# Digitally Preserving Architecture: An Engineering Approach to Cultural History

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## ABSTRACT

This research examines the application of 3D printing and digital modeling as engineering tools to preserve architecture in both historic and contemporary settings. Traditional restoration methods are often costly, damaging, and time-consuming, but new technologies, such as 3D printing, computer-aided design (CAD), LiDAR, and digital photogrammetry, offer faster, more cost-effective, and more accurate options. This paper looks at how 3D printing can help save, rebuild, and display historical buildings, making it easier for architects, historians, researchers, teachers, and the public to learn about and appreciate cultural history. Some countries, like England, have used these tools to digitally and physically preserve historic buildings, while others, like South Korea, have lost important architecture due to fast urban growth and a lack of proper records. This project uses programs such as Fusion 360, Tinkercad, and Blender to create 3D models of buildings and test how these technologies can be used for preservation, teaching, and engineering studies. Two examples, England's use of preservation technology and South Korea's rebuilding after war, show the effects of choosing preservation versus redevelopment. The bigger picture includes global access to historical sites, eco-friendly restoration, lower costs, help in disaster recovery, and better learning tools. Overall, the study finds that 3D printing and related technologies can connect modern engineering with the need to protect cultural heritage, supporting both innovation and tradition.

## Introduction

As mentioned in the abstract, new technologies like 3D printing and digital modeling offer affordable, accurate ways to protect architectural heritage. Preserving architecture isn't just about saving old buildings; it's about recording a society's identity, culture, and creativity. Buildings reflect the people who built them, revealing political systems, beliefs, engineering skills, and design styles. But in today's rapidly changing cities, many historic buildings are being lost to natural disasters, neglect, war, or urban development.

For example, after the Korean War, South Korea prioritized economic growth and city expansion, replacing many traditional hanoks, which are wooden Korean homes with curved roofs and an emphasis on harmony with nature, with modern apartment complexes.[1] In contrast, England has worked to preserve buildings from the medieval, Tudor, and Victorian eras using modern engineering tools.

This paper explores how 3D printing and related methods, such as CAD modeling and digital scanning, can help document, teach, analyze, and rebuild cultural sites. A key part of the project involves digitally designing and 3D printing a traditional hanok using Fusion 360 and PLA plastic. The paper argues that engineering technology is not just important for the future of architecture; it is also essential to preserving its past.

## Why Architectural Preservation Matters

Preserving architecture helps protect the knowledge built into construction techniques, materials, and layout designs. More than just beautiful, old buildings show how engineering has developed over time—from stone arches and wooden frames to domes that spread out weight. In England, preservation laws and government funding have made it possible to study these buildings in depth and open them to visitors. Famous sites like Canterbury Cathedral and York Minster allow tourists, students, and engineers to learn directly from historical structures, strengthening both cultural understanding and technical education.

In contrast, South Korea has often chosen redevelopment over preservation. Although areas like Bukchon still have traditional hanoks, many were renovated without being digitally recorded. As a result, important details like how weight was supported, how parts were joined, and what materials were used have been lost. Without this information, it's hard to model, repair, or accurately rebuild these buildings.

That's where 3D printing and digital modeling come in. These tools can save detailed records of architecture, predict how buildings age, and create small-scale replicas. Preserved buildings can then serve as gateways to history and hands-on learning tools for design, materials science, and civil engineering.

