Informationsveranstaltung am 28.04.2022, 17.00 Uhr über Zoom Videokonferenz

Master-Arbeiten und Master-Projektarbeiten am IBI

Prof. Dr. B.T. Adey, Prof. Dr. Catherine de Wolf, Prof. Dr. G. Habert
Our built environment is constructed, operated, and maintained to support the functioning of our society, in economic, social and environmental terms.

The institute for construction- and infrastructure management has the general mission to equip our students to ensure that this happens, optimally.

The fulfillment of this mission requires teaching the fundamentals of, and conducting research in, the general fields of construction engineering and infrastructure management.
Challenges short term – Digitalization

- Digitalization of planning
- Robotization and digitalization of construction
- Digitalization of maintenance and operation
- Smart meters and monitoring
- Big data
Urbanization: Doubling the building stock by 2050
Greenhouse Gas emissions mitigation: Reach Zero emission by 2040
Climate change adaptation: Resilience to more extreme events than system initially designed for
Renovation & maintenance of existing aging buildings and infrastructure in a context of reduction of public investment.
IBI is structured along 3 main streams

- Infrastructure management
  - Prof. Dr. Bryan T. Adey

- Circular Engineering for Architecture
  - Prof. Dr. Catherine De Wolf

- Sustainable Construction
  - Prof. Dr. Guillaume Habert
Our students continue on to high impact positions....
There are two possible prizes for great work with us

**Fonds Bau und Infrastruktur-Förderungspreis**

**Ziel:**
- Hervorragende Master- und/oder Doktor-Arbeiten aus dem Bereich „Bau- und Infrastrukturmanagement“ mit einem Preis auszuzeichnen
- Interesse für Probleme im Bereich des Bau- und Infrastrukturmanagements bei der heranwachsenden Ingenieurgeneration wecken und die Innovationsfreudigkeit für Weiterentwicklung von Bau- und Infrastruktursystemen gefördert werden.

**Preisverleihung:**
- In der Höhe von CHF 2’000 (Master-Arbeit)

**Helbling-Preis**

**Ziel:**
- Masterstudierende für die Themen des lebenszyklus-orientierten Planens, Bauens, Betreibens und Erhaltens von Infrastruktur mit einem besonderen Fokus auf Nachhaltigkeit zu begeistern
- Ambitionierte Masterstudierende, die exzellente Leistungen im Bereich Bau- und Infrastrukturmanagement erbracht haben, auszuzeichnen

**Preisverleihung:**
- Kann einmal pro Semester erfolgen in der Höhe von CHF 5’000
Infrastructure Management Group
Vision: Infrastructure management more quantitative / formal

Establish service level goals and constraints

There are clear definitions of the service to be provided and how this service is to be valued to enable aligned and transparent decision making throughout the organisation.

Establish structures, processes, models, and strategies

The structures and processes are established with the goals of the organisation in mind so that decisions are not silo dependent. The models to be used in the processes are optimal in terms of effort and accuracy and the goals to be achieved. The strategies per object are clearly defined and have been estimated as being optimal with respect to the organisational goals.

Construct monitoring programs, intervention programs

Determined in a quantitative manner to provide the most net-benefit, take into consideration synergies with the network and with other networks, and all impacts on stakeholders.

Plan and perform monitoring activities, interventions

Clear guidance is given as to how the activities and interventions are to be performed.

Analyse effectiveness of monitoring activities and interventions

Appropriate analysis of effectiveness with respect to organisation goals done with information flowing back into the process for future improvements.

Analyse process

Thorough analyses are done with respect to how the infrastructure management process runs and where improvements can be made.
Vision: Infrastructure Management Group 2040

- In 2040, infrastructure managers will be able to look back on a period in which the IMG created the methodologies used in the next generation of IM tools for railway networks, road networks, water distribution networks, sewage networks, and combined municipal networks.

- These methodologies will be coupled with models enabling unprecedented levels of technological detail for management decision-making without losing the essential overall picture, and with systematic coupling of decisions to the service being provided by the networks.

- They will exploit the latest technologies in digitalization, e.g. GIS, BIM, and the latest developments in applied mathematics, e.g. OR models, deep neural networks, Bayesian belief networks, and advanced search algorithms.
Topics

Infrastructure growth over time
Long-term Infrastructure planning under future uncertainty
Evaluation of sensing and responding systems for infrastructure using real options
Stress tests for the transport systems of urban areas
Effects of resilience enhancing interventions considering spatial and temporal cascading events
Estimating the probability of railway asset failure using fault trees
Estimating railway link reliability, availability and maintainability
Costs and benefits of cycling infrastructure
Evaluation of the use of RELAST in infrastructure maintenance strategies
Predicting future interventions on bridges using Monte Carlo simulations
Connecting future bridge predictions to BIM
Integrated planning of interventions on road sections comprised of assets of different types
Optimization of supply and inventory recycling streams
1 – Modelling infrastructure network growth over time

