Doctoral Programme in Civil, Environmental and Mechanical Engineering

Research subjects proposed for the 42nd cycle – second call

A mandatory attachment of the application is a description of the research project (approx. max 4 pages) relative to the research areas of the Doctoral Programme in Civil, Environmental and Mechanical Engineering on specific topics as described below.

Curriculum A - Civil and Environmental Engineering

- *Reference person:* Davide Noè Gorini (UNITN/DICAM)

Participants: Marco Andreini (Head of Infrastructure Safety Section at CERN, Switzerland); Michele Grossi (Coordinator of the Hybrid Quantum Computing Infrastructures and Algorithms at CERN, Switzerland)

A1 - scholarship on reserved topic

Funded by: University of Trento - Department of Civil, Environmental and Mechanical Engineering. European Organization for Nuclear Research (CERN, Switzerland).

Title: Quantum-Integrated Multi-Physics Soil-Structure Interaction Framework for Nonlinear Dynamic Analysis of Large-Scale Civil Structures

The project aims to establish a quantum-integrated computational framework for the nonlinear dynamic analysis of civil engineering structures, explicitly accounting for Thermo-Hydro-Mechanical (TIM) coupling of Soil-Structure Interactions (SSI). The research moves beyond conventional high-performance computing paradigms by embedding advanced quantum algorithms within multi-physics numerical models of mega-scale structural systems subjected to natural hazards.

The core objective of the PhD research is the substantial extension of an emerging quantum formulation, currently under development by the proposing research group, toward fully coupled TIM-SSI problems. The resulting framework will enable high-fidelity multi-physics simulations of the urban fabric that cannot be handled through classical approaches.

A major pillar of the project is the integration of the quantum-assisted formulation into internationally adopted computational platforms for dynamic performance assessment of civil engineering structures. This integration will ensure methodological transparency and worldwide dissemination.

As a flagship application, the framework will support the development of high-resolution seismic digital twins of the strategic underground infrastructure network at CERN, providing unprecedented insight into multi-physics interaction mechanisms and seismic risk associated with its components.

Expected Outcomes

Open-Source Computational Module

Release of a documented quantum-assisted module integrated within established numerical platforms for civil engineering dynamic problems.

Validated Large-Scale Demonstrators

Implementation and verification of the framework on flag-ship, large-scale infrastructure systems, including benchmark models for reproducible assessment.

- Reference person: **Marco Tubino (UNITN/DICAM)**

Participants: Luca Adami (UNITN/DICAM), Gabriele Barile (ETH Zurich)

A2 - scholarship on reserved topic

Funded by: University of Trento - Department of Civil, Environmental and Mechanical Engineering.

Title: Transport processes in transitional environments

Water management is facing a growing number of challenges in many river basins worldwide, as the equal distribution of the available water resources is increasingly influenced by several, uncertain hydro-climatic and anthropogenic pressures. Within the current and projected water scarcity and drought scenario, such issue represents even a greater challenge in those basins that were massively regulated in the XX century, as water managers are asked to find balanced policies to stay ahead with multiple, interdependent and ever-increasing human water-related requirements. In this context, water conflict has become a recurring problem in many regulated systems, with the sole providers of the water benefits - the freshwater ecosystems - experiencing a severe alteration of their natural renewability and ecological integrity.

Among the water ecosystems most at risk, transitional wetlands stand out. Physical processes in lentic, transitional systems are driven by different forcings than those in lotic environments, where hydrodynamic actions are dominant. As the flow velocity gradually decreases, other processes begin to play a significant role, such as temperature gradients, wind forcing, and the presence of vegetation. Furthermore, the slowdown of the water velocity enhances the sedimentation of suspended particles. This is the case of the Mincio fluvial system near the city of Mantua (Lombardy, Northern Italy), where the morphology changes from a single-thread river to a fluvial lake complex, passing through a multiple-channel transitional wetland. The site is located downstream of a heavily human-altered environment with intensive agricultural use. As a result, it suffers from many environmental problems including eutrophication, siltation and spread of invasive macrophytes, further worsened by low discharge. The flow regime in the Mincio River is regulated by a complex system of hydraulic infrastructures, which was designed primarily for flood protection. In case of high discharge, the Mincio River is diverted into an artificial channel bypassing the wetland and the Mantua lake system to protect the city of Mantua. Concurrently, the incoming discharge from the river's tributaries is usually higher because of heavy rainfall. These tributaries collect water from agricultural drainages; as a result, they carry huge amounts of nutrients and fine sediments originating from surface runoff. This contribution to the Mincio River has a detrimental effect on water quality of the wetland, further worsened by the low incoming discharge of clear water that could dilute suspended sediments and nutrients input. As a consequence, most of the secondary channel network is threatened by terrestrialization, with a switch from hydrophytes to helophytes and ultimately terrestrial plants. This process leads to the loss of habitats of great ecological value, listed in the NATURA2000 European protected sites.

Research aims and methodology

Within the above framework, the aims of the project are as follows:

i) develop a comprehensive analysis of various physical processes that are relevant to the case study of the River Mincio and to analogous freshwater ecosystems, such as sedimentation, anoxia, water mixing, and the role of aquatic vegetation;

ii) develop a numerical model to compute the transport of suspended sediments within a multiple- channel transitional wetland, based on recent advances on river bifurcations dynamics, and take part in the development of a suite of models aimed at building a digital twin of the Mantua hydraulic network.