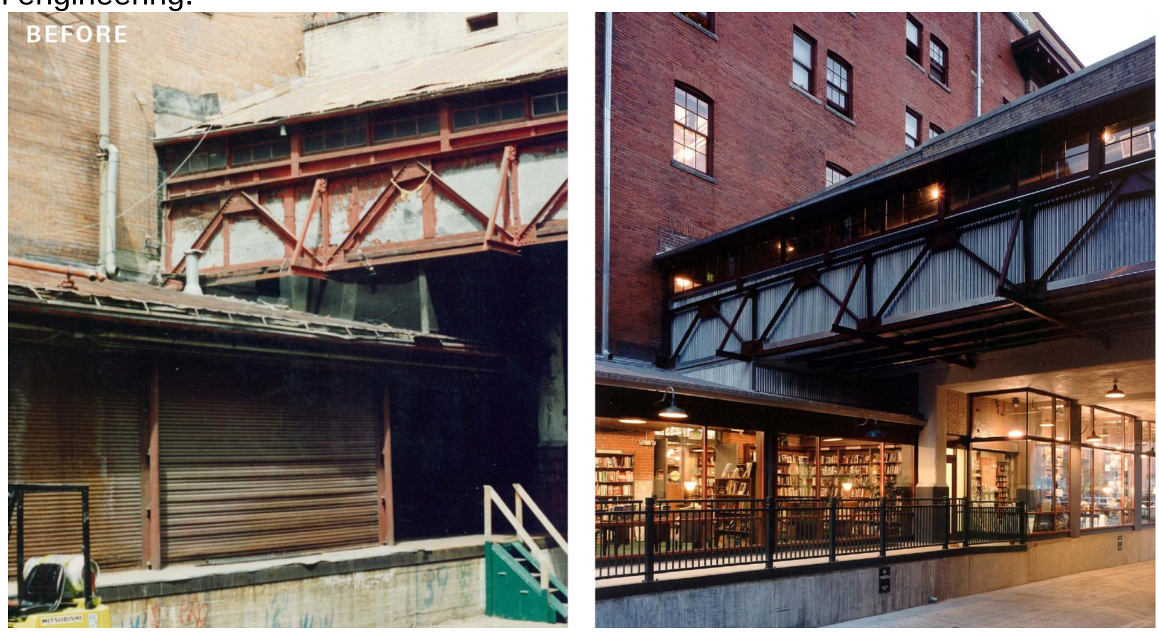



**Figure 1.** Comparison of redevelopment and preservation in urban architecture. The left side shows a modern urban area with high-density buildings and new construction, while the right side displays preserved 1800s masonry warehouses that retain historical character and cultural heritage. This contrast illustrates the need to balance economic development and city growth with the protection of historical sites, as emphasized by McIntyre in The Fundamental Role of Preservation in New Urban Architecture.

## Case Studies

The rapid growth of digital tools has changed how we think about preserving architecture. Traditional methods, often costly, slow, and sometimes damaging, struggle to keep up with the challenges of saving old buildings in fast-developing cities. In contrast, newer technologies like 3D laser scanning, CAD modeling, and 3D printing (additive manufacturing) offer cheaper, faster, and non-invasive ways to document and restore historic structures. These tools not only make it easier to accurately record and rebuild buildings, but they also open up access for education, engineering research, and cultural appreciation.

Still, how widely these technologies are used depends on the country. Some, like England, have actively adopted digital preservation to protect and archive historic buildings. Others, like South Korea, have focused more on economic growth, often allowing historical buildings to be replaced. This paper looks at the real-life outcomes of these different priorities through two case studies: one on England's use of 3D scanning and modeling at Leicester Cathedral, and another on the loss of traditional Korean buildings in Seoul due to ongoing redevelopment. These examples highlight the larger effects of choosing preservation or replacement in today's digital world.

Case Study 1: Digital Documentation and Preservation of Leicester Cathedral, England

(a) (b)

**Figure 2.** This figure shows two results from the laser scanning project at Leicester Cathedral. Panel (a) displays a 3D Revit model of the cathedral's exterior created from point cloud data. Panel (b) features a detailed interior model that documents key architectural elements, tombs, and structural features important for preservation planning.