- **Supervisors:** O. Roman (roman@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey
- **Goal:** To develop a model of how an infrastructure network change over time
- **Main Tasks:**
  1) Document / explain the evolution of an infrastructure network from at least 1920 to 2020,
  2) identify the potential key parameters driving these changes,
  3) develop a model to explain the network growth and test the potential key parameters driving the growth,
  4) estimate future values of all relevant parameters, and
  5) forecast potential futures for the evolution of the network.
- **What you will learn:** how to synthesize data collected from different sources, the key parameters that drive change in infrastructure networks, how to use models based on past information to forecast potential futures.
- **What is a successful project?** Convincing arguments that the key parameters driving the change in infrastructure over the last 100 years have been identified and that they can be used to estimate what might happen to the infrastructure network in the future.
- **Prerequisites:** Network Infrastructure 1, enrolled in the RE&IS Masters, GIS, discussion with Mr. Roman and/or Prof. Adey. Knowledge or interest in spatial analysis or statistics will be recommended.
2 – Long-term Infrastructure planning under future uncertainty

- **Supervisors:** O. Roman (roman@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey
- **Goals:** To develop a model to support the decision-making process in long-term infrastructure planning. To develop a plan for an infrastructure system to dynamically adapt over time according to how the future unfold.
- **Main Tasks:**
  1. Select and gather information for an infrastructure system (Some options: energy system in a Caribbean island, water system in Scotland, transport system in Switzerland),
  2. develop a model to relate key uncertainties to future outcomes of the system (e.g. how climate change will affect future water supply),
  3. perform simulations of potential future states of the world,
  4. develop a plan that can adapt over time by monitoring key uncertainties and triggering adaptation interventions.
- **What you will learn:** how to deal with uncertainty by developing adaptive plans that can learn about uncertainties over time and intervene in the system to avoid undesirable consequences.
- **What is a successful project?:** A clear description of the assumptions and steps of the planning process, and a clear adaptive plan for the selected infrastructure system.
- **Prerequisites:** Real Options or Network infrastructure, GIS and/or programming skills will be recommended. Discussion with Mr. Roman and/or Prof. Adey. Comfort working with relatively uncertain situations and interest for bringing clarity to them.
3 – Evaluation of sensing and responding systems for infrastructure using real options

- **Supervisors**: O. Roman (roman@ibi.baug.ethz.ch), Prof. Dr. C. Martani (martani@purdue.edu), Prof. Dr. B.T. Adey
- **Goals**: To construct a simulation model to identify costs/benefits of sensing and responding system. To develop a tool to evaluate optimal designs of infrastructure, considering uncertainty related to future use and environmental conditions
- **Main Tasks**: 1) model the effect that a variation in use and environmental condition has on the infrastructure service, 2) generate possible sensing and responding systems to manage variations in real time, 3) adapt the model provide to the model to evaluate the specific systems, 4) estimate the costs and benefits of the systems on a real world case study
- **What you will learn**: how to consider the impact of uncertainty related to use and the environment in the evaluation in evaluating the impact of sensing and responding infrastructure.
- **What is a successful project?**: A clear description of the steps of the evaluation process, and a clear demonstration of its use to evaluate sensing and responding infrastructure.
- **Prerequisites**: Real Options or Network infrastructure, Comfort working in with relatively vague situations and love for bringing clarity to them

Example: Flexible corridor on Lake Lugano

Example: Flexible entrances to train stations
4 – Stress tests for the transport systems of urban areas

- **Supervisors**: H. Nasrazdani, Prof. Dr. B.T. Adey
- **Goal**: To develop a set of stress tests for transport system of urban areas with 20'000 to 50'000 in inhabitans
- **Main Tasks**: 1) define the transport system, 2) define the stress tests, i.e. what needs to be checked to be able to say that there are acceptable levels of transport system risks, 3) determine the approach to be used, 4) define the system representation, 5) determine how to estimate risk, 6) determine how to evaluate whether the stress tests are passed.
- **What you will learn**: how to establish stress tests that balance the need for an overview of potential problems and an appropriate level of detail striking a balance between qualitative and quantitative measures
- **What is a successful project?** Convincing proposals of stress tests that can be used regularly to check to be able to say that there are acceptable levels of transport system risks
- **Prerequisites**: Infrastructure Management 1 or Network Infrastructure 1, discussion with Hossein Nasrazdani and/or Prof. Bryan Adey.
5 – Estimating the effect of resilience enhancing interventions considering spatial and temporal cascading events

- **Supervisors**: H. Nasrazdani, Prof. Dr. B.T. Adey
- **Goal**: To evaluate the ability of sets of pre-, mid-, post- hazard interventions to improve resilience using simulations
- **Main Tasks**: 1) understand the software developed by the IM group to simulate the effect of flood hazards on infrastructure, 2) identify possible interventions to improve resilience, 3) identify the costs and effects on service of a series of potentially disruptive events, 4) use the software to estimate the costs and effects on service of the interventions, 5) build an argument as to the interventions to be executed and why.
- **What you will learn**: how to use simulations software to evaluate the potential of resilience enhancing interventions, and how to use cost-benefit analysis to build arguments as to the interventions that maximize net-benefit
- **What is a successful project?** Convincing arguments as to the resilience interventions to be executed out of the set analyzed
- **Prerequisites**: Being comfortable with python, Infrastructure Management 1 or Network Infrastructure 1, discussion with Hossein Nasrazdani and/or Prof. Bryan Adey.
Supervisors: Dr. S. Moghtadernejad (moghtadernejad@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey

Goal: Estimate the probability of failure of a railway bridge subjected to both gradual deterioration, such as the corrosion of steel beams, and natural hazards such as scouring of abutments during floods.