The project methodology envisages the integration of field measurements, remotely-sensed data and mathematical modelling. Field work will include bathymetric surveys, measurements of flow velocity and discharge partition at the network nodes, sediment sampling, dissolved oxygen monitoring and analysis of time series of suspended solid concentration from in situ instrumentation. Effectively tackling this project is made possible by two key factors: (i) the availability of an extensive dataset of field measurements, covering two years of observations, and of continuous measurements of turbidity; (ii) the availability of a hydrodynamical model of the wetland. The research is aimed at producing physically-based management guidelines that can be used by management agencies to plan future maintenance works and dredging operations and to predict the effects of different river regulation strategies.

The ideal candidate will have a background in Environmental Engineering or related fields. Candidates should also possess strong computer and scientific, have excellent communication (oral and written) skills, have the ability to work independently and as part of a team, self-motivation, adaptability, and a good attitude for critical thinking. Since foreseen activities include model development and on-site measurements, the candidate is required to have (or the will to pursue them) computational proficiency (preferably in Fortran, R/python/Matlab and GIS products) and experience in experimental methodologies.

- *Reference person:* Marco Broccardo (UNITN/DICAM)

Participants: Davide Noè Gorini (UNITN/DICAM), Chiara Nardin (UNITN/DICAM), Alfio Viganò (Provincia Autonoma di Trento - PAT)

A3 - scholarship on reserved topic

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering within the project "Rischio sismico" CUP no. C65E24000330003 of the Provincia Autonoma di Trento

Title: Next-Generation High-Resolution Seismic Hazard Maps for Trentino with Site Amplification and Soil-Structure Interaction

This research project aims to develop a prototype for **next-generation, high-resolution seismic hazard maps** for the Trentino region by explicitly accounting for **site amplification** and **soil–structure interaction (SSI)** in a fully probabilistic setting. The project advances beyond conventional regional hazard products by coupling state-of-the-art regional PSHA with microzonation-informed local geology, physics-based (and computationally efficient) site-response modeling, and SSI-aware definitions of the input motion relevant to the built environment. The research outcomes are structured into three key contributions:

1. **Probabilistic High-Resolution Hazard Downscaling and Microzonation Integration**

- Development of a methodological framework to incorporate microzonation products (geological models, stratigraphic units, Vs profiles, basin geometry where available) into regional-scale PSHA, with explicit treatment of aleatory and epistemic uncertainties.
- Systematic comparison between national/regional hazard assessments and microzonation-informed hazard at finer resolution, quantifying where and why hazard levels change (amplification-prone sediments, topographic effects, impedance contrasts, basin edges).
- Production of hazard outputs consistent with engineering practice (hazard curves and uniform-hazard spectra) at map resolution compatible with regional planning and municipal decision-making.

2. **Site Amplification and Nonlinear Site Response Embedded in Hazard Mapping**

- Implementation of scalable site-response models that move beyond proxy-only approaches (e.g., single-parameter site classes), enabling frequency-dependent amplification and uncertainty propagation within the hazard calculation.
- Inclusion of nonlinear soil behavior where relevant, to avoid systematic bias in predicted spectral ordinates at short periods and moderate-to-strong shaking levels.
- Generation of spatially coherent amplification factors and period-dependent amplification maps, directly linked to the microzonation inputs and calibrated/validated against available local information (geotechnical, geophysical, and recorded motions where available).

3. **SSI-Aware Hazard Metrics and GIS-Based Mapping for Trentino**

- Extension of conventional "free-field" hazard to structure-relevant input motion incorporating SSI-aware transformations. This will be achieved by employing novel thermodynamic-based macroelement representations capable of capturing, in an efficient and rigorous manner, the multiaxial, nonlinear, frequency- and rate-dependent response of soil-foundation systems. Through their systematic application at the regional scale under consideration, this framework will enable: i) the computation of the effective translational-rotational input motions acting at the foundation level, and ii) the rigorous incorporation of SSI into the seismic assessment of the urban fabric.
- Development of a GIS-based pipeline that delivers high-resolution hazard layers (free-field and SSI-aware) suitable for integration into regional risk management workflows and for prioritizing detailed local studies.
- Demonstration on the Nord Garda Region with a systematic comparison against standard microzonation practice to identify i) contexts in which SSI effects are negligible, favourable, or detrimental, and ii) correlations enabling their systematic assessment, providing a valuable tool for preliminary design of new structures and large-scale evaluation of the existing urban fabric against expected natural hazards.

Overall, the project provides a replicable and scalable methodology for **high-resolution seismic hazard mapping** that better reflects the physical processes controlling ground motion in Trentino, strengthening the scientific basis for mitigation strategies and alignment with modern European hazard modeling practices.