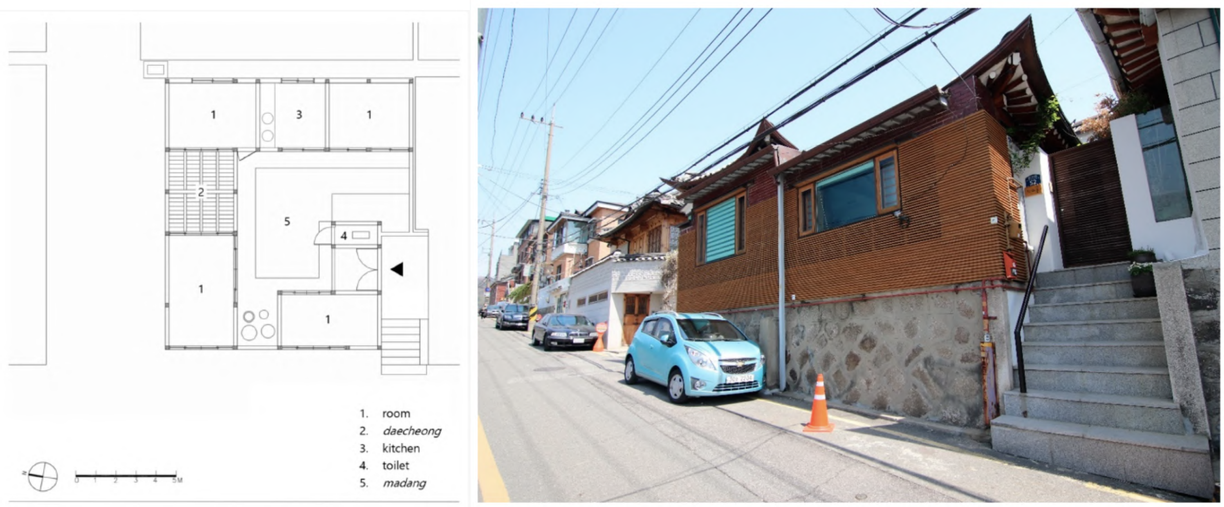
Leicester Cathedral, originally built in the Norman period and reconstructed over several centuries, was digitally scanned to support both the reburial of King Richard III and a major interior redesign. The engineering firm Plowman Craven used a Leica P40 laser scanner, which captures over one million data points per second with 3mm precision. This allowed for a full, accurate spatial record of the building without touching the structure.

The project shows how advanced scanning tools, combined with HDR imaging, parametric Revit modeling, and cloud-to-cloud registration using Leica Cyclone, can offer precise, scalable, and non-invasive solutions for heritage conservation. The final model included not only visible architectural features but also hidden infrastructure like service tunnels, which are essential for understanding weight distribution and planning future changes.

Since the cathedral remained open during the project, engineers carefully planned scanning paths to avoid disrupting religious services. They also addressed safety risks, such as tight spaces and asbestos exposure, by following strict safety protocols and using protective equipment.

The resulting Revit model, with Level of Detail (LOD 2–3) and Level of Information (LOI 200–300), now serves as a long-term digital archive and an engineering resource. This case illustrates how tools like 3D scanning and Building Information Modeling (BIM) are transforming heritage preservation, offering safer, more accurate ways to document and protect historical sites while maintaining their integrity and adaptability for the future.

Case Study 2: Korea's Reconstruction Challenges




(a) (b)

**Figure 3.** (a) An original urban-type hanok built in the 1940s in Samcheong-dong, Seoul. (b) A renovated version of the same hanok, completed in 2000 by architect Wook Choi.

Unlike in England, where engineering tools are routinely used to carefully preserve historic buildings, South Korea often renovates traditional architecture without digital documentation or structural analysis. The Samcheong Hanok, located in Seoul's Bukchon Hanok Village, is a clear example. Originally built in the 1940s as a mass-produced urban-style hanok, it was remodeled in 2000 into a modern home. Although the exterior still reflects traditional Korean design, the renovation did not involve laser scanning, CAD modeling, or structural documentation.

From an engineering perspective, this approach has serious limitations. Without a point cloud, Revit model, or any digital record of the original structure, valuable data was permanently lost. Important details such as how joints were built, how weight was supported, and how materials aged over time are now missing. Without that information, engineers cannot simulate structural behavior, test for earthquake resistance, or accurately recreate the building in the future. The renovation also lacked design validation using simulation tools or iterative modeling in software like Fusion 360 or Rhino.

In comparison, England's preservation process includes detailed scans, 3D parametric modeling, and cloud-based data storage. These tools are essential for accurate analysis and reconstruction.

South Korea's lack of digital preservation points to a larger issue. There are no national requirements for digitally archiving heritage sites, no engineering surveys before renovation or demolition, and little use of virtual modeling for study or education. As a result, much of the engineering knowledge embedded in traditional Korean buildings is being lost. That knowledge could have been preserved, studied, and even recreated using tools like 3D printing.

The Samcheong Hanok shows that when renovation happens without digital preservation, engineering history is lost, even if the building still appears traditional on the outside.

## Comparative Analysis

The two case studies, Leicester Cathedral and the Samcheong Hanok, show how engineering tools can shape the way architectural heritage is treated. In England, the preservation of Leicester Cathedral was guided by a clear goal: to protect cultural history using advanced digital technologies. Tools like 3D laser scanning, Building Information Modeling (BIM), and point cloud registration allowed engineers to build a complete digital replica of the cathedral. This preserved not only its physical details but also made future changes, education, and long-term storage possible. The structure was updated with care but stayed connected to its original identity.

