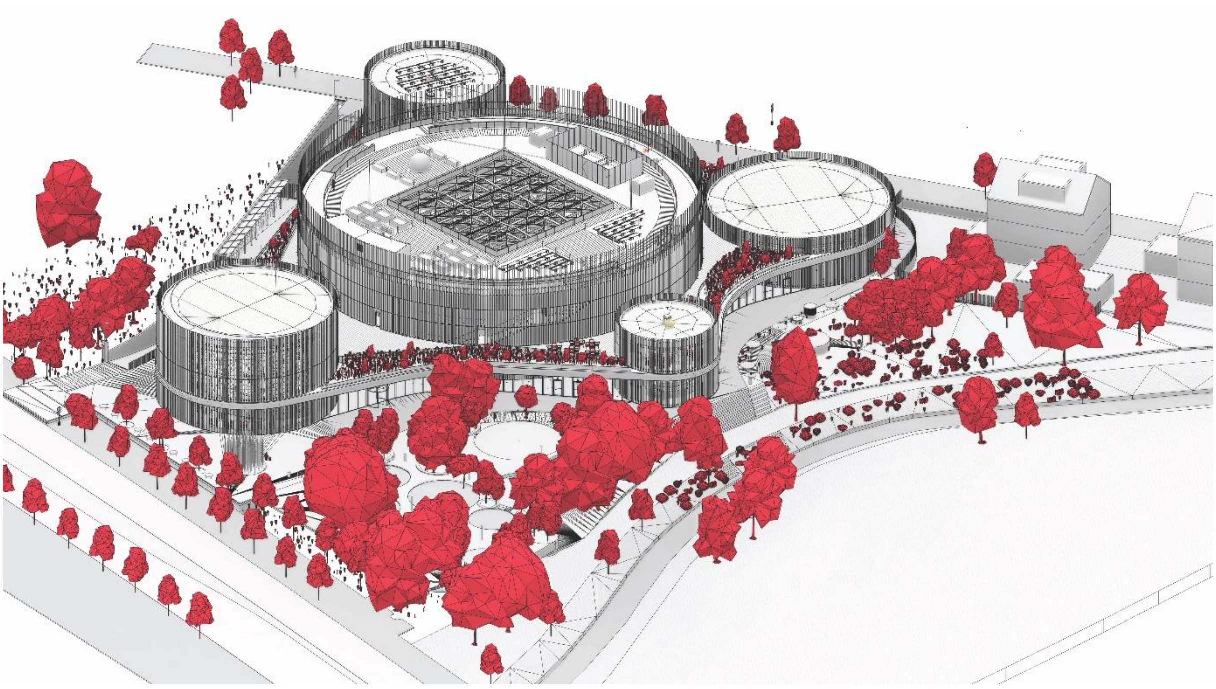

Figure 39: 3D view of the Revit model of Science Centre with Enscape Assets

With this setup in place and the Enscape interface open, you can swiftly assess the overall materials and effortlessly select project categories using the BIM filter.

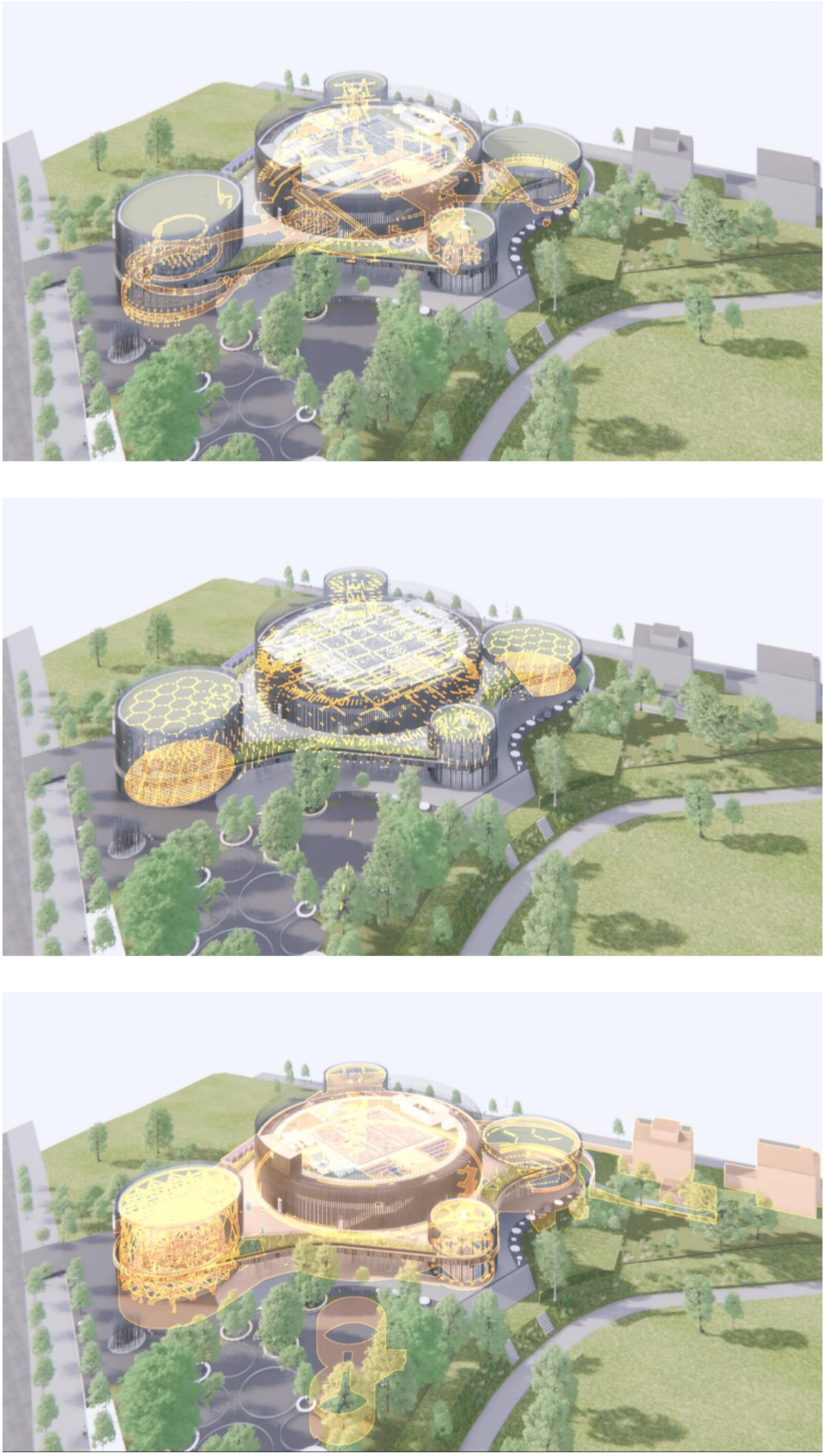

Figure 40: Enscape View - Bim Filter – HVAC/ Lighting / Structure

8.5 Images, Breakdown Process

The process of working with images in Revit and Enscape involves creating high-quality visualizations of your architectural or design project. Here's an overview of the steps:

1. Model of the Project: All necessary elements, materials, lighting, and any other details that are relevant to your project.
2. Open Enscape: Launch the Enscape plugin from the Revit toolbar. This will open a window within your Revit interface where you can see a real-time rendering of your project.
3. Adjust Settings: Enscape provides various settings that allow you to fine-tune your visualization. You can control the time of day, lighting, camera angles, and other visual parameters to achieve the desired look and feel.
4. Navigate and Explore: Use Enscape's navigation controls to move within your project. This can include walking through interiors, flying over exteriors, or simply changing your viewpoint to capture different angles.
5. Set Up Views in Enscape: Define the specific views within your Revit project that you want to render.
6. Adjustments: According to every view is important to improve the materials, lighting, composition, and other elements.
7. Capture Images: When you're satisfied with the view and settings, you can capture high-quality images directly from the Enscape interface.
8. Post-Processing (Optional): Depending on your requirements, you may choose to further enhance your Enscape images using post-processing software like Adobe Photoshop or similar tools.