- *Reference person:* Oreste S. Bursi (UNITN/DICAM)

Participant: Nicola Tondini (UNITN/DICAM)

A4 - scholarship on reserved topic

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering within the project “Research Fund for Coal and Steel "MULTI-STABLE" – Grant Agreement n. 101286340 - CUP E63C26000990006

Title: Innovative self-centering multi-stable dampers with high-performance properties and bi-stable metapanels with auxetic lattices for performance-based steel design in seismic engineering

One of the most challenging issues of structural engineering lies in the handling of dynamic phenomena, the most concerning being earthquakes. Given the emerging nature of metamaterials and metastructures, which, with proper repeated patterns and/or repeated nonlinear elements are capable of controlling amplitude-dependent behaviour in nonlinear media, the project proposes to introduce vibration mitigation concepts that capitalise on the control of nonlinear stability effects and develop some measures for protecting low- mid-rise steel structures against strong earthquakes. To this end, two complementary solutions are going to be developed in the project, focusing on structural Metabraces and nonstructural Metapanels.

- Structural Metabraces incorporate bistable nonlinear components with self-centering and nonlinear elasticity. These elements aim to prolong the duration during which the system operates near peak velocities, enhancing energy dissipation and allowing the system to recover without permanent deformation, maximise efficiency during seismic events and reduce the need for repairs and replacements;

- non-structural Metapanels are equipped with bistable and auxetic components combined with viscous sheets for enhanced energy dissipation.

Adoption of such an innovative approach shifts the current passive seismic protection of buildings from a displacement-based methodology to a velocity-based approach, employing dissipation across the entire structure.

Through simulations and experiments at different scales, the PhD Candidate will demonstrate the potential of these innovative solutions that rely on multi-stability, self-centering and nonlinear elasticity in Metabraces and Metapanels, in enhancing structural protection. Adoption of such non-conventional designs allows the shift of the current passive seismic protection of buildings from displacement-based to velocity-based devices that, with nonlinear elasticity, are capable of mobilising the dissipation in the whole structure within performance-based seismic design.

Curriculum B - Mechanics, Materials, Chemistry and Energy

- *Reference person:* Vittoria Benedetti (UNITN/DICAM)

Participant: Marco Cozzini (Eurac Research, Institute for Renewable Energy)

B1 - scholarship on reserved topic

Funded by: University of Trento – Eurac Research, Institute for Renewable Energy.

Title: Advanced Control Strategies for Aggregated Heat Pump Systems: Enhancing Flexibility and Efficiency

The increasing integration of renewable energy and the evolution of energy markets demand smarter operation of civil heating systems. Heat pumps (HPs), widely deployed in residential and commercial buildings, offer significant potential not only for efficient thermal management but also as providers of flexibility services to the energy grid.

This PhD project aims to develop advanced control strategies that extend existing algorithms from single HP installations to aggregated multi-plant systems, unlocking new opportunities for energy efficiency, demand response, and grid-support services. While previous studies have explored predictive control for single systems or coordination within energy communities, this work advances the field by implementing and validating scalable, coordinated control algorithms on real demo cases, bridging the gap between theoretical optimization and practical application in HP networks.

The methodology combines robust, phenomenologically-driven rule-based control with forecasting-enabled predictive control, enhanced through suitable optimization techniques (e.g., dynamic programming) to maximize system performance across multiple time steps and configurations. This hybrid approach allows the project to improve energy efficiency and operational performance of individual HP installations while enabling aggregated networks to provide flexibility services to the grid, ensuring that control strategies are both practical and optimization-driven.

Experimental validation will be carried out on demo cases being followed by EURAC and UniTrento in different projects, enabling the collection of high-resolution operational data and ensuring the applicability of the developed algorithms under real-world conditions. Testing directly on these platforms ensures that the developed control strategies are not only theoretically sound but also applicable in practice, while producing detailed operational data that can inform further refinements and the coordination of aggregated systems.

Building on EURAC Research's long-standing expertise in advanced control systems and its extensive portfolio of related research projects, this PhD work will conduct a rigorous, application-oriented study designed to produce practical solutions for real-world HP systems.

The project is intended to generate high-quality scientific outputs, including dissemination at national and international conferences and at least one peer-reviewed journal publication, while producing actionable knowledge to enhance the operational flexibility and efficiency of HP networks.

- *Reference persons:* Maria F. Pantano (UNITN/DICAM), Alvise Bagolini (FBK), Andrea Adami (FBK)

B2 - scholarship on reserved topic

Funded by: Fondazione Bruno Kessler (FBK) – CUP C63C23001090006.

Title: Development of novel SiC MEMS-based microanalytical systems for low-power, field-deployable monitoring

The development of innovative microanalytical technologies for real-time, on-line measurements is a critical bottleneck in modern industrial monitoring. This project proposes a monolithic micromachined system based on Silicon Carbide (SiC), strategically leveraging SiC's superior chemical inertness and mechanical robustness compared to standard Silicon. By utilizing SiC, the system achieves enhanced thermal stability for microhotplate configurations and improved frequency stability in resonant sensors. The architecture integrates (i) an ultra-low form factor microfluidic separation module and (ii) a multi-modal SiC sensor for precise analyte identification. The seamless integration of a microfluidic pretreatment stage with a SiC-based sensing core eliminates sample degradation during transport, enabling sub-minute analytical cycles essential for precision farming and safety monitoring. The final output is a low-power, field-deployable platform tailored for the agri-food sector, capable of detecting early-stage contamination or quality shifts directly in harsh production environments.

