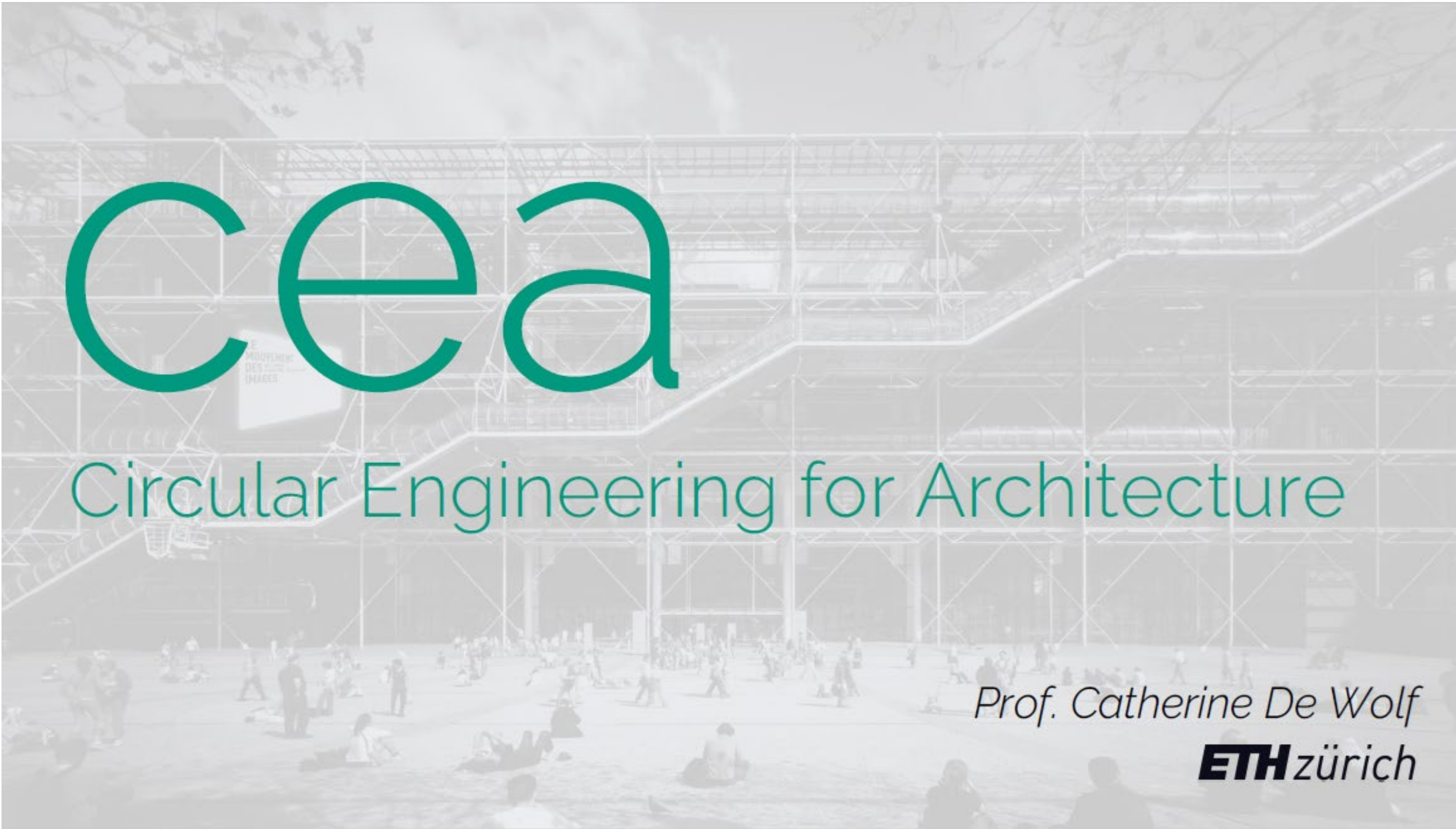
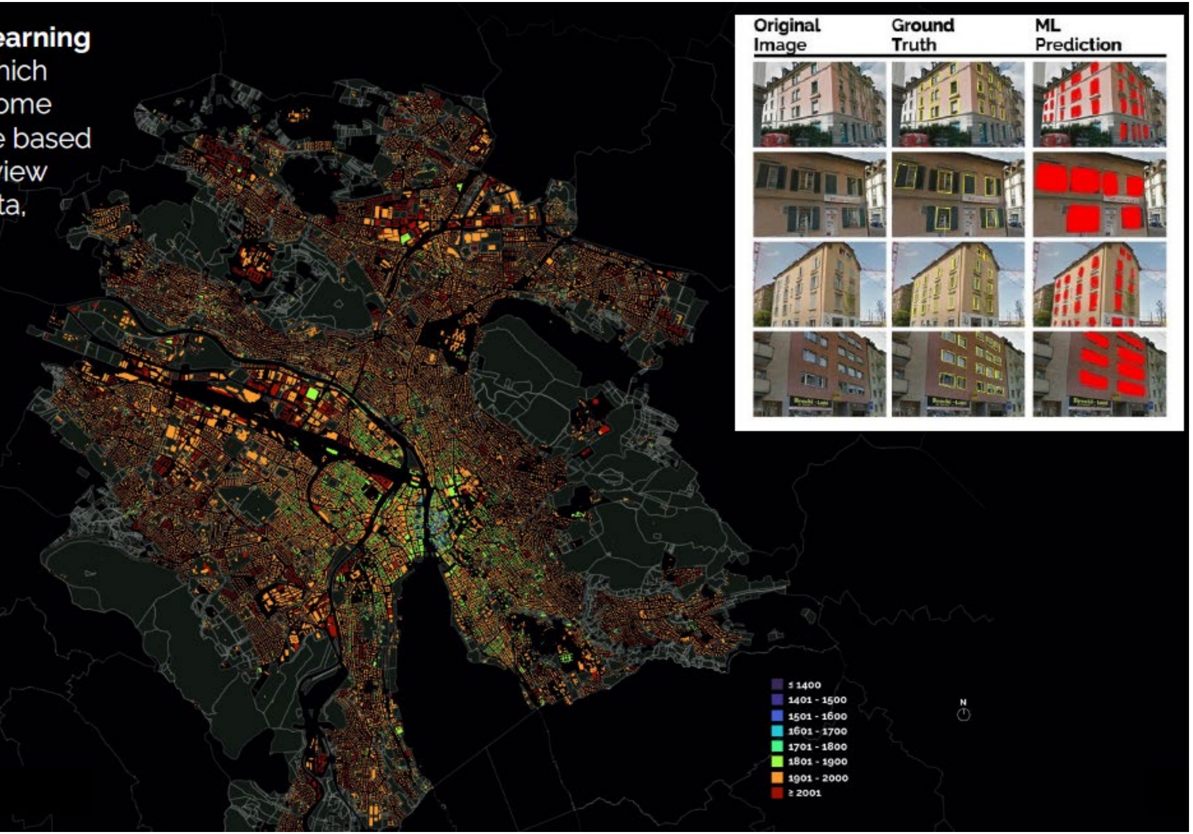