Collaborating closely with the Dekleva Gregorič Architects team, we thoughtfully curated views that aptly emphasize and communicate the project's pivotal features. Each image was thoughtfully chosen with a distinct and strategic viewpoint, guaranteeing the comprehensive representation of essential elements, field of view, and spatial attributes. On the following page, you can observe the outcomes, beginning with the Revit-edited view, followed by the Enscape rendering, and lastly, the post-production process carried out consecutively in Photoshop.

8.5.1 BIM Visualization Results

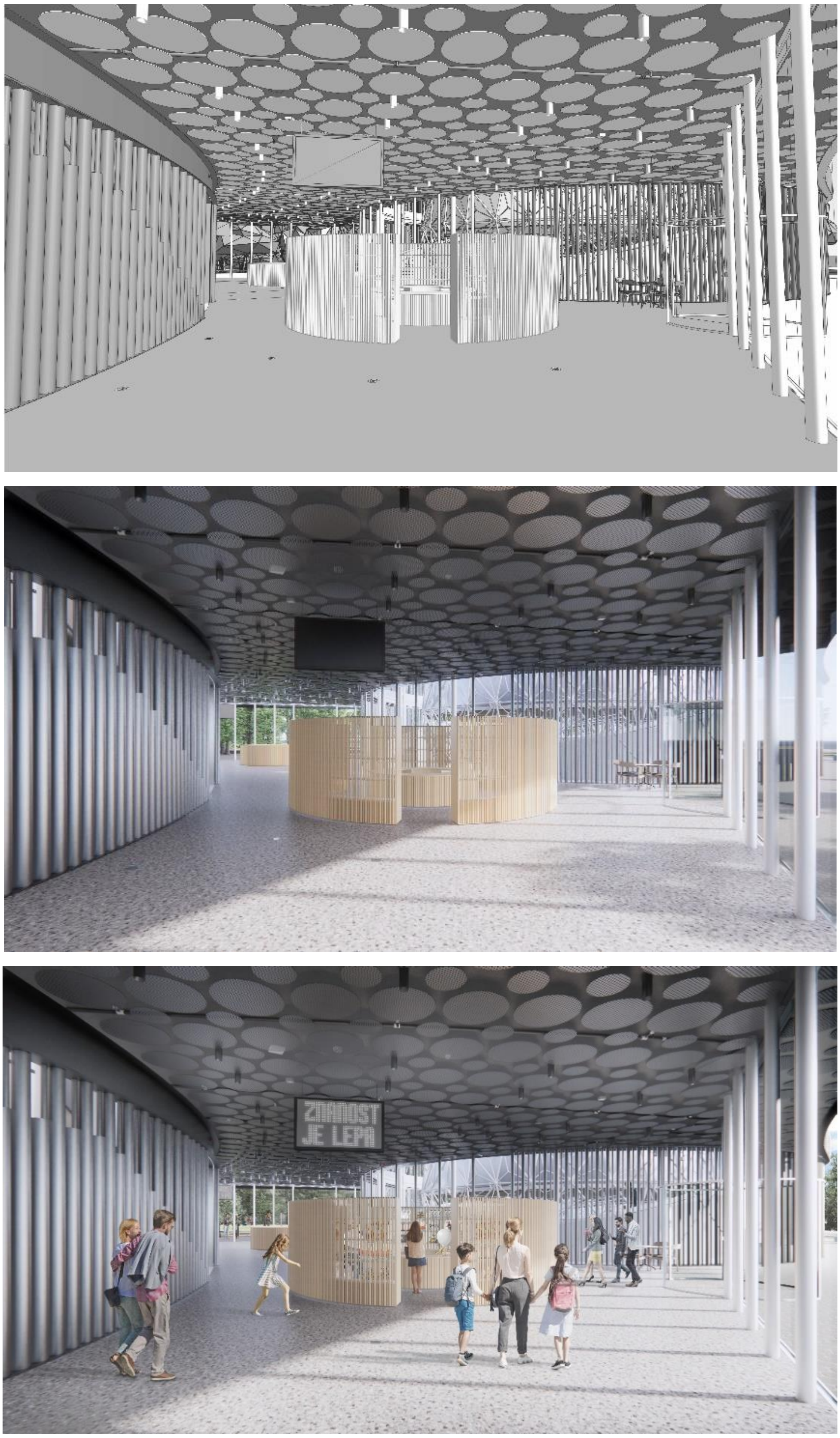

Figure 41: Shop Render - Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

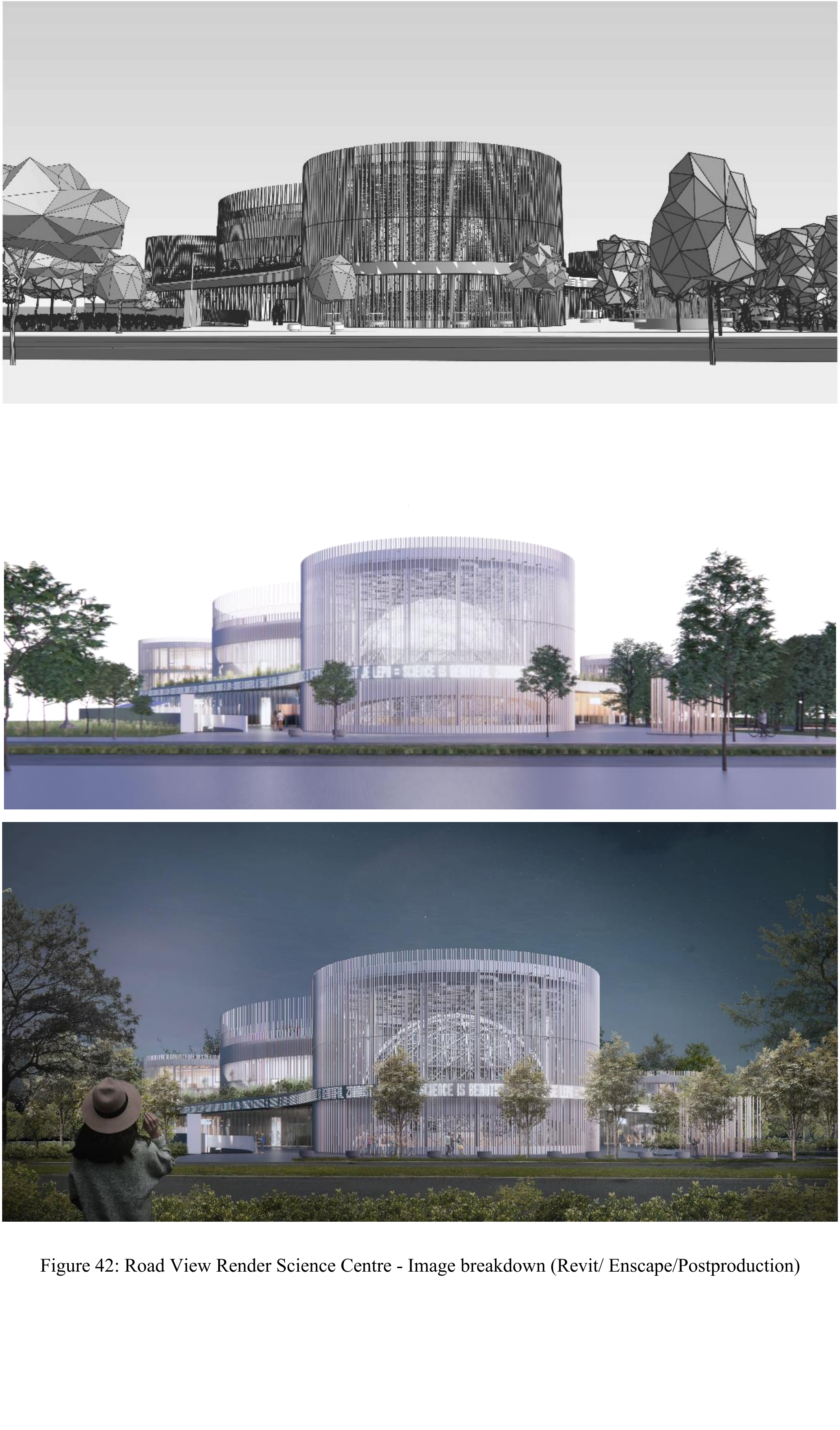

Figure 42: Road View Render Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

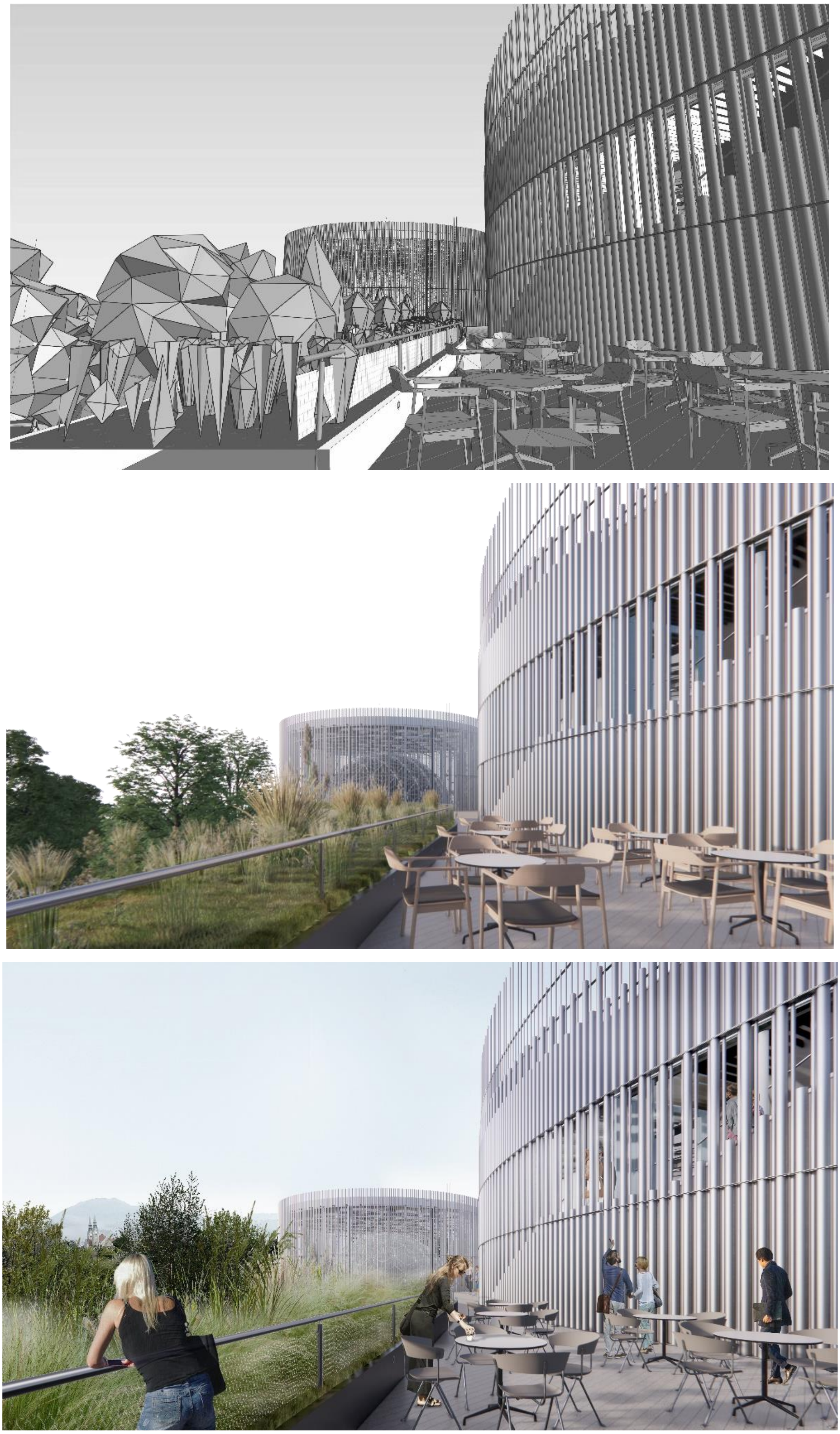

Figure 43: Restaurant Render Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