Intellectual Property Notice for PhD candidates under the UniTrento-FBK Agreement
Please read the following information carefully before submitting your application.
Intellectual Property of Research Results. The intellectual property rights of research results generated by PhD students under scholarships within the UniTrento-FBK Agreement shall belong to FBK.
Transfer of Intellectual Property Rights. FBK will establish agreements with PhD students regarding the transfer of intellectual property rights related to their research results.
Collaboration with UniTrento. If UniTrento academic staff contribute to research results obtained through PhD scholarships funded by FBK, the determination of IP shares will be defined through separate written agreements based on each party's contribution. PhD students are required to collaborate with UniTrento in all necessary activities related to the joint management of IP.

- *Reference person:* Luca Fiori (UNITN/DICAM)

Participants: Michele Orlandi and Luca Matteo Martini (UNITN/PHYSICS)

B3 - scholarship on reserved topic

Funded by: Provincia Autonoma di Trento within the project "Trentino Energy Hub: materiali per batterie e idrogeno"

Title: From biomasses to carbon materials for high-tech applications

The research project aims to transform residual biomass (but possibly also virgin biomass and model biomass compounds) into carbon-based materials for energy- and environmental-related applications, particularly: carbon electrodes for batteries and fuel cells, catalysts and catalyst supports, adsorbents, and possibly others.

The circular economy approach will be applied to residual biomass (agricultural, agro-industrial, wood processing industry, organic waste) which, through appropriate processes, will be transformed into high added value materials.

The process stems from the expertise developed by the research group under the guidance of Professor Fiori in hydrothermal processes, particularly hydrothermal carbonization, pyrolysis, chemical and physical activation, and solvent extraction [1-22]. These processes will be used synergistically to obtain carbonaceous materials with high environmental and, above all, energy-related performance.

The approach is that of process engineering applied to the recovery of materials from residual biomass and for the synthesis of advanced carbonaceous materials.

Candidates are expected to work experimentally on hydrothermal, pyrolytic, activation, and extraction processes, as well as modeling these processes (e.g. microscale modeling, chemical kinetics modeling, reactor-scale modeling, and process and simulation modeling [7,12,15,20-22]). Candidates will also be required to interact competently with research partner laboratories that will perform chemical analyses and characterization of the materials produced.

Preferred qualifications include Bachelor's and/or Master of Science degrees in chemical engineering, process engineering, energy engineering, or similar, and experimental and modeling skills. Another appreciated qualification is having previously operated with the above-mentioned processes and in any case in the production and characterization of advanced carbon materials.

Expected research outcomes are research papers to be published in high-quality scientific international journals (Bioresource Technology, Chemical Engineering Journal…). More generally, scientific progress is expected on the topics covered by the doctorate.

Keywords: circular bioeconomy, hydrothermal carbonization, carbon materials.

References:

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4. Advances in Research and Technology of Hydrothermal Carbonization: Achievements and Future Directions, Agronomy, 14, 955, 2024, https://doi.org/10.3390/agronomy14050955

5. Identifying the Transition from Hydrothermal Carbonization to Liquefaction of Biomass in a Batch System, ACS Sustainable Chemistry & Engineering, 12, 4539-4550, 2024 https://doi.org/10.1021/acssuschemeng.3c07731
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9. Process water recirculation during hydrothermal carbonization as a promising process step towards the production of nitrogen-doped carbonaceous materials, Waste and Biomass Valorization, 13, 2349-2373, 2022, https://doi.org/10.1007/s12649-021-01603-x
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11. Valorizing municipal solid waste via integrating hydrothermal carbonization and downstream extraction for biofuel production, Journal of Cleaner Production, 289, 125781, 2021, https://doi.org/10.1016/j.jclepro.2021.125781
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Curriculum C - Modelling and Simulation

- ***Reference person:*** **Paolo Rocca (UNITN/DICAM)**

Participants: Andrea Massa (UNITN/DICAM), Giacomo Oliveri (UNITN/DICAM)

C1 - scholarship on reserved topic

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering

Title: Innovative Unconventional Array Antenna Architectures for Non-Terrestrial Networks

In the ever-evolving landscape of wireless communications, with the increasing need for global connectivity, the exploration of non-terrestrial networks (NTNs) based on the use of low Earth orbit (LEO) satellites has emerged as a promising frontier. In this framework, the development of new antenna technology is paramount for unlocking the full potential of NTNs in future wireless communications. By enhancing coverage, increasing data rates, mitigating interference, improving resilience, optimizing energy efficiency, and ensuring scalability, advanced antennas will play a pivotal role in shaping the next generation of global connectivity.

In order to connect ground stations to LEO satellites, electronic scanning array antennas are the ideal solution for achieving connectivity on-the-move due to their low-profile and agile beam pointing capabilities. However, these antennas are expensive and complex as compared to antennas characterized by a mechanical or hybrid scanning. The number of radiating elements increase significantly, and their dimension decrease when a large field of view and a large frequency bandwidth are required. A priority is nowadays the identification and optimization of antenna architectures (including radiating elements and beamforming network layout) suitable for large field of view and a large frequency bandwidth.

The objective of the PhD research activity will therefore be the study and development of innovative methodologies for the design and analysis (also based on HW emulators already available at the ELEDIA@UniTN laboratory) of unconventional array antennas (UAAs) for NTN enabling new cost-effective solutions.