Main Tasks: 1) determine failure modes, 2) determine events that would lead to failure, 3) construct failure trees for each failure mode, 4) determine the basic events for which probabilities of occurrence are to be estimated, 5) determine the values of importance, i.e. structural, Birnbaum, Criticality, Fussel-Vesely of each structural element, 6) make intervention strategy recommendations

What you will learn: How to use failure trees to estimate the probability of failure of a real world bridge. How to use expert opinion and literature to obtain estimates of failure probabilities.

What is a successful project? Failure trees providing complete and logical descriptions of how the bridge might fail, and defendable estimates of the probabilities of each failure type.

Prerequisites: Infrastructure Management 1 and 2, discussion with one of the supervisors
7 – Railway link reliability, availability and maintainability

- **Supervisors:** Dr. S. Moghtadernejad (moghtadernejad@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey

- **Goal:** To estimate the reliability, availability, and maintainability of an existing railway line comprised of assets of different types

- **Main Tasks:** 1) define the service provided by the railway line, 2) determine failure scenarios of the line, 3) develop equations to estimate the reliability, availability and maintainability of the line, 4) determine the failure modes of the assets, estimate the reliability, availability and maintainability of the assets, 5) estimate the reliability, availability and maintainability of the line, 6) make proposals for improvement

- **What you will learn:** 1) to evaluate the interplay between reliability, availability and maintainability in practice, 2) to identify potential for improvement to railway lines

- **What is a successful project?** Clear estimation of the reliability, availability and maintainability of the railway line, and clear illustration of how they might be improved.

- **Prerequisites:** Infrastructure Management 1 and 2, discussion with one of the supervisors

- **Supported by:** SZU
8 – Costs and benefits of cycling infrastructure

- **Supervisors:** A. Elvarsson (elvarsson@ibi.baug.ethz.ch), Dr. C. Kielhauser, Prof. Dr. B.T. Adey
- **Goal:** To provide an overview of the costs and benefits of implementing more cycling infrastructure in cities
- **Main Tasks:**
  1) identify and classify the different types of cycling infrastructure,
  2) identify and classify the types of changes that cities have to do when implementing cycling infrastructure,
  3) estimate the costs of cycling infrastructure using publically available literature and data from the city of Zurich,
  4) estimate the benefits of cycling infrastructure using publically available literature and data from the city of Zurich,
  5) demonstrate how the costs of implementation of cycling infrastructure might vary with the combining implementation with normal maintenance activities.
- **What you will learn:** about the costs and benefits of cycling infrastructure and the challenges with make solid business cases
- **What is a successful project?** A clear classification system for cycling infrastructure and reasonable ranges of costs and benefits of each type of cycling infrastructure, with and without combining interventions with maintenance.
- **Prerequisites:** Infrastructure Management 1, or Network Infrastructure 1 and discussion with one of the supervisors

Supported by: City of Zürich

Limited to 2 persons
9 – Evaluation of the use of RELAST in infrastructure maintenance strategies

- **Supervisors:** Dr. S. Moghtadernejad (moghtadernejad@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey

- **Goal:** To evaluate the advantages and disadvantages of the use of the RELAST system in infrastructure maintenance strategies

- **Main Tasks:**
  1) describe the functioning of the RELAST system, 2) develop a maintenance strategy for a structure without the use of the RELAST system, and with the use of the RELAST system, 3) estimate the speed of deterioration of the different components of the assets considering future uncertainty, 4) estimate the intervention costs associated with each type of intervention, 5) estimate the effects on service of each type of intervention, 6) simulate the costs and effects on service over time with both maintenance strategies, 7) competently discuss the advantages and disadvantages of the use of the RELAST system

- **What you will learn:** the activities involved in the maintenance of infrastructure, how to conduct thorough cost-benefit analysis of maintenance activities considering asset life-cycles

- **What is a successful project?** Clear illustration of the extent of the advantages and disadvantages of the use of the RELAST system

- **Prerequisites:** Knowledge of materials in recycling topics and supply chain, and discussion with Prof. Adey

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Supported by: Würth
10 – Predicting future interventions on bridges using Monte Carlo simulations

- **Supervisors:** H. Mehranfar (mehranfar@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey

- **Goal:** To determine when the next interventions are required on a railway bridge between Zollikofen and Brügg using Monte Carlo simulations.