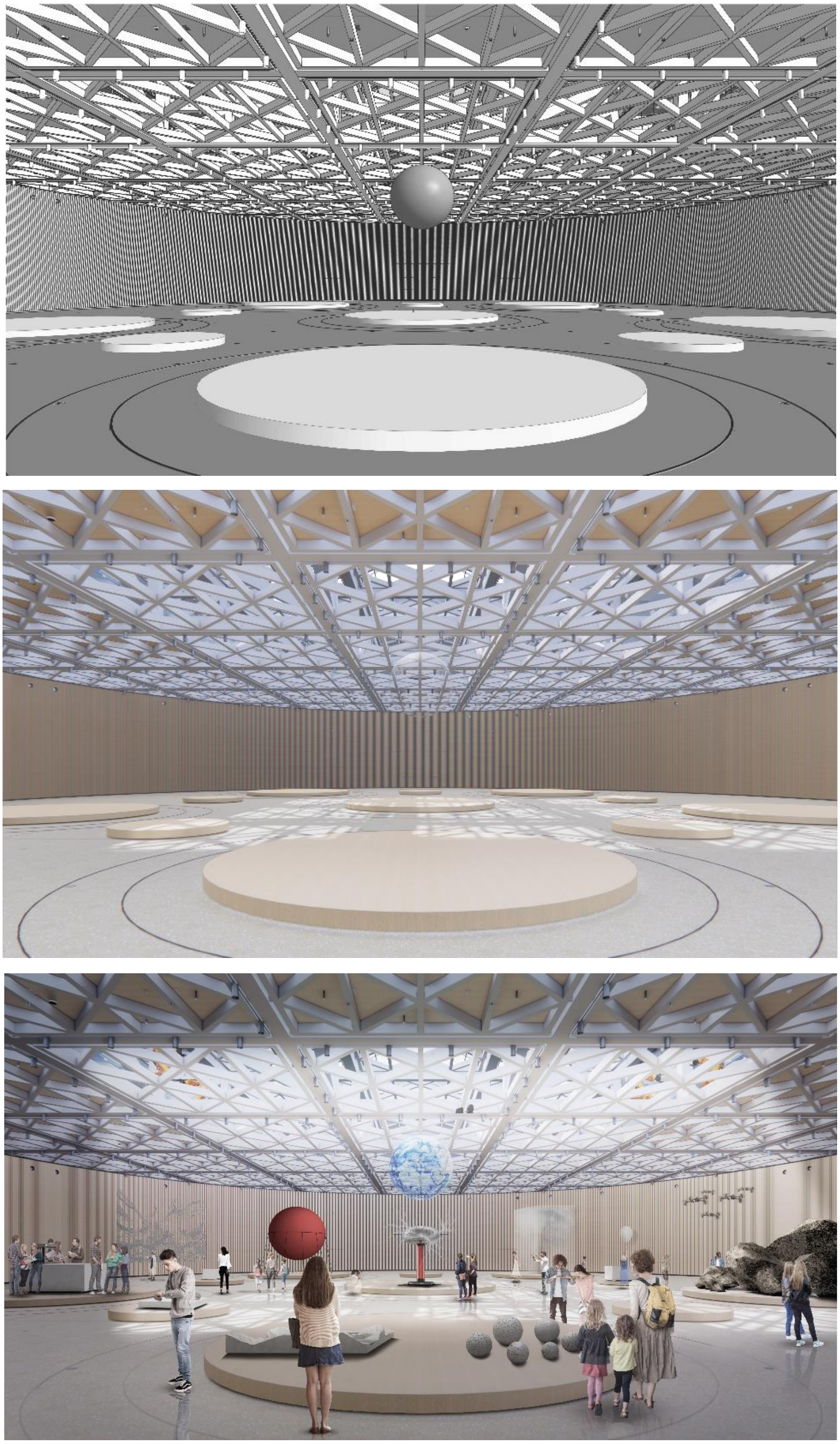

Figure 44: Main Render Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

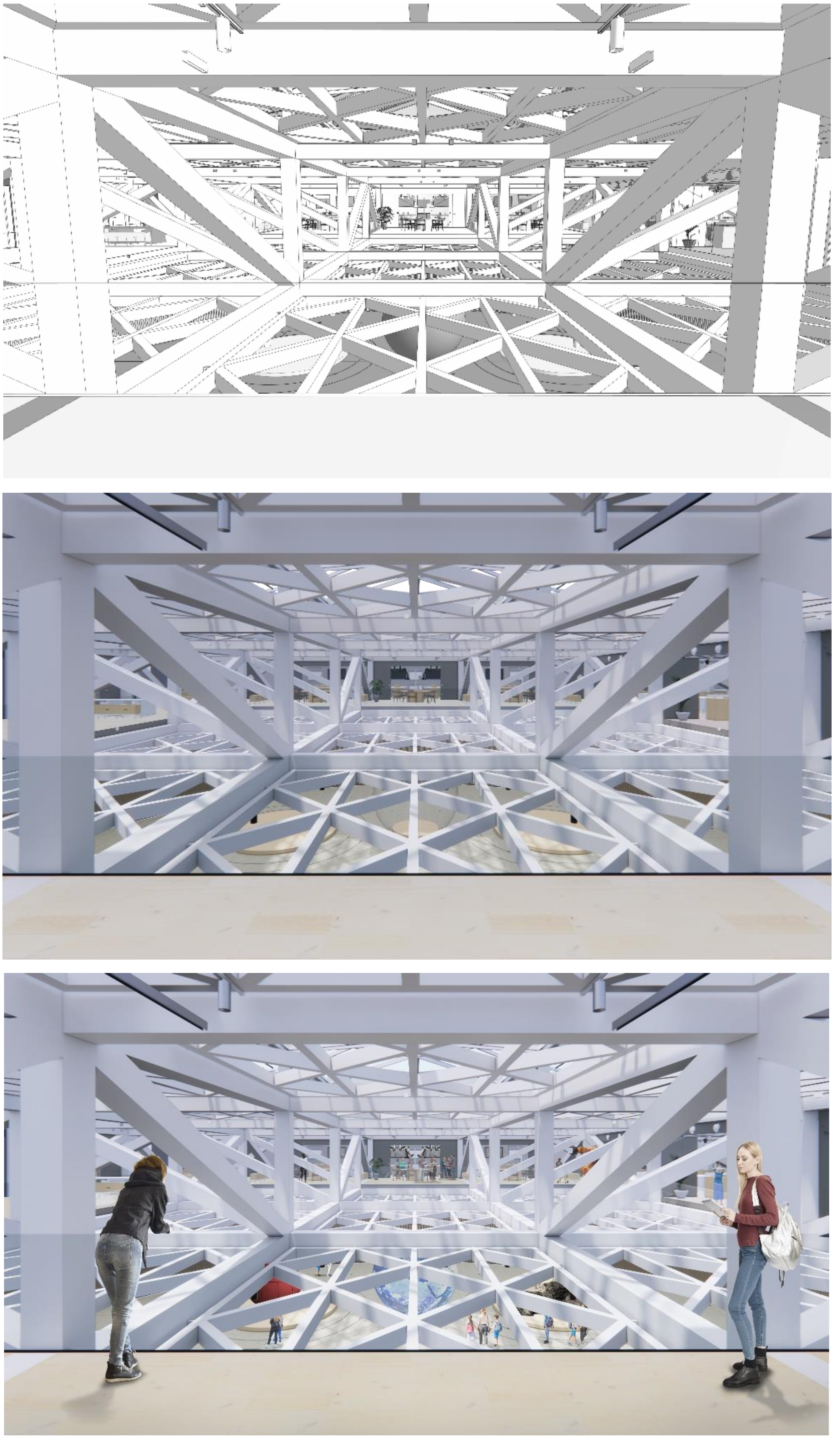

Figure 45: FabLab Render Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

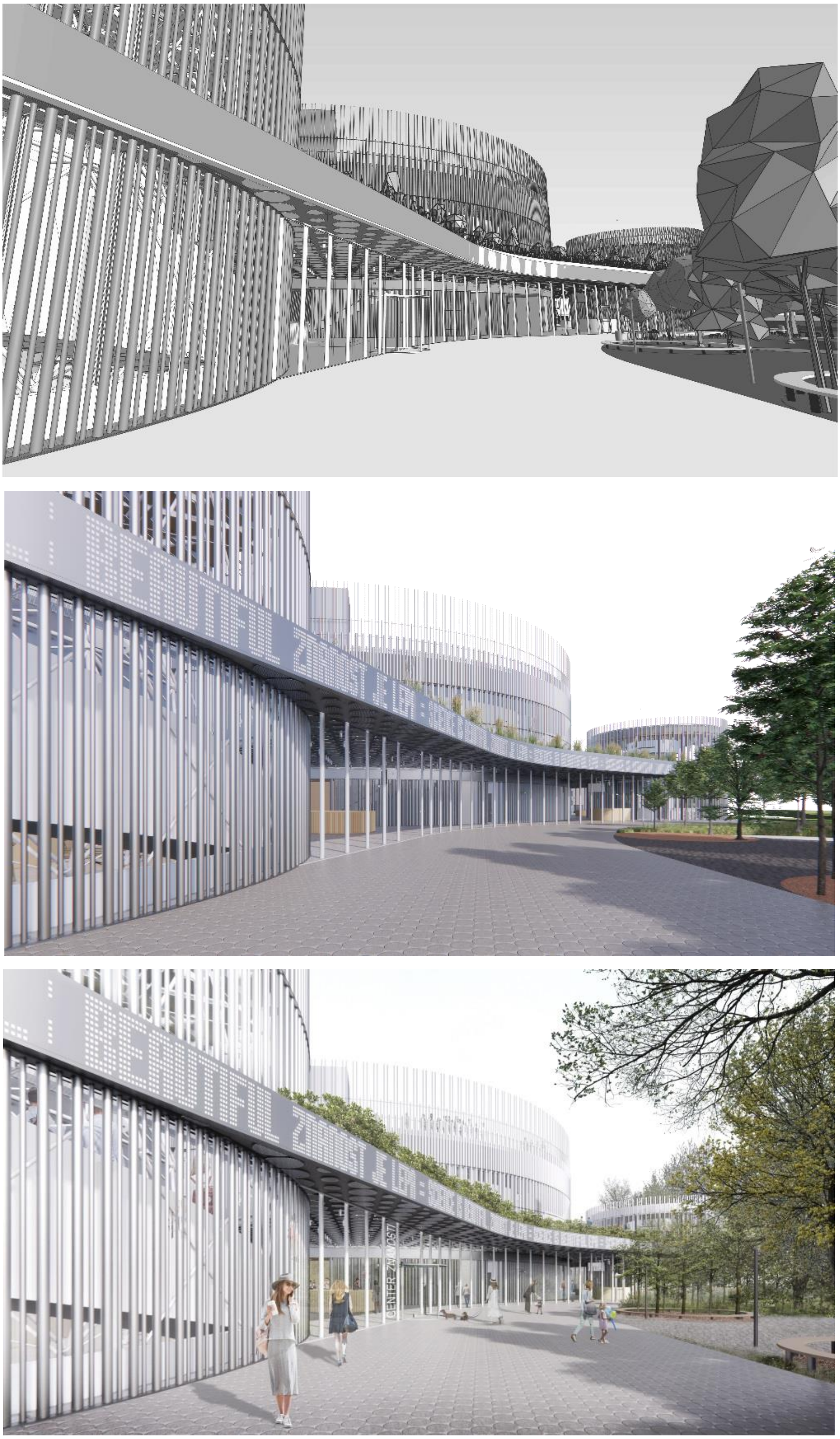

Figure 46: Entrance Render Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

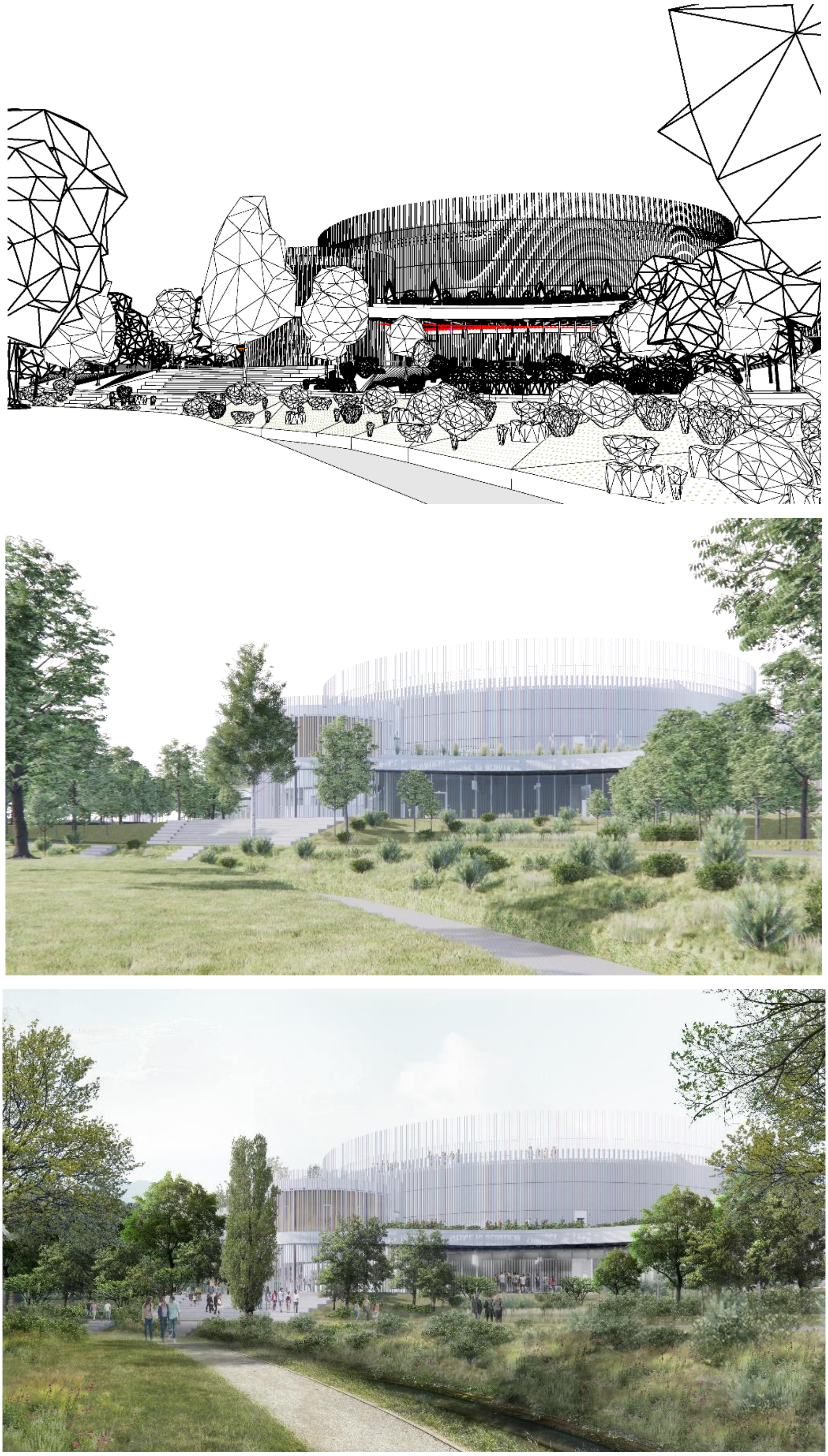

Figure 47: Park Gradaščica View Render Science Centre - Image breakdown (Revit/ Enscape/Postproduction)

8.6 Findings

Enscape, while a valuable tool, does have its share of challenges when used within Revit. One common issue is the slow connection between Revit and the Enscape interface, especially when dealing with large and complex models. This can lead to longer loading times and potential delays in the design workflow. Additionally, there is room for improvement in the realism of trees and vegetation in Enscape renderings, as they may not always appear as lifelike as desired. Addressing these challenges by optimizing the software's performance and enhancing the visual quality of natural elements would further enhance Enscape's capabilities within Revit, making it an even more effective tool for architectural visualization. Another important aspect of Enscape's improvement within Revit is achieving greater realism in overall visualization, including enhancing the appearance of glass elements. Realistic glass rendering is crucial for accurately representing architectural designs, especially in projects where transparency and reflection play a significant role. By improving the realism of glass materials and the overall visual quality, Enscape can provide architects with more convincing and immersive renderings, further enhancing its value as a visualization tool within the Revit environment.