To this end, the activity PhD Student will join a transdisciplinary team of Researchers and Professors working on a wide variety of domains from fundamental EM and antenna theory to advanced numerical antenna modelling, as well as advanced system-by-design methodologies for their analysis and optimization-driven design. The research activity will be conducted under the supervision of the PI/Advisor and the members of the ELEDIA@UniTN at DICAM of the University of Trento.

The expected outcomes of this activity can be listed as follows:

1. Review and analysis of the literature on UAAs architecture and design methods and of the specifications and requirements for NTNs;
2. Study and development of novel techniques for the design of new UAAs cost-effective array architectures for NTNs;
3. Modeling and optimization of dedicated single radiator to be integrated in the novel array solutions;
4. Design and analysis of multiple Pareto-optimal trade-off UAA solutions for NTNs for both uplink (ground to space) and downlink (space to ground) segments.

Suggested selected references:

1. P. Rocca, et al., “Unconventional phased array architectures and design methodologies - A review,” Proc. IEEE – Special Issue on ‘Phased Array Technologies,’ Invited Paper, vol. 104, no. 3, pp. 544-560, Mar. 2016.
2. P. Rocca, et al., “An irregular two-sizes square tiling method for the design of isophoric phased arrays,” IEEE Trans. Antennas Propag., vol. 68, no. 6, pp. 4437-4449, Jun. 2020.
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4. P. Rocca, et al., “Pareto-optimal domino-tiling of orthogonal polygon phased arrays,” IEEE Trans. Antennas Propag., vol. 70. no. 5, pp. 3329-3342, May 2022.
5. G. Oliveri, et al., “Capacity-driven low-interference fast beam synthesis for next generation base stations,” IEEE Trans. Antennas Propag., vol. 70, no. 6, pp. 4472-4484, Jun. 2022.
6. N. Anselmi, et al., “Optimal capacity-driven design of aperiodic clustered phased arrays for multi-user MIMO communication systems,” IEEE Trans. Antennas Propag., vol. 70, no. 7, pp. 5491-5505, Jul. 2022.

7. N. Anselmi, et al., "A self-replicating single-shape tiling technique for the design of highly modular planar phased arrays - The case of L-shaped rep-tiles," IEEE Trans. Antennas Propag., vol. 71, no. 4, pp. 3335-3348, Apr. 2023.

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- Reference person: **Massimo Cassiani (UNITN/DICAM)**

Participants: Espen Sollum and Gabriela Sousa Santos (NILU, Norway)

C2 - scholarship on reserved topics

Funded by: University of Trento – Stiftelsen NILU.

Title: *Advanced Lagrangian Modelling of Reactive Atmospheric Plumes from CO_2 Capture: Development, Validation and AI-Accelerated Prediction*

One of the main unresolved concerns associated with amine-based CO_2 capture (CC) technology (https://climate.ec.europa.eu/eu-action/industrial-carbon-management/about-industrial-carbon-management_en) is the potential formation and release of nitrosamines (NSAs) and nitramines (NAs), compounds that are potentially carcinogenic. These substances may form in the atmosphere due to the degradation of volatile amines that inevitably escape from capture plants together with treated exhaust gases. Depending on the amines emitted, chemical reactions may occur in the presence of atmospheric oxidants and nitrogen oxides, leading to the formation of NSAs and NAs.

This project aims at the further development and validation of a physics- and chemistry-based model designed to evaluate atmospheric dispersion, chemical transformation, and deposition of substances emitted from CO_2 capture processes in large industrial and power generation plants. The model is developed at NILU and the University of Trento within the FuNitr project (Future Drinking Water Levels of Nitrosamines and Nitramines near a CO_2 Capture Plant), funded by the Research Council of Norway. It is based on a Lagrangian particle-based plume-in-grid approach known as the Volumetric Particle Approach (VPA), originally proposed by the PI (Cassiani, M., Bound-Layer Meteorology. 2013, 146, (2), 207-233). The VPA accurately and efficiently handles atmospheric dispersion, turbulent mixing, and nonlinear chemical reactions.

The PhD candidate will contribute to both the further development and the validation of the VPA model.

Model development:

- Advancing dry and wet deposition parameterizations.
- Enhancing three-dimensional wind-field reconstruction in complex terrain to better represent local flow conditions.
- Implementing automated coupling with a chemical kinetics pre-processor enabling flexible and scalable integration of evolving reaction mechanisms.
- Integrating a physically consistent online stack plume-rise module within the Lagrangian framework.

Model validation:

- Comparing VPA model results with experimental data collected during dedicated aerial measurement campaigns planned within the FuNitr project. These unique measurements will be based on PTR-MS-TOF instruments mounted on helicopters. The campaigns will be carried out in collaboration with the University of Oslo in 2026 and 2027, and the resulting datasets will be made available to the PhD candidate for analysis and model evaluation.
- Benchmarking VPA results against alternative computational fluid dynamics models (CFD) based on high-resolution Large Eddy Simulation (LES) of turbulence. The LES simulations will be carried out on massively parallel high-performance computing (HPC) platforms. Although high-resolution LES models are computationally demanding and not suitable for operational applications, they rely on fewer assumptions regarding atmospheric mixing processes and therefore provide a valuable reference for validating specific aspects of the VPA framework.