- **Main Tasks:**
  1) assess the provided service,
  2) estimate deterioration speed and uncertainty of bridge components,
  3) determine optimal component strategies,
  4) develop failure trees to estimate risk,
  5) estimate probabilities of occurrence of base events,
  6) estimate consequences of failure,
  7) develop and run Monte Carlo simulations,
  8) predict the interventions in specific future time windows.

- **What you will learn:** how to obtain a quick overview of the required interventions for bridges, how to run Monte Carlo simulations and how to deal with complexity from a management perspective.

- **What is a successful project?** Component level estimates of the interventions required in future specific time windows for this bridge and estimates of risks if they are not done.

- **Prerequisites:** Infrastructure Management 1 or Network Infrastructure, discussion with one of the supervisors.

47% chance that the trusses require a renewal of the corrosion protection and 22% that trusses require complete replacement.

Supported by: SBB CFF FFS
11 – Connecting future predictions to BIM

- **Supervisors:** S. Chuo (chuo@ibi.baug.ethz.ch), Prof. Dr. Q. Chen (UBC), Prof. Dr. B.T. Adey
- **Goal:** To connect simulation software to BIM.
- **Main Tasks:** 1) understand how future condition state predictions are made for bridge components, 2) understand how future interventions are predicted, 3) develop a data base which contains this information, 4) connect the database to BIM, 5) illustrate the possible visualisations of the expected deterioration and possible interventions, 6) determine how to best illustrate uncertainty, 7) develop guidelines for implementation.
- **What you will learn:** How to predict deterioration and failure of bridge components in infrastructure management, how to predict future interventions automatically, and how to connect models to BIM.
- **What is a successful project?** Connection of prediction models to BIM and demonstration of the possible visualisation.
- **Prerequisites:** Infrastructure Management 1 or Network Infrastructure, discussion with Steve Chuo or Prof. Adey

Supported by: ![SBB CFF FFS]
12 – Integrated planning of interventions on road sections comprised of assets of different types

- **Supervisors:** H. Mehranfar (mehranfar@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey
- **Goal:** To develop optimal integrated intervention programs that cover all assets in a road section.
- **Steps:**
  1. Understand framework,
  2. Obtain detailed data on the assets in a test section,
  3. Estimate the optimal maintenance strategies for each of the assets,
  4. Estimate the probabilities of requiring interventions over future periods due to each of the assets,
  5. Determine the possible combination of interventions as well associated synergies,
  6. Determine the possible traffic configurations associated with the multiple combinations,
  7. Determine the possible intervention combinations per traffic configuration,
  8. Adapt an existing operations research model to determine the optimal intervention programs,
  9. Quantitatively determine the optimal intervention program.
- **What you will learn:** Insight into the complexity of planning activities on a road network, State-of-the-art thinking in the interaction between asset strategies and intervention programs
- **What is a successful project?** The demonstration of the model and the development of an optimal intervention program
- **Prerequisites:** Infrastructure Management 1, experience with optimisation, discussion with one of the supervisors

*Supported by: ASTRA*
13 – Material flows to optimize inventory and machine capacity use for a practical recycling case

- **Supervisors:** S. Chuo (chuo@ibi.baug.ethz.ch), Prof. Dr. B.T. Adey, Prof. Dr. C. De Wolf
- **Goal:** Draft and calculate optimal material flows of copper cables and inventory stocks in order to utilize a granulating machine for copper and other material flows in a recycling process.
- **Main Tasks:** 1) conduct value stream mapping of the recycling process from the construction site cable collection to sales of pure copper fractions *(and others like aluminum, stainless steel, etc.)*, 2) determine production parameters of granulating machine and economical operating point, 3) analyze input material stream in the past, predict forecast and determine variation and standard deviation, 4) determine working stocks, 5) propose supply chain strategy recommendations.
- **What you will learn:** How to optimize a material flow for a real-life recycling process (reverse supply chain). How to calculate and optimize inventories. How to plan an optimal utilization of a production capacity.
- **What is a successful project?** A transparent material flow analysis and a direct applicable inventory plan for the working stocks.
- **Prerequisites:** Knowledge of materials in recycling topics and supply chain, and discussion with one of the supervisors

* scope adjustable

Supported by: SBB CFF FFS
The Chair of Sustainable Construction gathers a group of scientists, engineers and architects who aim to ground sustainability in all disciplines involved in the built environment.
Identify pathways for sustainable construction

Over the last decades
significant improvement have been made
to increase energy performance of buildings

but it is linked with extreme complexity of building systems
and little consideration for embodied emissions from materials
Inter-disciplinary Project-Based Learning

Group challenge HS2020

In Zurich, build and operate a climate-neutral building or perform a climate-neutral renovation.