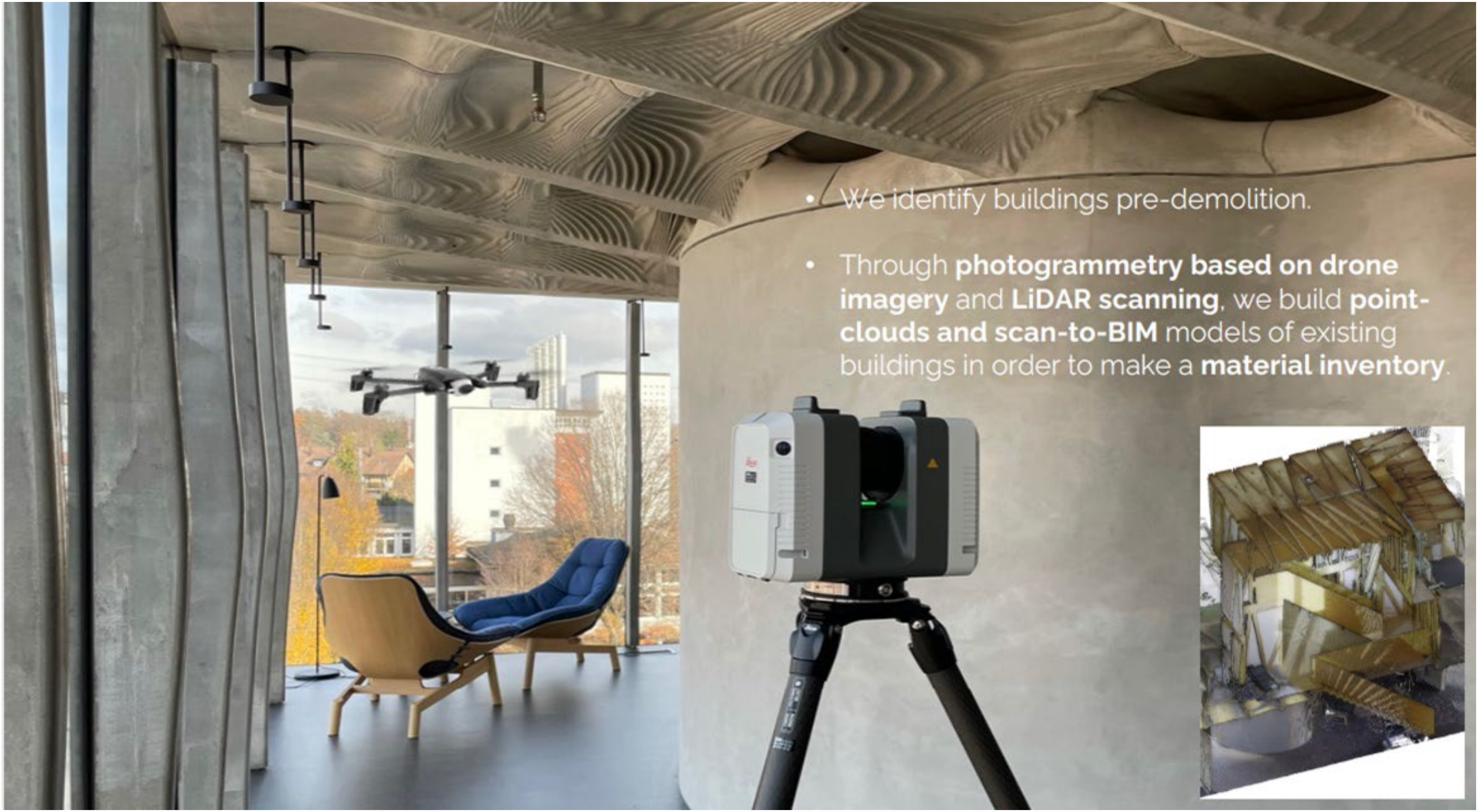