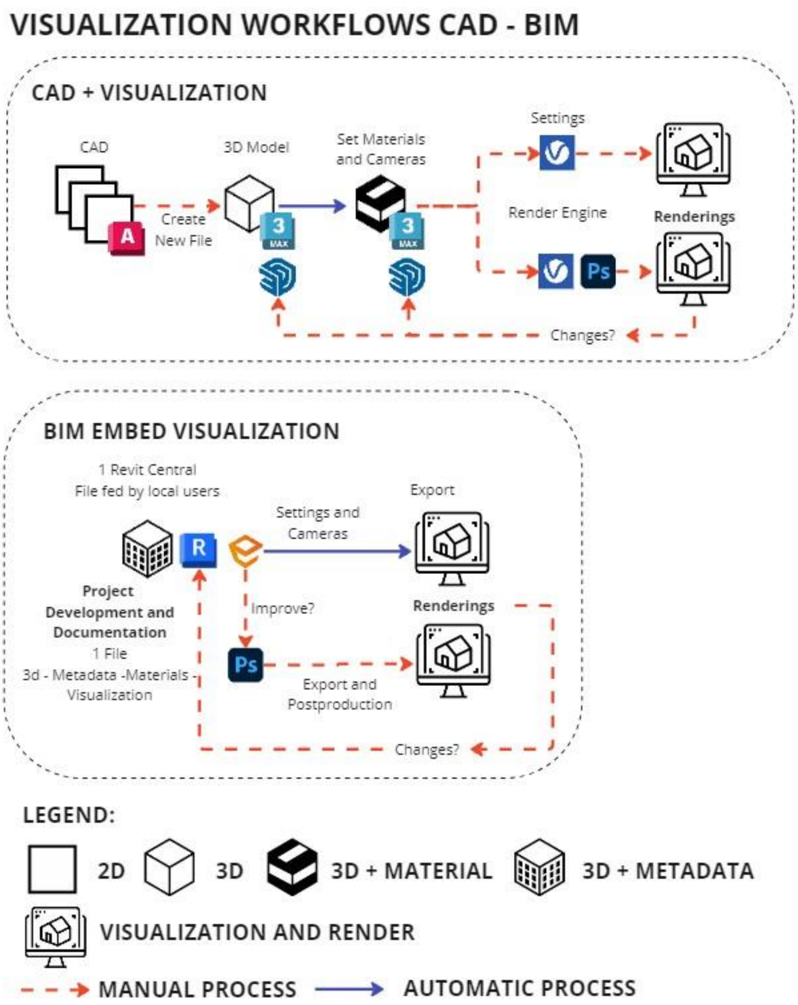

Figure 48: CAD and BIM visualization workflows

The CAD-based workflow, a long-standing practice in the field for many years, involves numerous manual processes and lacks automation. It often necessitates working with disparate files, exporting data into various formats, and frequently outsourcing image production for enhanced quality. In contrast, the BIM-embedded visualization workflow simplifies and automates this entire process. It offers real-time updates and previews of materials and lighting within the model, eliminating the need for multiple exports. Architects can now choose to develop high-quality images in-house, thanks to this streamlined approach, which not only saves time but also provides excellent results. Post-production adjustments can still be made, when necessary, further expanding the options for achieving exceptional visuals. The integration of BIM and rendering visualization strengthens the architectural practice by enabling more realistic and accurate representations of design concepts. It improves communication, supports decision-making, and contributes to effective collaboration throughout the project lifecycle. BIM Integrated visualization has big benefits:

-**Accurate Representation**: Rendering visualizations based on the BIM model provide a more precise representation of the design, capturing the intended look and feel of the building.

-**Design Exploration**: Visualizations allow architects to explore different design options, materials, and lighting conditions to assess their visual impact, helping in the decision-making process.

-**Stakeholder Communication**: Rendered visualizations are powerful communication tools that facilitate effective communication with clients, investors, and other stakeholders. They help convey the design concept and enable stakeholders to envision the outcome.

-**Marketing and Presentations**: High-quality visualizations are useful for marketing purposes, such as brochures, websites, and presentations. They create a compelling visual narrative that attracts potential clients and showcases the project's qualities.

-**Improved Collaboration**: BIM-based visualizations enhance collaboration between architects, engineers, and other project team members. They provide a shared visual reference that facilitates discussions, feedback, and coordination.

-**Decision Support:** Visualizations assist in evaluating design choices, identifying potential issues or conflicts, and making informed decisions early in the design process.

Integration of visualization and rendering tools like Enscape with BIM, empowers architects to create photorealistic renderings and real-time visualizations, streamlining the design process and improving client communication. Enscape's seamless integration ensures that visualizations stay current with design changes, reducing the need to outsource rendering tasks and allowing for better control. Enscape's user-friendly interface and rapid results enhance design efficiency and client satisfaction, making it a valuable in-house tool for architectural firms, simplifying workflows and producing compelling visuals.

9 CONCLUSIONS

In architectural design, the creative process extends beyond the conceptualization phase. It encompasses defining the overall massing, conducting facade studies, and continues throughout all phases until construction. Throughout these processes, architects are tasked with ensuring that their ideas and vision are fully realized. This necessitates collaboration, coordination, and communication with all project stakeholders and construction providers. The creative aspect is intertwined with the technical details, adapting to various analyses and cost-related considerations to bring the design to completion, transforming it into a reality.

Undoubtedly, BIM represents the future of work methodologies in the AEC industry. Despite having been in use for nearly two decades, it may not seem as new as it appears at first, perceived as rigid, with complexities, particularly concerning connectivity and interoperability with other software applications. As a work methodology nor a design and creative methodology. It may appear somewhat disconnected from the traditional path of architectural design, there should be improved methods for seamless integration with design-oriented software.

Future Developments:

As a further development developers can improve its weaknesses by incorporating the following improvements:

- **User-Friendly Interfaces**: Make BIM software more user-friendly, intuitive, and visually engaging to **reduce the learning curve**, especially for those in the early design phases. Streamlined interfaces with clear, easy-to-navigate menus can encourage broader adoption.
- **Flexible Sketching and Conceptual Tools**: Integrate more flexible and creative design tools within BIM software to allow architects to sketch, model, and explore conceptual ideas with the same ease and freedom as in 3D modeling software.
- Create simplified, lightweight models for the conceptual phase, which can be gradually developed into more detailed BIM models as the design progresses. This allows for quicker concept visualization without the complexity of full BIM.
- **Improved Interoperability**: Ensure better interoperability with various design software and formats commonly used in the early design stages. Smooth data exchange with popular 3D modeling tools like Rhino, SketchUp, or Blender can facilitate seamless transitions between software.
- **Parametric Design Capabilities**: Improve the integrated parametric design tools that enable architects to explore design variations easily, promoting innovation and experimentation in the early stages. more user-friendly, and intuitive.