Climate demonstration at the Rathaus in 2019 (Christoph Ruckstuhl / NZZ)
**Option 1:**
Go for digitalization to handle this complexity

**Research topics: Integration of LCA in design process.**
Considering uncertainties, improvement potentials and feedbacks from other digital tools
Option 2:
Rely on naturally multifunctional, low carbon and circular materials

Research topics:
Development of regenerative building materials which are viable economically
(Clay based materials with or without 3d printing, with or without biobased materials)
Topics

Master project and/or thesis

Master thesis

**Life cycle improvements of a new Swiss construction**

**Improving the end-of-life treatment of bio-based building materials for increased carbon storage**

**Studying the value chain of bio-based construction**

**Visual tools for the analysis and communication of multidimensional data for sustainable buildings**

**Lifecycle CO2 flows of bamboo based construction in the Philippines**

**Indoor Comfort and Air Quality - methods, impact of materials, and practical analyses**

**Healthy buildings: sustainable materials for improved indoor air quality**

**OH MY HEMP! Hemp-composites for sustainable and comfortable constructions**

**Hands-on plasters! A sustainable alternative to cement plasters in the Philippines**

**Hygrothermal simulations and optimization for users comfort**

**LCA of additive manufacturing techniques with earth-based materials**

**Open loop recycling within Circular Economy: LCA of alternative concrete**

**Close loop recycling within Circular Economy: LCA of recycled concrete**

**Barriers and opportunities for alternative cements**

**Impact of aggregates on poured earth wet and hardened properties**

**Life cycle assessment of industrialised construction system**

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Prof. Guillaume Habert  |  28.04.2022  |  30
1- Life cycle improvements of a new Swiss construction

**Supervisors:** Yasmine Priore  
(priore@ibi.baug.ethz.ch)

**Goal:** The climate crisis is pressuring all countries and sectors to reduce emissions and limit global warming. Although the overall goal is clear, current practices in the Swiss construction sector are not always designed for this goal. Life cycle studies are scarcely applied in the design process and results lack of a deeper understanding of potential environmental improvements. Furthermore, it is often assumed that building sustainably is more expensive, but is it really true?

**Main tasks:** A case study (residential or office) will be provided. The first task will be to conduct a detailed LCA and LCC. In a second step, improvements are to be proposed that reduce emissions, costs, and are structurally viable.

**Prerequisites:** Basic knowledge of LCA and LCC. Knowledge of structural feasibility.

**Students:** 1
2- Improving the end-of-life treatment of bio-based building materials for increased carbon storage

**Supervisors:** Dr. Verena Göswein
(goesein@ibi.baug.ethz.ch)

**Goal:** Bio-based materials, such as straw, store carbon in the building when the biomass is moved from the natural system into the building. However, if the material is incinerated at the end-of-life of the building, the carbon is released back to the atmosphere. How can we improve the end-of-life treatment of bio-based components for an increased carbon storage?

**Main tasks:** Define EoL scenarios and analyze (LCA) of EoL of bio-based construction products. Identify opportunities for improved carbon flows.

**Prerequisites:** Basic knowledge in LCA (experience with SimaPro)

**Students:** 1
3- Studying the value chain of bio-based construction

**Supervisors:** Dr. Verena Göswein
(goeswein@ibi.baug.ethz.ch)

**Goal:** Buildings are responsible for 38% of global carbon emissions. Circa half of those are related to the construction and materials. Bio-based materials, such as straw, can reduce embodied emissions, store carbon and are a regenerative resource. Even though straw-based products exist on the market, so far architects and building owners still decide to use conventional (fossil-based) materials. The reason is related to the value chain. So, how can the value chain be improved to increase the use of bio-based materials?

**Main tasks:** Map stakeholders and processes of value chain linking material producer to the final building contractor. Analyse potential future scenarios.

**Prerequisites:** Interest in policy questions

**Students:** 1
4 – Visual tools for the analysis and communication of multidimensional data for sustainable buildings

**Supervisors:** Dr. Verena Göswein (goeswein@ibi.baug.ethz.ch) and Dr. Alina Galimshina (galimshina@ibi.baug.ethz.ch)

**Goal:** The climate change discourse has reached the centre of society. Yet, even professionals have difficulties understanding the general importance of buildings, and the specific contribution of their decision-making regarding multi-dimensional parameters (energy, materials, water, waste, emissions). Visualisations, including Sankey diagrams and maps, can be tools for analysis and communication. The goal is to take inventory and to showcase good examples of visual tools for sustainable buildings at different scales.

**Main tasks:** Literature review, Classification of visual tools, Selection and comparative analysis of good examples.

**Prerequisites:** Affinity for visualizations

**Students:** 1-2
5- Lifecycle CO2 flows of bamboo based construction in the Philippines

Supervisor: Dr. Edwin Zea Escamilla zedwin@ethz.ch in collaboration with Luis Felipe Lopez BASE-Bahay Fundation (PH)

Background: Bamboo based buildings are being used in the Philippines as a solution to the housing provision challenge in that country. Bamboo based construction materials withhold a great potential to sequester CO2 during the growth phase of the plants. While producing durable products like buildings this CO2 gets stored for the service life of the buildings. Moreover, during the production and end of life phases bamboo based materials can be used on energy gain process.