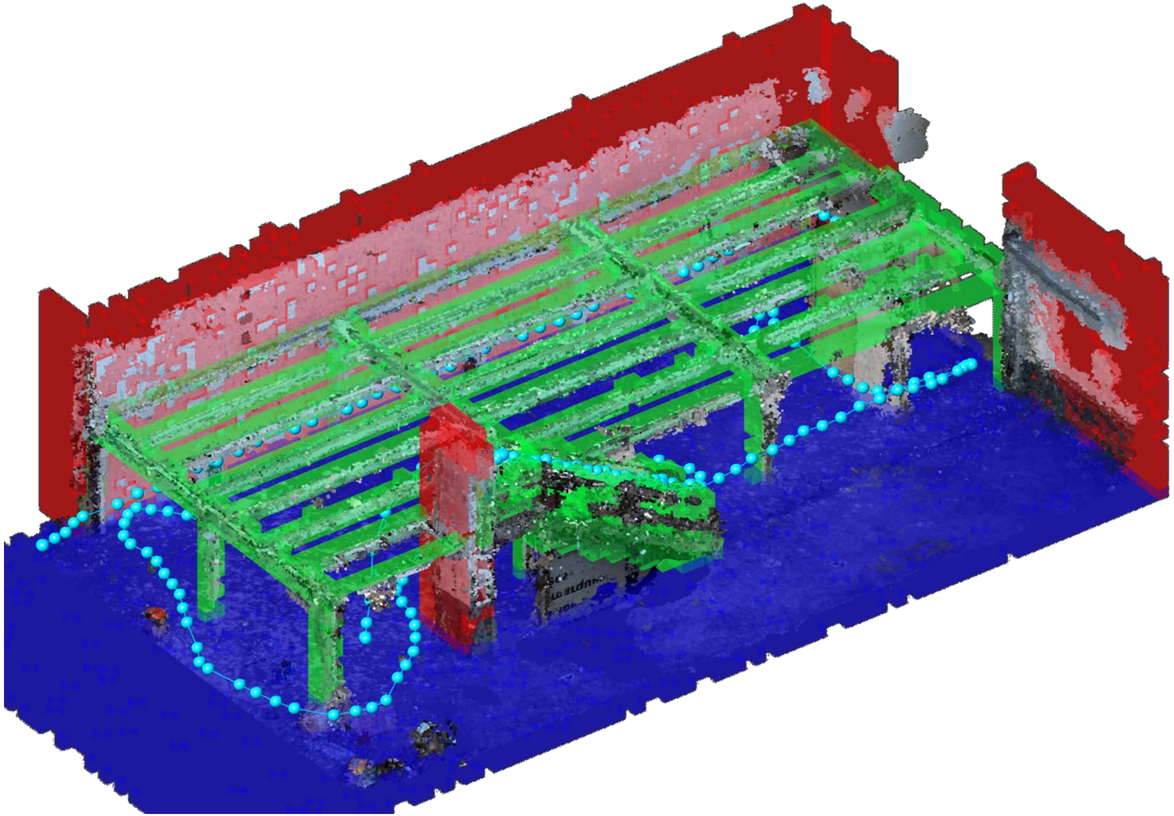
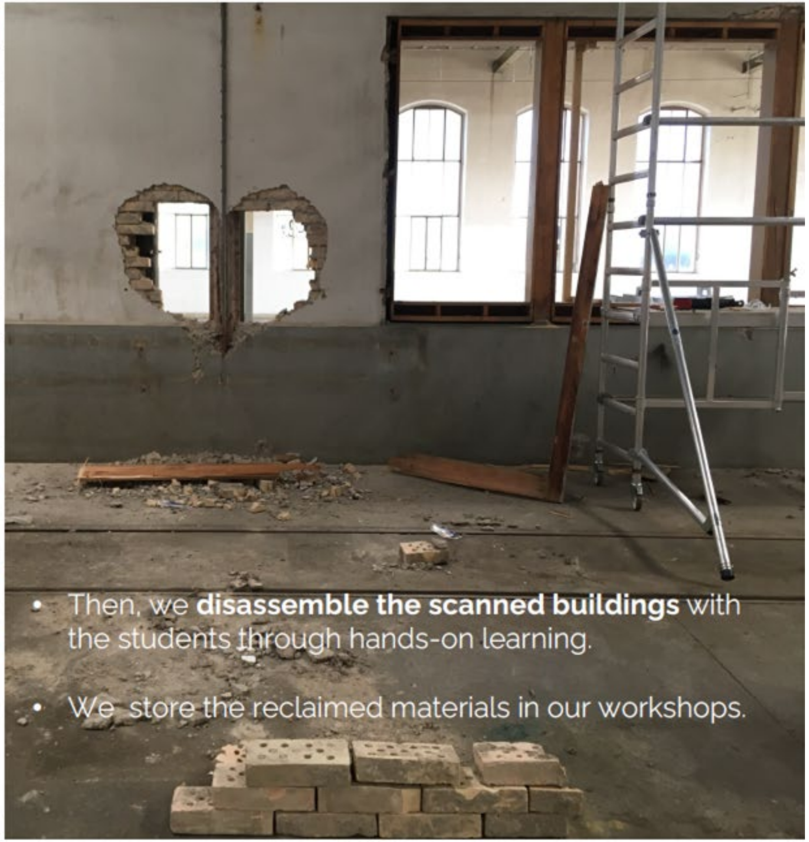