- **Real-time Rendering and Visualization**: Improve real-time rendering and visualization capabilities within BIM software, streamline the creative process, making it more agile and responsive, ultimately fostering efficient workflows and elevating the quality of architectural presentations.
- **Integration of AI and Generative Design**: Leverage AI and generative design algorithms to assist architects in generating design alternatives and optimizing solutions based on project goals and constraints.
- **Flexible Licensing Models**: To encourage wider adoption of BIM software, developers should consider lowering their prices or offering more flexible and affordable licensing options. This would make BIM technology more accessible to a broader range of users, including smaller firms and projects with tighter budgets. Lowering the cost of entry can help drive greater adoption and ultimately benefit both the software developers and the industry.

In the coming years, as BIM technology continues to evolve, enhance the architectural design process, making it more agile, responsive, and interconnected. BIM's role as a facilitator of creativity within architectural design will grow, transforming the way architects and designers bring their visions to life and ultimately contributing to the continued advancement of the AEC industry.

10 LIST OF ACRONYMS AND ABBREVIATIONS

2D: 2 Dimensions, 1

3D: Three Dimensions, 1

AA: *The Architectural Association School of Architecture in London*, 17

AEC: Architecture, Engineering, and Construction, 6

AI: Artificial intelligence, 80

BIM A+: European Master in Building Information Modelling BIM A+, 3

CDE: Common data enviroment, 30

HBIM: Historial Building Information Modelling, 2

HLOD: Hierarchical Level of Detail, 65

HVAC: Heating, ventilation, and air conditioning, 60

IT: *Information technology system*, 10

JMA: *John McCall Architects*, 10

KPI: *Key performance indicator*, 11

SME: Small and medium-sized enterprises, 9

SWOT: *strengths, weaknesses, opportunities, and threats*, 11

UK: United Kingdom, 8

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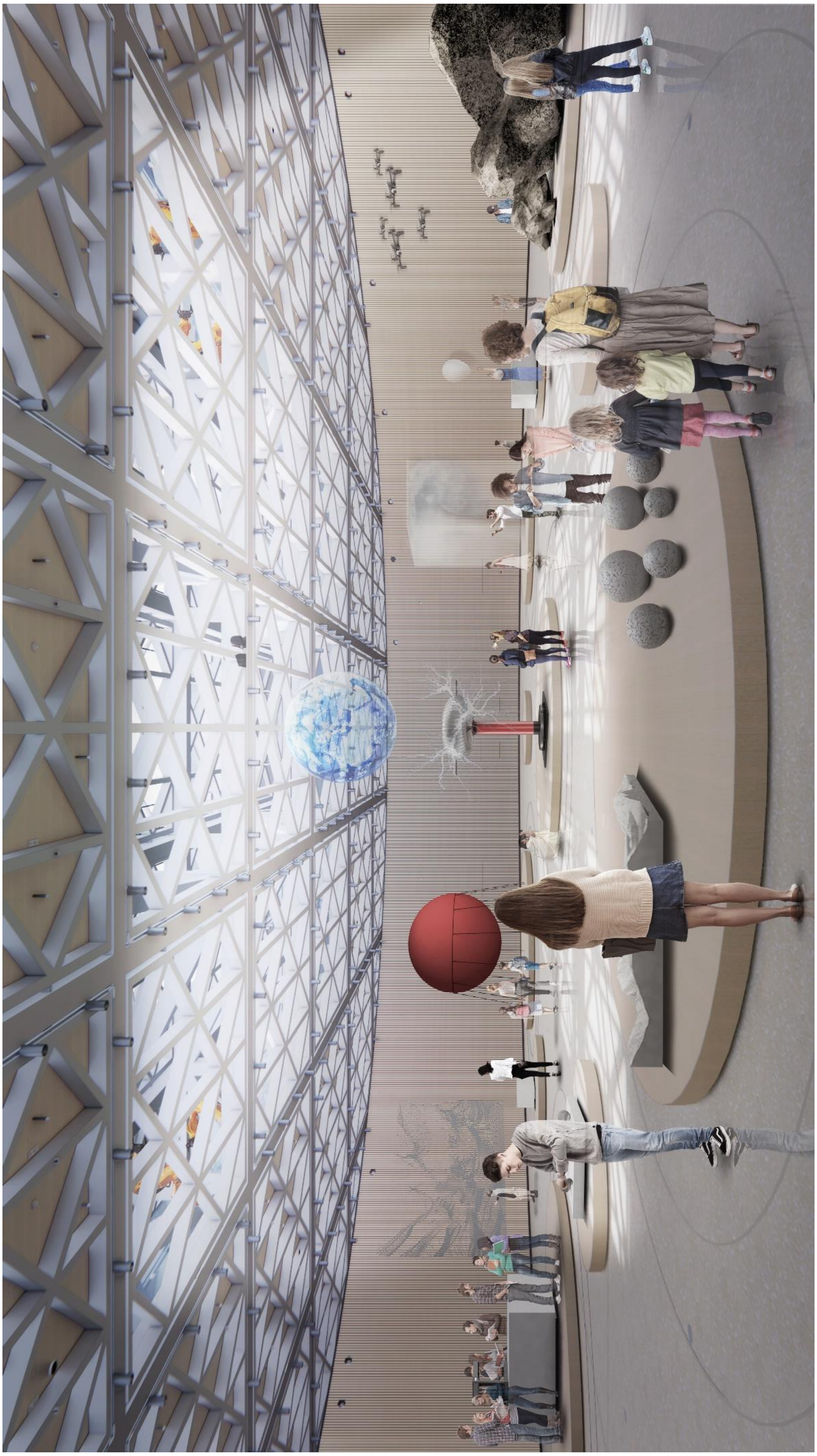
12 ANNEXES