Goal: To develop CO2 flow models form forest to end-of-life for bamboo based buildings in the Philippines. To develop LCA models to calculate the carbon foot print at different life cycle stages.

Main Task: Data collection and processing. Development of mass flow models and LCA models

Prerequisites: knowledge on bio-based materials and life cycle assessment are advantageous

Students: 1 (one)
6 - Indoor Comfort and Air Quality - methods, impact of materials, and practical analyses

**Supervisors:** Magda Posani (posani@ibi.baug.ethz.ch)

**Goal:** Our lifestyles lead us to live in closed environments most of our time, yet it is established that poor Indoor Air Quality can have consequences on the health of occupants ranging from simple discomfort to development of serious pathologies. A correct choice of building materials can help to regulate the concentration of indoor pollutants and improve indoor comfort. The goal of this investigation is to evaluate current knowledge on the topic and apply it to a case study.

**Main tasks:**
- **Literature review:** existing methods to evaluate indoor comfort, main concerns related to indoor air quality, main pollutants to consider, and the existing knowledge on the impact of material on passive improvement on IAQ. **Analysis and assessment** based on the data from a case study.

**Prerequisites:** interest in comfort and wellbeing in construction

**Students:** 1
7- Healthy buildings: sustainable materials for improved indoor air quality

**Supervisors:** Magda Posani (posani@ibi.baug.ethz.ch)

**Goal:** In last decades buildings have become more and more airtight, with negative consequence on indoor air quality and potential threatens to the users health and comfort. This investigation aims at studying materials based on hemp and biochar, which can contribute to passively improve indoor conditions. The goal of the study is to evaluate how sustainable materials can be adopted to improve wellbeing, in opposition to more commonly adopted materials.

**Main tasks:**
- Experimental tests on site, in a building containing hemp-based bricks and panels, and biochar plasters (IAQ).
- Numerical assessment of indoor comfort and pollutants.
- (Optional) use of dynamic hygrothermal simulations to compare the impact of hemp-composites to more common materials.

**Prerequisites:** interest in indoor comfort and wellbeing

**Students:** 1-2
Supervisors: Magda Posani (posani@ibi.baug.ethz.ch)

Goal: The potential for innovative hemp-based building materials to foster systemic innovation while lowering the carbon footprint of Switzerland is tremendous. What is more, hemp-based products can play a relevant role to enhance indoor comfort and improve users' well-being, both in new and rehabilitated constructions.

Main tasks:
- Laboratory tests to assess the main hygrothermal properties of the MATERIALS
- Use of dynamic hygrothermal SIMULATIONS (WUFI software) to assess the impact of the materials under realistic operational conditions
  → quantify indoor comfort and energy improvements

Prerequisites: interest in dynamic hygrothermal simulations

Students: 1

FROM EXPERIMENTAL CHARACTERIZATION…

…TO NUMERICAL HYGROTHERMAL SIMULATIONS
9- Hands-on plasters!
A sustainable alternative to cement plasters in the Philippines

Supervisors: Magda Posani (posani@ibi.baug.ethz.ch)
Dr. Edwin Zea Escamilla (zedwin@ethz.ch)
Natalia Pires Martins (martins@ibi.baug.ethz.ch)

Goal: BASE- Bahay is part of the HILTI foundation in the Philippines works on bamboo-based social housing solutions. Currently, the bamboo frame houses are plastered with cement plaster, a material that has relevant impact on the environment. A new solution is needed (maybe earth-based), to make an actual difference and reduce the emission in the large scale projects based on bamboo. The solution delivered will be used for real application, if the requirement needed are met.

Main tasks: Literature: find a suitable binder which is locally available Laboratory tests: prepare mortars, evaluate mechanical & hygrothermal performance. Evaluate CO2 footprint

Prerequisites: basic knowledge of building materials and LCA
Students: 1

EXPERIMENTAL WORK: Hands on plasters!

Future application: Bamboo social housing
10- Hygrothermal simulations and optimization for users comfort: Bamboo-based Social Housing in a hot-humid climate (Philippines)

Supervisors: Dr. Edwin Zea Escamilla (zedwin@ethz.ch)  
Magda Posani (posani@ibi.baug.ethz.ch)

Goal: Bamboo has been used for thousands of years in Asia. Now, it could help address construction's sustainability problem. Local initiatives are already working on modern construction project based on the use of bamboo. An example is the "BASE- Bahay" in the Philippines (http://www.base-builds.com/). Now that real constructions are available, some doubts arise. When working in a hot-humid climate, can bamboo construction help provide a comfortable indoor environment? Can we improve existing solutions to optimize users' well-being? Is this a matter of design or can material play a relevant role?

Main tasks:  
The project will involve dynamic hygrothermal simulations and material characterization via laboratory testing. The plan can be adjusted according to the needs and interests of the student. Additionally, it is possible to have tests done at the innovation centre from BASE in Manila, as well as prototyping and implementation.