cea
Circular Engineering for Architecture
Prof. Catherine De Wolf
ETH zürich

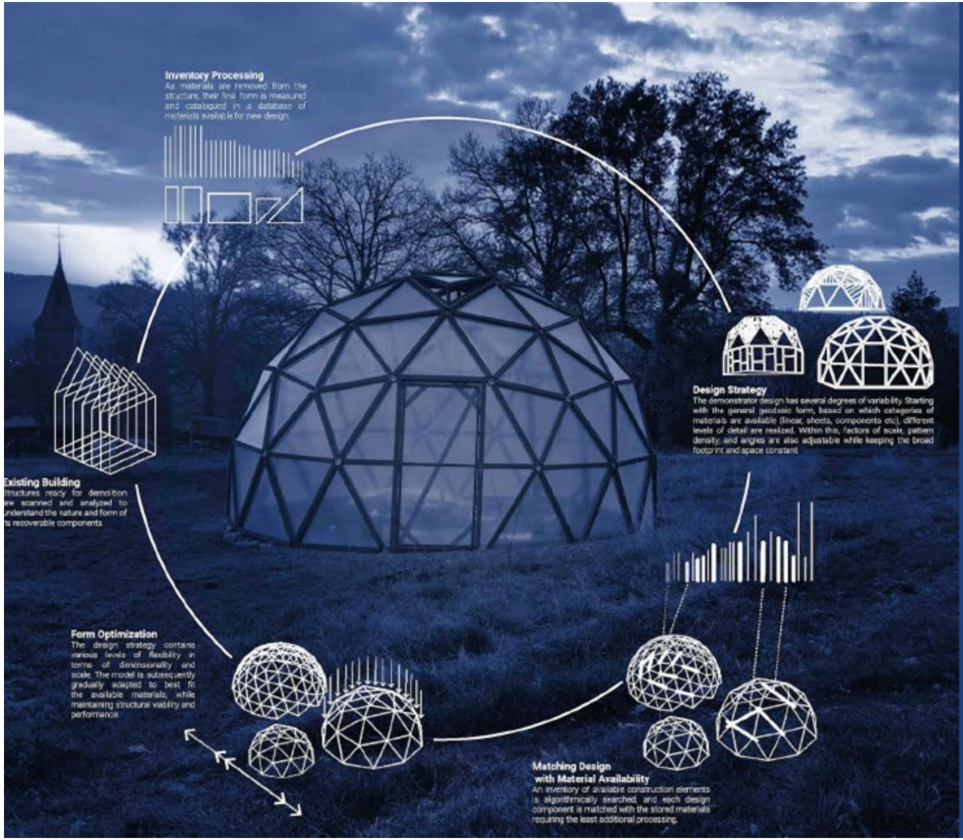
- Using **Machine Learning (AI)**, we predict which materials will become available for reuse based on Google Streetview data, cadastral data, photography, etc.




• We identify buildings pre-demolition.
• Through **photogrammetry based on drone imagery** and **LiDAR scanning**, we build **point-clouds and scan-to-BIM** models of existing buildings in order to make a **material inventory**.




• Then, we **disassemble the scanned buildings** with the students through hands-on learning.
• We store the reclaimed materials in our workshops.



- Next, we use **computational design algorithms to match** our new design with the inventory of available materials.
- Finally, we **robotically assemble** the new structure with the reclaimed materials.