AI-based accelerated modelling

By generating an extensive database of simulations covering a wide range of initial and boundary conditions and model parameter variability, an AI-based surrogate modelling approach will be explored to reproduce VPA model outputs at a fraction of the computational cost.

The PhD programme will include a research stay of approximately six months at the NILU research institute in Kjeller, Norway (Oslo area).

The project is expected to result in at least three publications in international peer-reviewed journals: 1. A paper describing the improved model developments. 2. A paper presenting the comprehensive model validation. 3. A paper on the AI-based accelerated modelling approach.

We are looking for a highly motivated candidate with a background in physics, applied mathematics, environmental and atmospheric sciences, mechanical, environmental or chemical engineering.

The ideal candidate should have a solid knowledge of physics (ideally fluid dynamics), numerical methods, and computer programming (the core model codes are written in Fortran; AI components will likely utilize Python).

- Reference person: **Ivan Giongo (UNITN/DICAM)**

Participants: Jason Ingham (University of Auckland), Tom Allen (University of Auckland), Daniele Casagrande (UNITN/DICAM)

C3 - scholarship on reserved topic

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering

Title: *Prestressed fiber-reinforced systems for strengthening and upgrading timber structural elements*

The structural retrofitting of existing timber structures and the upgrading of timber for new construction are becoming increasingly important research areas in the transition towards more sustainable and resource-efficient timber construction. While traditional reinforcements using Carbon or Glass Fiber Reinforced Polymers (CFRP/GFRP) increase load-bearing capacity, current research is shifting towards hybridization and the use of Natural Fiber Reinforced Polymers (NFRP e.g., flax, basalt, jute) to improve compatibility and sustainability.

This project focuses on the structural optimization of laminated and solid timber reinforced with composite systems with the aim to enhance the structural performance of timber components and prevent premature brittle failure modes.

A primary objective is to investigate pre-stressing techniques. As passive reinforcement often fails to fully utilize the tensile strength of fibers due to the lower ultimate strain of wood, pre-stressing is essential to engage the reinforcement at lower strain levels. This approach aims to increase stiffness, reduce deflection, and induce a pseudo-ductile failure mode, preventing catastrophic brittle collapse in the tension zone.

Attention will be paid also to the analysis of brittle failure modes of dowel-type connections in Cross Laminated Timber (CLT) panels. In order to promote ductile and energy dissipative failure mechanisms of connections, potential failure modes (e.g. plug-shear, block-shear, step-shear), which engage local failure of timber laminations, will be investigated. A comprehensive experimental campaign will be conducted to determine the influence of different factors (e.g. panel layout, fastener spacing and edge distances, fastener penetration length) on brittle failures and define simplified models for the prediction of resistance. The strengthening and improvement offered by NFRPs as local reinforcement of such connections will be also evaluated.

The project will also assess the durability of these composite systems, which remains a significant barrier to widespread adoption. The interface between the hydrophilic wood/natural fibers and the hydrophobic polymer matrix is sensitive to environmental fluctuations. To address this, the research will perform extensive experimental campaigns, including long-term aging cycles performed in a climatic chamber. These tests will evaluate the evolution of bond strength and flexural capacity under controlled temperature and humidity variations.

Methodology and Expected Outcomes:

The research will combine experimental testing (e.g., four-point bending, shear tests, connection tests, long-term testing in a climatic chamber) with numerical modelling. Advanced Finite Element (FE) models will be developed to simulate the non-linear behavior of wood and the progressive damage of the composite. Expected outcomes include:

1. Development of efficient pre-stressing devices and anchorage systems for NFRP/HFRP laminates.

2. Analysis of potential brittle failure modes in dowel-type CLT connections

3. Quantification of material decay and durability factors for the wood-fiber interface to predict service life.

4. Models for prediction and design guidelines.

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- Reference person: **Annunziato Siviglia (UNITN/DICAM)**

Participant: David F. Vetsch (ETH Zurich)

C4 - scholarship on reserved topic

Funded by: University of Trento – ETH Zurich within the project BASEMENT

Title: ***Integration of physics-based river hydrodynamic and morphodynamic modelling with machine learning***

There is a growing consensus that tackling challenging research questions and diverse engineering problems requires innovative approaches that combine traditional physics-based modelling with advanced machine learning (ML). Physicsbased models are widely used in engineering and environmental domains, and their ability to accurately simulate complex phenomena is crucial for promoting long-term environmental sustainability and improving quality of life.

This PhD project focuses on the simulation of hydrodynamic and morphodynamic processes in rivers. These simulations are essential for mitigating flood risks, improving our understanding of river dynamics in a changing climate, and informing water resource management decisions.

BASEMENT is a state-of-the-art physics-based model, based on the solution of the Shallow-Water-Exner equations, that has been developed to address these challenges at reach scale. However, like many physics-based models, it has some well-known limitations. These arise from the need to simplify the representation of complex physical processes and the inherent difficulties in selecting appropriate parameters. In contrast, while state-of-the-art machine learning models can sometimes outperform physics-based models given sufficient training data, they may produce results that lack physical consistency.