Prerequisites: Interest in hygrothermal simulations

Students: 1
Supervisors: Julie Assunçao (assuncao@ibi.baug.ethz.ch) & Anastasija Komkova (komkova@ibi.baug.ethz.ch)

Goal: As digital construction with earth-based materials has received more visibility lately, there is also a need to evaluate the life cycle analysis and costs of this new technique. For this purpose, a general approach of the main concepts that permeate this so-called digitalization of construction with earth will be the focus of this project/thesis.

Main tasks: Perform LCA and compare consolidated techniques, such as cob and adobe, with the relatively new ones, like layer deposition (3D printing).

Prerequisites: Basic knowledge of LCA is an advantage. Interest in earth-based construction techniques.

Students: 1
Supervisor: Anastasija Komkova (komkova@ibi.baug.ethz.ch)

Goal: Can we substitute CO₂-intensive cement concrete and thereby ensure efficient use of resources in construction sector? In Europe, industrial wastes that are currently landfilled can be recycled in alkali activated materials (AAM). The project aims to assess the environmental impacts of developed AAM mixes throughout their life cycle and examine effectiveness of open-loop recycling of waste materials at a regional context.

Main tasks: Perform LCA of provided AAM mixes that have been developed in different European countries using local materials, compare to cement concrete. Examine impacts associated with transportation. Assess material stocks and flows.

Prerequisites: Basic knowledge of LCA is an advantage.

Students: 1
13- Close loop recycling within Circular Economy: LCA of recycled concrete

**Supervisor:** Anastasija Komkova (komkova@ibi.baug.ethz.ch)

**Goal:** What is the environmental impact of recycled concrete in different national context. Indeed, in Switzerland, recycled concrete is a widely adopted technique, but this is not the case everywhere. The objective is to get a better overview of the different practices, in Switzerland, Europe and the rest of the World and to quantify the environmental impact associated with such practices.

The results will be able to show in which context, performing recycled concrete is effectively reducing environmental impact compared to concrete made with natural aggregates.

**Main tasks:** Perform LCA of recycled concrete. To do so, it will be necessary to gather data from different countries and recycling process. Site visits, interview and report will be the source of data. Calculation will then be performed using LCA software.

**Prerequisites:** Basic knowledge of LCA is an advantage.

**Students:** 1

Makul et al. (2021) https://doi.org/10.3390/cryst11030232
14-Barriers and opportunities for alternative cements

**Supervisor:** Anastasija Komkova (komkova@ibi.baug.ethz.ch)

**Goal:** Cement is the most widely used construction material, that is responsible for 7% of total GHG emissions. While alternative binders are being developed that allow to reduce CO2 emissions and recycle waste, the real-world adaptation of emerging technologies is rather limited. What are the barriers that prevent the upscale of alternative cements? Are there opportunities for regional industrial symbiosis?

**Main tasks:** Identify potential stakeholders and examine their perspectives on potential supply chains. Stakeholder assessment. Quantify materials flows. Examine barriers and opportunities along the emerging supply chains.

**Prerequisites:** Interest in supply chains. Knowledge of GIS could be useful, but not necessary.

**Students:** 1
15- Impact of aggregates on poured earth wet and hardened properties

**Supervisors:** Daria Ardant (ardant@ibi.baug.ethz.ch) ; Dr Coralie Brumaud (brumaud@ibi.baug.ethz.ch)

**Goal:** The aggregates’ quantity and quality are important parameters for performing a robust poured earth with excavated material. As adjuvanted poured earth is still a technique under research, optimized mix design at the clay-concrete scale has not been defined as it can be seen for cement-concrete. Knowing that the binder does not have the same properties as in cement-concrete, the formulation taken from this field cannot be applied as it is on poured earth and must be better understood.

**Main tasks:** This research will focus on the impact of the quality (different elastic modulus...), the aspect (crushed or round), and the quantity of several aggregates on the poured earth wet and hardened properties. A focus on the interface between binder and aggregates will be done.

**Prerequisites:** Work in a laboratory. Exchange will be in English

**Students:** 1
Goal: The climate crisis is pressuring all countries and sectors to reduce emissions and limit global warming. There is a growing interest in use of industrialised construction system (CREE Building) with improved productivity, quality and speed of construction. Life cycle study of such a system could help improve the understanding of potential environmental benefits of using such a system in relation to conventional construction. Study of flexibility/adaptability in-use such systems offer.

Main tasks: Evaluation of industrialised construction system and a project that has used such a system. The first task will be to conduct a detailed LCA and LCC. In a second step, improvements are to be proposed that reduce emissions, costs, and are structurally viable.

Prerequisites: Basic knowledge of LCA and LCC. Knowledge of structural feasibility.