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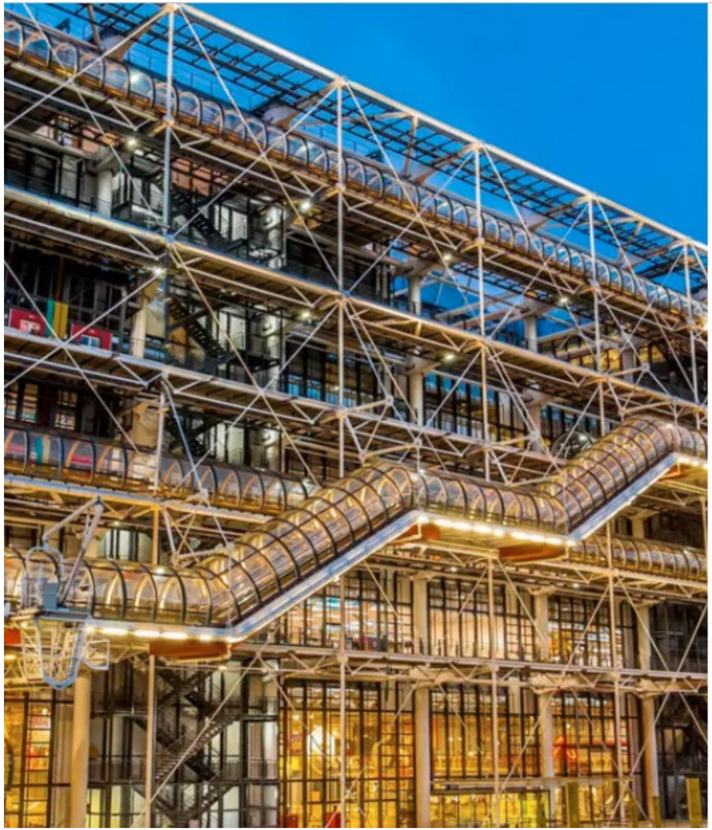
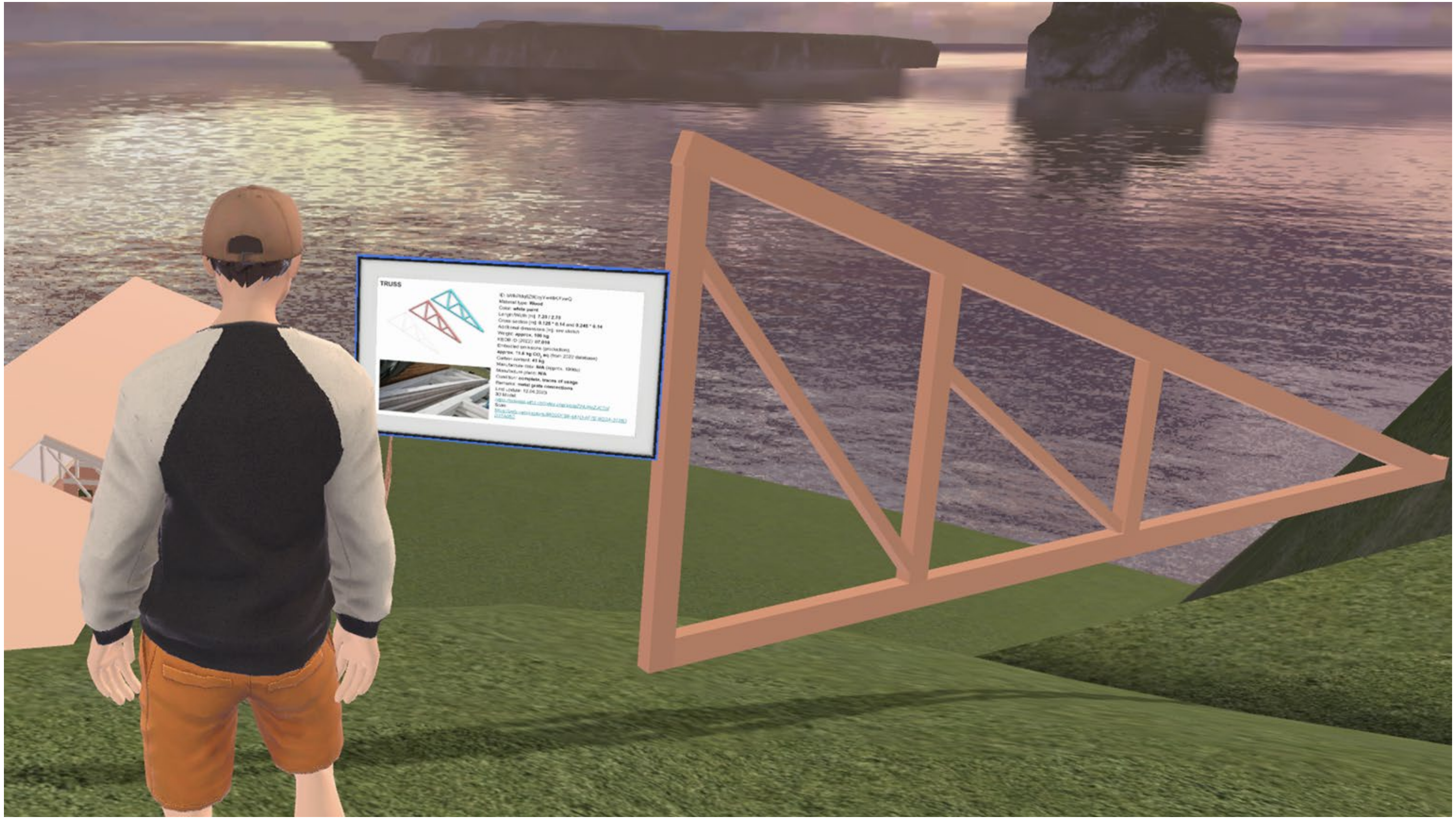



The CEA lab fosters the reuse of building materials (such as the glass of the Centre Pompidou) through digital innovation to accelerate the transition to a circular construction industry