The goal of this project is the development of a physics-based model that integrates physics-based methods with ML - leaving the specific ML approach open for exploration - to exploit their complementary strengths. The resulting framework can be applied to a range of problems, such as improving prediction accuracy, enhancing parameterizations for missing physics, enabling reduced-order modeling (including sub-grid processes), and generating data for virtual simulations.

The successful candidate will have a strong engineering background, basic knowledge of hydrodynamics, morphodynamics, and numerical modelling, as well as coding skills in languages such as C++, FORTRAN, Python, MATLAB, or Julia. The candidate should also have a strong interest in working on numerical modelling. Fluency in spoken and written English, together with good communication skills, is required.

The expected outcomes of this project include the development of a novel physics-based model that builds on and extends the simulation capabilities of BASEMENT, specifically targeting to capture nonlinear processes in hydrodynamic and morphodynamic river modelling. Research outcomes will be published in high impact factor journals in the field of modeling of environmental science.

Curriculum D – Architecture, Planning, and Landscape

- Reference persons: **Mario Claudio Dejaco (UNITN/DICAM), Lidia Pinti (UNITN/DICAM)**

D1 - scholarship on reserved topic

Funded by: University of Trento – INRES Coop

Title: ***Construction use risks - Methods and tools for the evaluation, control and reduction of risk factors during the use of buildings***

The significant presence of “aged” buildings in public and private real estate, and the lack of resources, highlights the need to keep the as-is condition of buildings and their components under control, safeguarding their conditions of use.

This topic takes on relevance in the case of real estate assets for office use (both public and private) and commercial use, where the safety of third-party users must be guaranteed.

It must also be considered that the data to be analyzed do not only concern technical aspects, but also have economic, social and environmental implications.

Thise research aims to define investigation procedures that, through the definition and use of appropriate survey and analysis tools, allow to:

- collect legal provisions that define "safety obligations" in relation to different intended uses of buildings and related spaces;
- define, for different intended uses, the conditions/situations that may cause risks for the different users of the spaces;
- propose a suitable data collection tool on buildings (digital building booklet) and their components;
- develop procedures for analyzing the risk level of buildings and spaces, based on their as-is condition and intended uses;
- propose digital databases for the collection, organization and extraction of data;
- propose probabilistic procedures to analyze historical data on maintenance and risk events related to the as-is condition of buildings and components;
- develop reports to support the definition of investments to ensure real estate assets safety in use in the short, medium and long term.

The procedures used will concern both the application of expeditous investigation methods of survey and classification/evaluation of the as-is condition of the buildings and their parts, and the systematization of probabilistic procedures for the analysis and control of historical events that have occurred on buildings and assets of a similar type and intended use.

The aim is to propose control and intervention predictive procedures in order to minimize “accidents”.

In addition to technical analyses, it will be appropriate to introduce simplified procedures for the economic/financial control of investments, considering also the social and environmental contexts, consistent with the current attention of investors and users.

Although focusing on the analysis of existing real estate assets, it is believed that what is proposed could also have design implications, not only for the redevelopment of existing assets but also for new design interventions.

During the research, publications and articles are expected to be written. The outcomes of the research will be the implementation of procedures and methodologies for the investigation and control of the as-is condition of buildings and their components, as well as the development of digital tools to support the operators involved in the safety management and control of an asset.

Private operators will provide real case studies (COOP group, both for offices and mall).

It is also planned to discuss and collaborate with research groups from other universities involved in similar and related fields (Politecnico di Milano, Università di Brescia, Napoli Federico II).

Keywords:

digital building booklet; digital data management; safety of use; risk assessment.

Candidate must have:

- skills in digital data management and BIM;
- adequate knowledge of Italian building legislation;
- proficient/fluent in Italian having to interact with Italian operators in the real estate management field.

- Reference persons: Gianluca Maracchini (UNITN/DICAM), Fabio Remondino (FBK)

Participant: Rossano Albatici (UNITN/DICAM)

D2 - scholarship on reserved topic

Funded by: University of Trento – Fondazione Bruno Kessler (FBK)

Title: *Urban Digital Twins for Climate-Ready Cities*

This research aims to create urban Digital Twins designed to support Climate Change Mitigation (CCM) and Climate Change Adaptation (CCA) simulations and activities in urban environments. The PhD project should leverage multi-scale geospatial data (remote sensing/aerial imagery, point clouds, maps, etc.) and GeoAI methods and GIS tools to create 3D environments that integrate high-resolution 3D urban models with climate-resilience objectives. This should help policymakers and citizens optimize energy-efficiency processes for operational carbon reduction (mitigation) and simulate microclimate interventions to reduce heatwave vulnerability (adaptation).

The research tasks include:

Critical analysis of data and digital enabling technologies (DETs). Definition of a minimum viable, interoperable data model (GIS + 3D city model) to support both retrofit decarbonisation and heat-risk indicators in an integrated CCA–CCM workflows.

Computer vision & geomatics for "energy-ready" urban digital twins. Development of an advanced methodology based on aerial/oblique imagery and point clouds to extract building and urban-morphology features (roof geometry, shading context, façade fractions, vegetation proxies) to populate a GIS/3D environment at neighbourhood/city scale.