Students: 1

What is the embodied emissions savings when an industrialised construction system is adopted?
Chair of Circular Engineering for Architecture

Circular Engineering for Architecture

Prof. Catherine De Wolf
Chair of Circular Engineering for Architecture
• 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.
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.
Supervisors: D. Raghu / C. De Wolf

Goal: Carbon emissions are rising not only due to the waste produced during construction but also due to increased raw material consumption. There is a window of opportunity to respond to the climate crisis by critically examining the possibility of reusing components from existing buildings. New methods and tools for reusing building elements and adapting existing structures to suit changing needs are the need of the hour.

Main Tasks: (i) Data gathering, and documentation of a building commissioned to be demolished using drones (ii) Development of an automated method to work with reclaimed building materials in a parametric environment that can aid the design process and help visualize results

What you will learn: Automated computational procedures for manipulating data and informing the design process with reclaimed materials; Aggregation and structural analysis techniques to inform the design; Machine learning methods for optimization of the design process

What is a successful project? Development of proof-of-concept digital tools that can showcase the potential of circular design and construction.

Prerequisites: Architecture or construction background; Experience in grasshopper is a requirement and an interest in circular construction will be an advantage.
Diagnosis of the condition of materials in existing building stock for reuse assessment using Machine Learning

- **Supervisors:** D. Raghu / C. De Wolf

- **Goal:** Reusing building materials is favorable when their sourcing, processing and manufacturing input is lower than that of new materials. A range of parameters of the existing building stock such as performance, cost, ease of disassembly, reuse potential and future environmental impact need to be taken into consideration. This project will develop a multi-parametric analytical tool for the diagnosis of materials for reuse in architecture and construction.

- **Main Tasks:**
  1. Data gathering, and documentation of a building commissioned to be demolished
  2. Analysis of factors and conditions that facilitate or obstruct the reuse of building materials

- **What you will learn:**
  - Automated computational procedures for manipulating data and informing the design process with reclaimed materials
  - Machine learning workflows for circular construction
  - Integration of results with BIM

- **What is a successful project?** Development of proof-of-concept digital tools that can help assess the reuse potential of materials and components to enable circular construction.

- **Prerequisites:**
  - Architecture or construction background
  - Experience in grasshopper is a requirement and an interest in circular construction will be an advantage.
Goals:

This project is part of a broader research into using automated tools to create inventories of materials in pre-demolition sites. In particular, the value of potential building components is affected by the viability of their removal, based on their original methods of installation.

Tasks and what you will learn:

- Development of a category system for structural connections based on their relative ability to be disassembled, and visual distinguishability
- Assembly of real-world photo dataset of connection types in a variety of conditions
- Augmentation of dataset using BIM modeling and computer rendering
- Evaluation of developed model under ideal and degraded environmental and photographic conditions
- Possible: integration of existing models for detecting structural damage to augment the disassembly score

Prerequisites:

Basics of computer vision concepts, familiarity with a contemporary machine learning framework
Master project – Construction Procurement Strategies as Applied to Circular Materials

- **Supervisors:** M. Gordon / C. De Wolf

- **Goal:** Material reuse matching systems generally focus on the individual geometric and structural properties of elements - these considerations also have cumulative effects on the overall process. The project will assemble a set of real-world case studies of material reuse in both a structural and aesthetic context. Between these projects, the following points will be compared:

  - In structural situations, how much was the structure over-specced to account for structural uncertainty
  - When receiving materials, how much loss was there due to unforeseen damage during the initial lifespan or during removal
  - During construction with the materials, how much new waste was generated due to mismatch in dimensions
  - How did the inclusion of reused materials affect the timing of procurement and installation.
  - To what extent was the design altered to account for the specifics of available materials

  - Between these factors, the project will synthesize the areas of greatest disruption due to reuse of materials, and where new management interventions are needed.
Building Data Modeling for Interoperability of a Component Database

Supervisors: B. Byers / C. De Wolf

Main Goals

- Implement existing proposed schemas for material passports & linked building data with given dome project data
- Integrate with built up online database stack to be queryable

Prerequisites

- Desired familiarity with data trees (i.e. JSON/XML) or graphs
- Desired familiarity with databases
Development of High-tech and Low-tech Building Material Tracking Solutions

**Supervisors:** B. Byers / C. De Wolf

**Main Goals**
- Propose and build two different solutions for building material component tracking
- Analyze use-cases for both (e.g. rural community with limited resources or advanced factory setting)

**Prerequisites**
- Experience with IoT, sensors, electronics desirable
Prototype of a Physical <> Digital <> Crypto connection for Building Components

**Supervisors:** B. Byers / C. De Wolf

**Main Goals**

- Create an “on-chain” token associated with an “off-chain” asset
- Explore challenges and opportunities for ensuring the physical <> crypto connection
- Possible further work of connection with digital representation of asset

**Prerequisites**

- Familiarity with ERC token standards
- Desired familiarity with solidity and python (or equivalent)
Propose your own master topic in following fields applied to circular construction (reuse of buildings and building materials)

- Blockchain
- Materials Passports and Tracking
- Data & Databasing
- Extended Reality
- Computer vision
- Computational design
- Machine learning
- Reality Capture