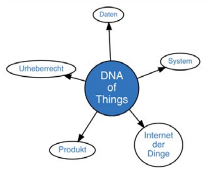

SSWM 20
Ariza, Rust, Silvestru, Taras, Gramazio, Kohler, & De Wolf (2024).
"Lost and bound: adaptive detailing with robotic additive joining for reclaimed steel." Robarch


TRUSS
Material type: Wood
Color: white paint
Weight: approx. 100 kg
Carbon content: 41 kg
Condition: complete, traces of usage
Remarks: metal plate connections
3D Model
Scan

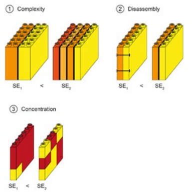
Topics

Master project and thesis

Master thesis



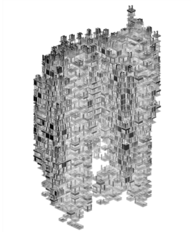
Optimal Integration Techniques of Data Storage via DNA in Setting Construction Materials



Evaluating the degree of reusability of buildings: A case study

Mixed Reality as Digital Tool for Teaching Life Cycle Assessment of Buildings

Validation of Hybrid Reclaimed Timber + 3D Printed Wood elements.

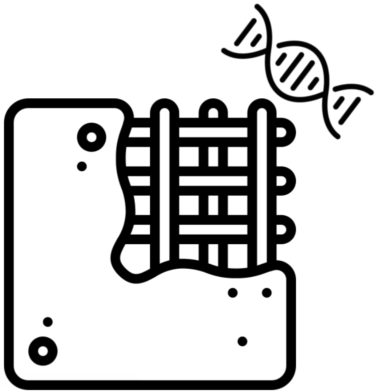


Machine Learning in Circular Design with Reclaimed Building Elements

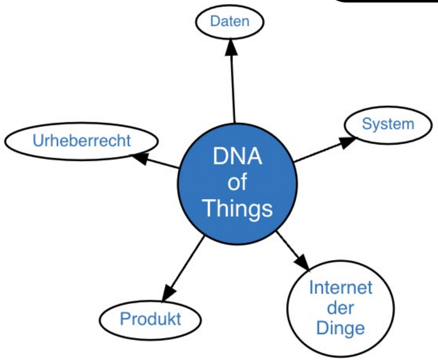
coop

Master Planning Circular Construction with Coop at Wädenswil

Optimal Integration Techniques of Data Storage via DNA in Setting Construction Materials



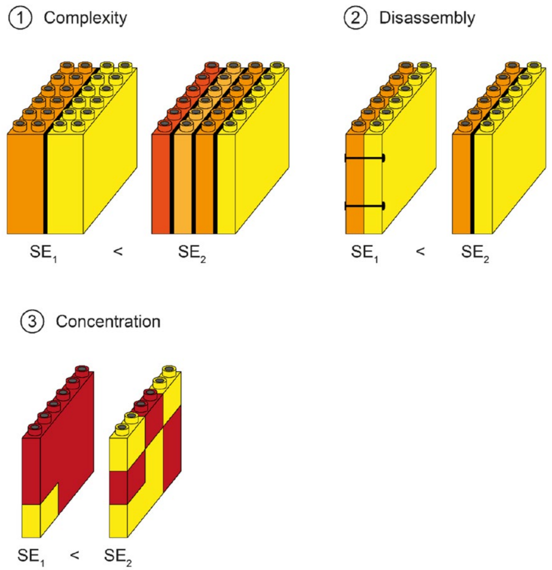
- **Supervisors:** Brandon Byers (byers@ibi.baug.ethz.ch), Prof. Dr. Robert Grass (D-CHAB), Catherine De Wolf (D-BAUG)
- **Goal:** Determine the best methods for embedding DNA into [paint or concrete] and establish the minimum concentration needed for reliable data retrieval.
  - Which techniques most effectively incorporate DNA into paint and concrete without compromising material or DNA quality?
  - What's the least DNA concentration required in materials to ensure data is consistently readable?
- **Main Tasks:**
  - Sample Preparation: Create paint and concrete batches with varying DNA concentrations.
  - Data Retrieval & Analysis: After material curing, extract/ decode DNA to gauge readability. Assess if DNA concentration affects retrieval success.
- **What you will learn:** Material track & trace for circular construction, state-of-the-art data storage techniques
- **What is a successful project?** A guideline on effective DNA integration in [paint and concrete], including the least DNA concentration required for reliable data retrieval
- **Prerequisites:** Curiosity and interest in biology, openness to collaboration with different departments and labs, experience w/ handling construction materials