In contrast, South Korea's renovation of the Samcheong Hanok shows how heritage can be reshaped through change, rather than preserved through documentation. While the updated building kept a traditional appearance, it lacked the precision and depth that engineering tools could have provided. There was no attempt to scan or model the original structure, no engineering record of how it was built, and no digital archive created. What remains is a visually familiar building, but one that can't be technically studied, rebuilt, or fully understood.

This difference points to a deeper cultural difference. England sees heritage as a continuous story, where the past guides the future through detailed engineering records. In Korea's case, heritage becomes more of a visual memory, open to change and modernization. One approach values historical accuracy and continuity; the other values present-day relevance and flexibility. Engineering tools like 3D modeling and 3D printing can support either perspective, but whether we choose to use them or not decides if we preserve our history or transform it into something new.

**Table 1**: Summary of the two case studies.

| Engineering Aspect | Leicester Cathedral, England | Samcheong Hanok, South Korea |
| --- | --- | --- |
| **Documentation Tools** | 3D laser scanning (Leica P40), HDR imaging, BIM (Revit), point cloud registration | No 3D scans, CAD, or BIM used |
| **Model Output** | Detailed parametric digital twin (LOD 2–3, LOI 200–300) | No engineering model or digital archive |
| **Structural Analysis** | Enables load assessment, stress simulation, and design validation | No structural simulation or engineering analysis |

This comparison reveals key engineering differences between the two case studies. In England, Leicester Cathedral was preserved using advanced tools like 3D laser scanning, BIM modeling, and point cloud registration. These technologies allowed engineers to create a detailed digital twin, enabling precise structural analysis, load evaluation, and safe long-term data storage for future restoration and study. In contrast, South Korea's Samcheong Hanok was remodeled without any digital documentation or engineering modeling. As a result, important structural information was lost, no simulations or safety checks were performed, and there is no engineering data to guide future preservation. This contrast highlights the importance of using engineering technologies to ensure accurate, sustainable architectural conservation.

**Design Process and Engineering Tools**

Preserving architecture through 3D modeling and printing involves a variety of engineering tools, from scanning devices to digital design software. This section explains the workflow and specific programs used in this project to digitally and physically model architectural structures.

The process started with Tinkercad, a user-friendly platform that helped shape early design ideas. Its simple drag-and-drop interface allowed for quick prototyping of basic forms, making it easy to test space and proportions. After the initial shapes were defined, the project moved into Fusion 360, a more advanced CAD program used for parametric modeling, precise measurements, and detailed structural design. Fusion 360 enabled the creation of accurate parts that reflect real architectural elements with engineering accuracy. The completed model was then brought into Blender, a visualization software. Blender's powerful rendering features helped simulate realistic lighting, textures, and materials, providing a detailed and lifelike view of the final structure.

For physical preservation and presentation, the model was processed in Creality Slicer software and printed using a filament-based 3D printer. The resulting printed model serves as a physical record of architectural heritage, showing how tangible replicas can support education, documentation, and preservation work.

**Engineering Analysis and Design Application: Traditional Hanok Roof Geometry**

Accurate digital preservation of historic buildings goes beyond just copying their appearance; it requires understanding the original engineering principles built into their design. In reconstructing the traditional Korean hanok for this study, the design used architectural proportions based on detailed research. A 2024 study published in Buildings (MDPI) examined the geometric rules behind traditional hanok roofs, providing important engineering knowledge about how they distribute weight, regulate temperature, and create balanced spaces.

The research found consistent design patterns: hanoks have an eave-to-roof height ratio of about 5.5 to 4.5, and the combined angle of the roof and eaves ranges from 118° to 120°. These measurements aren't random; they reflect hundreds of years of adapting to Korea's climate and optimizing structural strength. Using these exact proportions in the Fusion 360 CAD model improved the accuracy and authenticity of the digital reconstruction.