Park Gradaščica View Render Science Centre - Dekleva Gregorič Architects

Entrance Render Science Centre - Dekleva Gregorič Architects

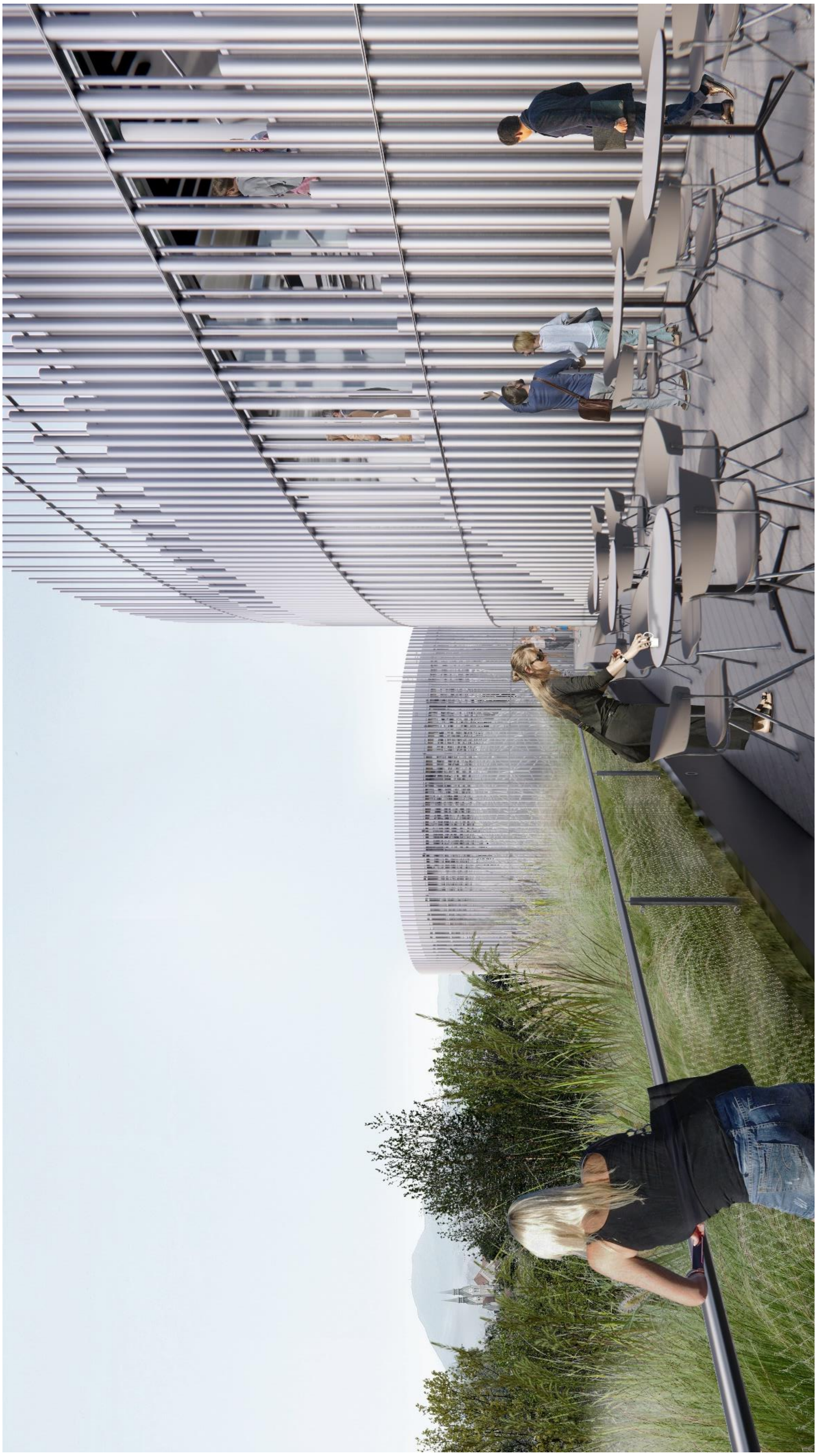
Planetarium Render Science Centre - Dekleva Gregorič Architects

Shop Render Science Centre - Dekleva Gregorič Architects

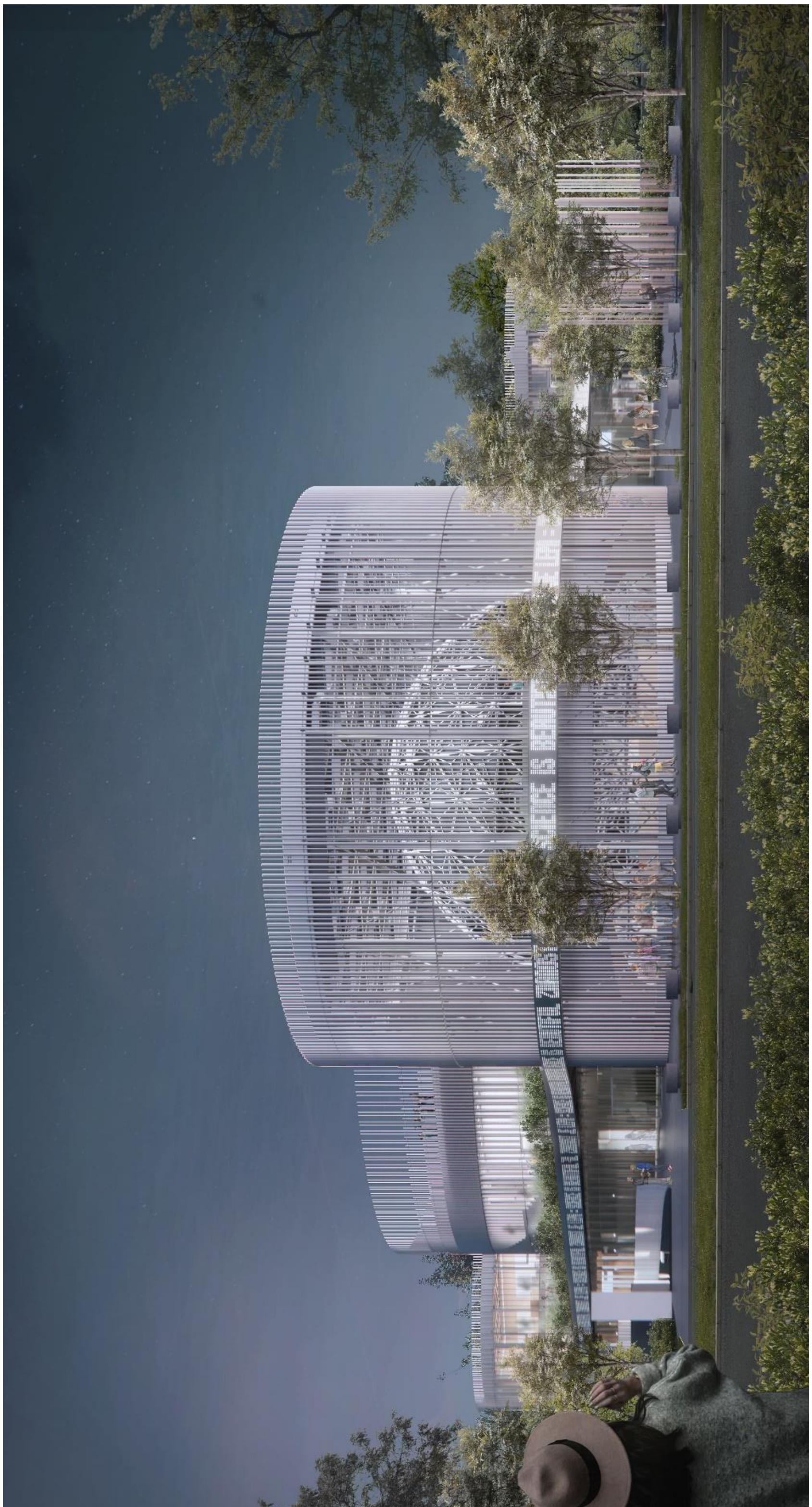


Main Render Science Centre - Dekleva Gregorič Architects

FabLab Render Science Centre - Dekleva Gregorič Architects



Restaurant Render Science Centre - Dekleva Gregorič Architects



Road View Render Science Centre - Dekleva Gregorič Architects

Torre Rinalda Competition Proposal – ReUse Italy – Cesar David Grisales