Evaluating the degree of reusability of buildings: A case study

- **Supervisors:** Dr. Katarina Slavkovic (slavkovic@ibi.baug.ethz.ch), Prof. Dr. Catherine De Wolf (ETH), Prof. Dr. Helmut Rechberger (TU Wien)
- **Context:** The relative product-inherent recyclability (RPR) is a robust assessment method for evaluating the degree of recyclability at building assembly scale (e.g. external wall). Researchers at Technical University of Vienna developed and tested the method [1].
- **Goal:** Explore the adaptation of the RPR method to evaluate reusability of an office building, thus introducing an additional tool to the existing building evaluation metrics. If interested, other building types, such as educational, cultural, or industry, could be discussed with the supervisor.
- **Main Tasks:** (1) Analyse the RPR method and review the existing methods for assessing reusability, (2) extend the scope and adapt the method to reuse, (3) apply the new method to a case study, and (4) support dissemination of new knowledge by writing a paper.
- **What you will learn:** Circular economy principles, with a particular focus on reuse strategies in the construction industry. Principles of statistical entropy, notably, complexity, disassembly, and concentration, associated with material composition of buildings.
- **What is a successful project?** Successful project demonstrates the application of the new method, and potential benefits of using the method on an architectural design project.
- **Prerequisites:** familiarity with reuse and recycling; basic academic writing skills, .
- **Extra**: Potential participation in a conference to present your research and join the discussions on circular built environment. Please contact the supervisor: slavkovic@ibi.baug.ethz.ch.

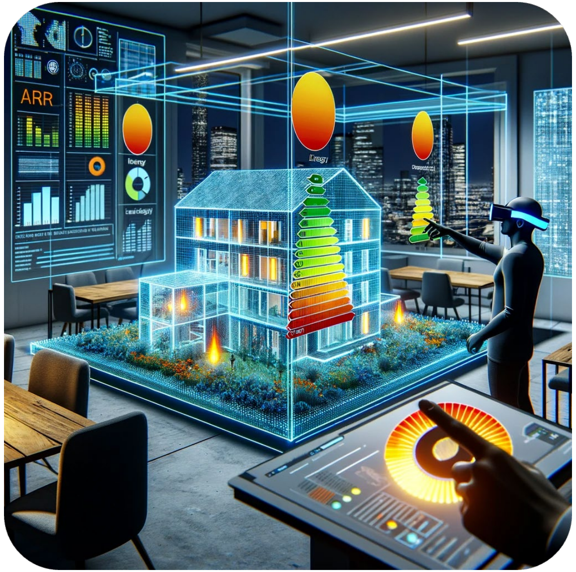
[1] Roithner C, Cencic O, Honic M, Rechberger H. Recyclability assessment at the building design stage based on statistical entropy: A case study on timber and concrete building. Resources, Conservation and Recycling. 2022;184:106407.



Examples of building wall designs described with Statistical Entropy (SE): 1. complexity of assembly structure, 2. disassembly into elements and 3. material concentration in element. Source: [1].

Mixed Reality as Digital Tool for Teaching Life Cycle Assessment of Buildings

- **Supervisors:** Dr. Katarina Slavkovic (slavkovic@ibi.baug.ethz.ch) and Dr. Eleftherios Triantafyllidis (triantafyllidis@ibi.baug.ethz.ch), Catherine De Wolf
- **Context:** Mixed Reality (MR) has the potential to be significantly engaging for users. LCA is a standardised method for quantifying environmental flows associated with the build environment. By combining MR and LCA, there is a notable potential to educate the public about the environmental impact of the circular build environment *(Helamini et al, 2024)*.
- **Goal:** As one of a two-member team, develop a tool that relies on immersive solutions, for educating users about the life cycle environmental performance of buildings.
- **Main Tasks: (1)** Analyze current educational practices on LCA with a focus on MR integration. **(2)** Develop an MR application, showing life cycle environmental impact of a building, quantified with LCA. **(3)** Evaluate the effectiveness of the MR tool in educating users, by conducting a workshop followed by a questionnaire. **(4 - Bonus)** Contrast it with conventional education (e.g. text-books).
- **What you will learn:** Gain insights into LCA and MR, develop an MR educational tool, and contribute to sustainable building practices.
- **What is a successful project?** Engaging and informative MR tool that educates the general public on what constitutes LCA and its concepts, underlining the necessity for circular practises.
- **Prerequisites:** Familiarity with reuse strategies, LCA, MR (ideally have tried it before; but not necessarily), software engineering background (e,g, Unity3D, Unreal, C#, C++) and basic academic writing skills.
- Please contact the supervisors: slavkovic@ibi.baug.ethz.ch and triantafyllidis@ibi.baug.ethz.ch

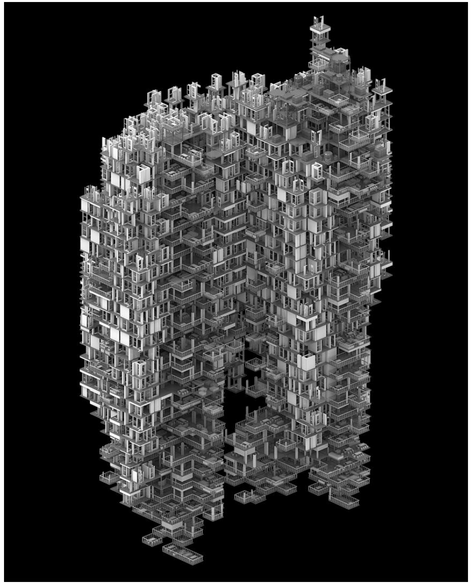


Artistic depiction of using MR to engage users about LCA and understanding the principles of LCA – the impact of our building on the environment. Through immersive visualisations and interactions, users educate themselves about LCA.