**Table 2:** Traditional Hanok Roof Geometry Based on MDPI Study and CAD Implementation

| Parameter | Study Value | Applied to the Fusion 360 Model |
|---|---|---|
| **Eave-to-Roof Height Ratio** | 5.5 : 4.5 | 5.5 : 4.5 |
| **Combined Roof + Eave Angle** | 118°–120° | 119° |
| **Ridge Beam Curvature** | Moderate curve | Modeled with Bézier surface |

To replicate the traditional roof slope, the model was adjusted to fit the specified angles, ensuring that the load from the tiled roof transfers properly to the post-and-beam structure below. The roof's curved shape, typical of historic hanok design, was created using Bézier surfaces to mimic the curved wooden beams (seon-deung). This careful use of traditional proportions offers several benefits.

Matching the CAD model to these hanok ratios improves how well it simulates structural load behavior, allowing realistic analysis of stress under the roof's weight. These angles also naturally support passive ventilation and shading, which are important for thermal and environmental modeling of Korea's climate-adapted architecture. Beyond technical gains, this approach enhances educational value by letting students and engineers study not just the hanok's shape but also the logic and proportions built into its design.

In short, integrating traditional proportional engineering into the model boosts structural simulation accuracy, optimizes climate performance, and provides a richer learning tool that reveals the hanok's underlying design principles.

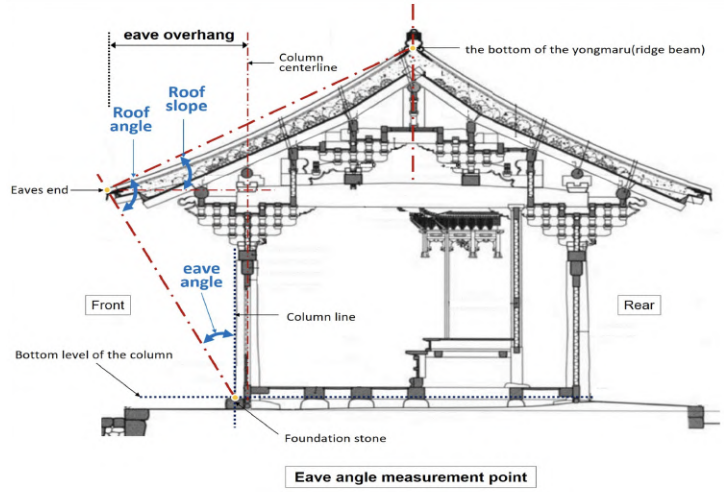



**Figure 4**. An annotated cross-sectional side view of a traditional Korean hanok roof, adapted from Shin et al. (2024).

This diagram shows key architectural measurements and proportions typical of traditional wooden **hanok** construction. The roof angle, around 118°–120°, balances structural needs with the building's graceful curve, while the eave-to-roof height ratio of about 5.5:4.5 reflects the joinery techniques used in hanok engineering. Important parts like the main rafters (chunyeo), purlins (yeonmok), and ridge beam are marked to show how vertical and horizontal loads are carried across the tiled roof. This figure serves as an accurate geometric guide for the Fusion 360 CAD model, helping shape the roof's curve, overhang size, and joinery locations.

This part of the project illustrates how engineering analysis deepens cultural preservation by respecting both the look and the structural purpose of historic architecture. It highlights that digital modeling and 3D printing work best when they combine modern technology with traditional craftsmanship.

### Showcasing a Sample 3D Model: Hanok Reconstruction

To show the preservation power of 3D modeling, a digital reconstruction of a traditional Korean hanok was created. Using historical sources, photos, and existing floor plans, the design was rebuilt in Fusion 360, focusing on key features like the wooden post-and-beam frame, tiled roofs, and traditional courtyards. Since many historic hanoks have been lost due to urban redevelopment and poor documentation, this virtual model helps save an important part of Korea's cultural heritage that might otherwise disappear.

This digital reconstruction allows researchers to study the building's structural design, proportions, and layout, filling in gaps left by missing preservation rules. To make the model more accessible and educational, it was rendered in Blender and 3D printed using PLA plastic to create a durable physical replica. This tangible model shows how 3D printing can create tools that keep historical memory alive even when original buildings no longer exist. Such replicas are useful for museum displays, classrooms, and engineering workshops, offering hands-on ways to explore cultural architecture.