Cross-scale modelling of retrofit decarbonisation and heat risk. Rapid assessment modules for building-stock retrofit scenarios coupled with heat-exposure/UHI indicators, ensuring consistency across building/district/city scales.

Multi-objective prioritisation and scenario design. A decision-support engine to rank and bundle interventions (e.g., envelope/system retrofits, PV suitability, cool/green strategies), balancing operational carbon, costs, and heat-risk reduction, with sensitivity analysis on weights and assumptions.

Validation on real portfolios and replicable deployment. Application to representative urban areas / real building portfolios (e.g., public housing), testing transferability and reproducibility via open workflows and cloud services/APIs.

Expected research outcomes:

- A validated pipeline for urban digital twin creation and building-stock analyses, with quantified uncertainty/quality indicators.
- Integrated assessment framework for CCA+CCM (e.g. whole-life carbon and heat-risk metrics) to support cross-scalar scenario comparisons and policy-aligned decision-making.
- Decision Support Model (prototype platform). A replicable 3D tool to support public agencies and practitioners in prioritising retrofit packages that jointly reduce emissions and heat vulnerability.
- Scientific contribution. Publications at conferences and in journals.

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Intellectual Property Notice for PhD candidates under the UniTrento-FBK Agreement
Please read the following information carefully before submitting your application.
Intellectual Property of Research Results. The intellectual property rights of research results generated by PhD students under scholarships within the UniTrento-FBK Agreement shall belong to FBK.
Transfer of Intellectual Property Rights. FBK will establish agreements with PhD students regarding the transfer of intellectual property rights related to their research results.

- Collaboration with UniTrento. If UniTrento academic staff contribute to research results obtained through PhD scholarships funded by FBK, the determination of IP shares will be defined through separate written agreements based on each party's contribution. PhD students are required to collaborate with UniTrento in all necessary activities related to the joint management of IP.

- *Reference persons:* Mario Claudio Dejaco (UNITN/DICAM), Lidia Pinti (UNITN/DICAM)

Participants: Carla Strumendo (PAT); Alfonso Vitti; Gianluca Maracchini; Rossano Albatici (UNITN/DICAM); Alessandro Rossi; Erica Santini (UNITN/DEM)

D3 - scholarship on reserved topic

Funded by: Department of Civil, Environmental and Mechanical Engineering within a project of the PAT (Provincia Autonoma di Trento) – CUP C63C26000200003

Title: Definition of procedures, methods, and tools for the digital management of historical and predictive data for building production, and the application of circular economy principles

The building production sector has undergone substantial market volatility in recent years, which cannot always be traced back to circumstantial events (such as the COVID-19 pandemic and economic downturn) and/or technical and 'policy' factors (PNRR, legislative and regulatory evolutions).

Moreover, the implementation of digital process control procedures and the call for heightened attention to circular economy policies among construction actors are fostering further evolutions in public and private building design and execution, profoundly affecting technological choices and material consumption.

These factors are resulting in the need to redefine procedures and monitoring methods for material and raw material consumption, especially in sectors that are technically, economically, and environmentally sensitive.

Within this broad framework, where interdisciplinary skills come together, it is advisable to set up procedures for gathering, managing, and analyzing complex and diverse data to provide reliable insights to public administrations planning the protection and utilization of land resources.

One of the sectors most affected by this need is that of construction aggregates, where environmental and regulatory factors have undergone significant developments, and there is a growing need for reliable consumption forecasting and control criteria that remain robust even as boundary conditions vary.

This research, funded by the PAT (Autonomous Province of Trento), therefore aims to structure investigation procedures that, through the definition and use of appropriate survey and analysis tools, will make it possible to:

- analyze local supply chains regarding the extraction and consumption of aggregates and construction materials, from the perspective of both primary use and recovery;
- monitor and forecast the consumption of construction materials, with particular reference to aggregates and the needs of quarry sites in the short, medium, and long term;
- define algorithms capable of analyzing consumption time series and establishing correction factors that account for relevant variables as conditions change;
- propose data collection structures and procedures for both the territory (e.g., quarries) and public administrations (e.g., public and private projects) in order to monitor the actual needs of the Province;
- expand reference indicators and the information to be collected with a view to managing the territory coherently, organizing ESG policies, and pursuing circular economy processes.

The purpose of the research is to provide public entities and private operators with control and planning tools for the construction process and the use of construction materials, with particular reference to aggregates and land management.

During the research, publications and articles are expected to be written.

Public and private operators will provide real case studies.

It is also planned to discuss and collaborate with research groups from other universities involved in similar and related fields.

Keywords:

process management; supply chain analysis; digital data management; circular economy.

The candidate must demonstrate:

- proficiency in digital data management and the use of "AI procedures";
- adequate knowledge of Italian legislation, with particular reference to the construction production context (e.g., public procurement laws; CAM) and quarries;
- proficient/fluent in Italian having to interact with public and private Italian operators.

In particular, the latter two aspects are necessary as this is a research project sponsored by the PAT, related to an "institutional collaboration on topics of shared interest". Consequently, this entails close contact with operational entities of the Italian Public Administration and its relevant legislation, as the work requires participating not only in the research but also in drafting methods and tools for public administration use.

The research developments will primarily focus on the Italian context but may also involve evaluating similar frameworks at the European level.