Helamini Sandagomika, Safoura Salehi, & Mehrdad Arashpour (2024). Hybrid Life Cycle Assessment (LCA) of prefabrication: A comparison of conventional and mixed reality-based solutions. *Journal of Cleaner Production, 450, 141883.*

Machine Learning in Circular Design with Reclaimed Building Elements

- **Supervisors:** Beril Önalan (oenalan@ibi.baug.ethz.ch), Vanessa Schwarzkopf (schwarzkopf@ibi.baug.ethz.ch), Catherine De Wolf
- **Goal:** The aim is to understand and map out possible Machine Learning (ML) applications for designing from reused materials
- **Main Tasks:** Systematic Literature Review for ML (Generative and Discriminative Models) in digital design and architecture and their potential of application for circular design tasks
- **What you will learn:** Throughout this project, you will gain insights into ML application of computational design methods to circular design problems. In particular you will explore deep learning models (NN,GAN, VAE, CCN, Transformer, …) with an emphasis on using discrete three dimensional reclaimed building material inventories to investigate scalable computational design methods to provide solution to increasingly pressing environmental issues.
- **What is a successful project?** Providing an overview of current research on ML for circular design and identifying research gaps and potentials through presenting your research results
- **Prerequisites:** Interest and curiosity for the research on the digital transformation for circular engineering and architecture, especially in the field of Artificial Intelligence and early-phase design



Housing GAN 2021, Immanuel Koh

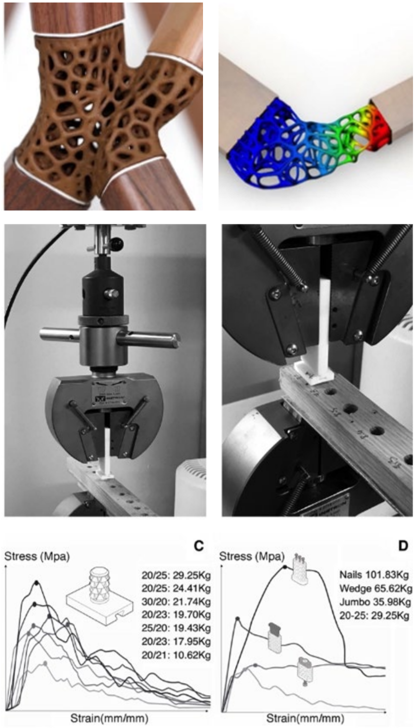
An example of implementing Generative Adversarial Networks with 3D data to a design task

Master Planning Circular Construction with Coop at Wädenswil

- **Supervisors:** Elias Knecht (knecht@ibi.baug.ethz.ch), Arabelle de Saussure (desaussure@ibi.baug.ethz.ch), Catherine De Wolf
- **Goal:** Investigate, quantify and qualify the potential for circular construction for the planned refurbishment of existing houses of Coop in Wädenswil.
- **Main Tasks:** (1) Conduct a comprehensive literature review of existing research on digital innovation, reuse-friendly modern architecture, and circular economy concepts. (2) Conduct fieldwork in Wädenswil and set up an inventory of reusable materials. (3) Evaluate the potential environmental and economic benefits of incorporating digitally innovative techniques for circular construction into the refurbishment project of Wädenswil.
- **What you will learn:** You will learn practical skills in fieldwork and data collection; circular economy concepts; digital innovation; the challenges and opportunities of circular construction
- **What is a successful project?** A successful project demonstrates the potential environmental and economic benefits of circular construction in the Swiss Mill site while incorporating digital techniques into modern architecture design and construction.
- **Prerequisites:** Critical thinking and problem-solving skills; familiarity with digital tools, architecture, (de-)construction processes, and circular economy concepts, experience using excel, photography and CAD.

Structural Simulation and Validation of Hybrid Reclaimed Timber + 3D Printed Wood elements.

- **Supervisors:** Vanessa Costalonga(costalonga@ibi.baug.ethz.ch), Catherine De Wolf
- **Goal:** Create a simulation protocol for Hybrid structures made from Reclaimed Timber and 3D Printed Wood Waste, and validate this simulation with destructive testing.
- **Main Tasks:**
  - Material Testing to define mechanical properties of the hybrid material
  - FEA Modelling of a series of given case studies.
  - Preparation of test samples for destructive testing.
  - Make recommendations for the design refinement based on simulation and test results.
  - Topology optimisation of designs could be explored.
- **What you will learn:**
  - How to simulate 3D Printed structures.
  - Structural Testing protocol: Assess the structural performance of Hybrid Timber/3D Printed elements based on EU regulations.
- **What is a successful project?** A successful project will simulate, test and analyse the given case studies and present structural recommendations for design refinement.
- **Prerequisites:** Familiarity with Finite Element Analysis (FEA) tools and willingness to conduct destructive structural testing. Knowledge of Rhino/Grasshopper is recommended.



Magrisso, Shiran, Moran Mizrahi, and Amit Zoran. "Digital Joinery For Hybrid Carpentry." In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, 1–11. Montreal QC Canada: ACM, 2018. https://doi.org/10.1145/3173574.3173741.