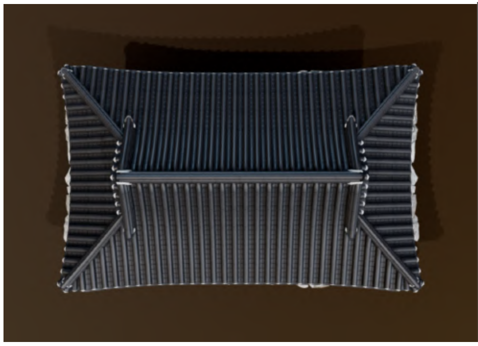
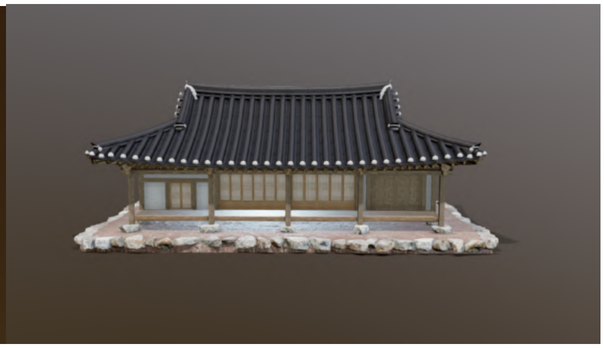



**Figure 5.** Top view of the roof and courtyard. **Figure 6.** Front entrance and framework.

**Figure 7.** Left eaves and joinery.


**Figure 8.** The right roof curve and walls. **Figure 9.** Rear structure and entrances.

### Alternative Technologies for Preservation

While 3D printing plays an important role, other modern technologies also greatly support architectural preservation. Photogrammetry captures 3D information using photos, making it especially useful when laser scanners aren't available. LiDAR (Light Detection and Ranging) uses laser pulses to measure distances and create detailed 3D maps, improving accuracy in digital models. Augmented Reality (AR) and Virtual Reality (VR) let people explore reconstructed historical sites in immersive ways, bringing vanished or hard-to-access buildings to users around the world. Digital twins, full digital copies of buildings, allow engineers to simulate stresses, test renovation plans, and explore structural changes without affecting the real structure.

Together, these tools complement 3D printing and enrich the digital preservation ecosystem by helping protect cultural heritage while increasing access and sustainability.

**Benefits of Visiting Preserved Sites**

Visiting preserved historical buildings provides a unique, multisensory link to the past. Being inside a hanok or cathedral lets visitors feel the materials, sense the scale, and understand the symbolism in ways photos or drawings can't capture. Such experiences inspire empathy, curiosity about history, and respect for culture. Educational programs and tourism also benefit from access to these sites; students can study real engineering techniques, and visitors gain deeper insight into craftsmanship, cultural change, and how architecture responds to environmental and social challenges.

**Solutions and Strategies for Preservation**

To overcome challenges in protecting cultural heritage, a mix of digital and physical strategies is needed. First, engineering analysis based on historic research ensures digital reconstructions stay true to structural and climate realities, preserving the building's original intent beyond just looks.

Second, using accessible tools like Fusion 360 for modeling, Blender for rendering, and affordable 3D printing materials like PLA helps more researchers, educators, and cultural groups join preservation efforts. Making these technologies available beyond specialized labs empowers communities and schools.

Third, combining scanning and visualization methods, such as photogrammetry, LiDAR, AR, and VR, builds rich digital archives that capture both shape and context. This layered documentation supports restoration, disaster recovery, and virtual tourism.

Finally, teamwork between engineers, architects, historians, and local communities ensures projects honor cultural values and traditional knowledge. Educational outreach and interactive exhibits with physical and virtual models engage the public and build support for ongoing conservation.

**Conclusion and Broader Impacts**

This research shows that 3D modeling and printing are powerful engineering tools for preserving cultural architecture. Digital reconstruction allows us to archive building dimensions, analyze structural logic, and create faithful replicas. England's use of 3D scanning and Building Information Modeling (BIM) in preserving Leicester Cathedral supports this approach's success. In contrast, Korea's modernization of hanoks without digital documentation shows the irreversible loss caused by neglecting preservation technology.

Beyond just saving buildings, additive manufacturing democratizes heritage access by letting people worldwide explore, print, and learn from historic models. It lowers restoration costs, aids disaster recovery, and creates interactive educational tools. Technologies like CAD, laser scanning, and VR bridge historical knowledge and future innovation, ensuring that as cities grow, the stories and systems of the past are not forgotten but actively protected. With increasing urbanization and threats to historic buildings, these tools are essential to safeguarding architectural legacies.

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