# PhD Course
# in Civil and Industrial Engineering (DICI)
# University of Calabria

## 1. Description of the PhD Course

The Doctorate programme in Civil and Industrial Engineering (DICI) stems from the experience of the "Pitagora" Doctoral School in Engineering Sciences at the University of Calabria. DICI aims to establish a solid methodological culture achieved through the provision of third-level courses complemented by personalized paths for scientific and transversal training, based on laboratory activities and research conducted at the University or other national and international institutions. The proposal is structured into two curricula: Civil Engineering and Industrial Engineering, which include multidisciplinary and interdisciplinary approaches between the two areas, promoting high-profile insights within the fields of interest of each disciplinary sector.

The Civil Engineering curriculum is based on the areas characterizing civil engineering and building architecture, such as hydraulics and hydraulic structures, infrastructure and transportation systems, geotechnics, construction science and technology, technical architecture, architectural composition and restoration, urban planning, and territorial planning. In each of these areas, themes related to the transformation of works are developed, revisiting classical themes of civil engineering and architecture in light of new sustainability and safety requirements. In particular, the course promotes original and innovative research on criteria and methodologies for architectural design, surveying and restoration of cultural heritage, sustainable construction techniques, protection of constructions and territory in relation to natural risks, particularly hydrogeological and seismic, design, management, and maintenance of hydraulic and maritime works, infrastructures, and transportation systems, territorial planning, and urban regeneration.

Regarding the Industrial Engineering curriculum, the course promotes original and innovative research on topics specific to the various scientific-disciplinary sectors relevant to the Industrial Engineer profile, particularly in the fields of technical physics, machinery and systems for energy and the environment, mechanics applied to machinery, industrial design, and mechanical constructions, manufacturing technologies and systems, mechanical industrial plants, and managerial economic engineering, material science and technology, systems, methods, and technologies of chemical and process engineering. In these areas, research is conducted aimed at advancing the state of the art through the development of innovative methodologies and overcoming technological gaps limiting the use of such methodologies in industrial contexts. Thus, the research conducted by doctoral students will impact not only on their own training but also on the scientific community and the industrial world, where the curriculum aims to be a potential promoter of development and innovation lines.

DICI, with a strong technological vocation, represents the natural completion of the study paths offered in the aforementioned disciplinary areas. In addition to research collaborations with national and international institutions and universities, the DICI Board of Professors maintains ongoing collaborations and joint activities with private companies (e.g., Siemens, Airbus, Stellantis, Baker and Huges and many others) and research centres (Virtual Vehicle, ENEA, CERN,…). Therefore, the professional profile obtained through participation in the doctoral course is oriented towards research in basic sciences, technologies, and complex systems serving civil and industrial engineering, experimentation, and dissemination of innovative techniques and materials, but also towards the training of future highly specialized researchers and executives in the design, management, control, safety, and monitoring of civil and industrial works and artifacts, also for their interaction with the environment and territory.

## 2. Research and Training objectives of the PhD

The objectives of the Research Doctorate consist of providing innovative scientific, technological and transferrable competencies and knowledge covering a wide range of topics within the fields of Civil and

Industrial Engineering, aimed at training highly specialized researchers and engineers capable of addressing complex research and applied issues using advanced tools and methods.
Due to the interdisciplinary nature of the topics, the doctorate is organized into educational paths with general and specialized courses aimed at transferring basic and advanced knowledge of each disciplinary field and developing specific research topics, which are the subject of doctoral theses. Training is complemented by experiences in the laboratories of the Departments to which the DICI Board members are affiliated, with research periods at accredited national and international institutions, as well as through participation in courses, seminars, conferences, and other training and dissemination experiences, including outreach activities. Moreover, transversal training activities are planned to integrate technical knowledge by acquiring skills in linguistic, computer, research management, knowledge of research and funding systems, research results valorization and intellectual property, and new business creation. Therefore, aligned with the strategic plan of Unical, the main training objectives of the DICI are:

- Advanced interdisciplinary/multidisciplinary training in the fields of civil and industrial engineering.
- Preparation for basic and applied scientific research, which also allows addressing problems characterized by high levels of complexity.
- Interaction with the national and international scientific community, especially through participation in workshops, conferences, summer schools, and seminars.
- Interaction with the general public (children and young people of school age and their families, industry associations, public and private stakeholders, etc.) through public engagement activities that promote a bilateral exchange of information: on one hand, young researchers from DICI will have the opportunity to illustrate the purposes and potential of their research, receiving, on the other hand, information on the needs and expectations of society, useful for directing their studies towards topics of high social impact.
- The development of innovative and autonomous research capacity, in terms of scientific deepening and production of research products in line with the demands of scientific-disciplinary sectors (e.g., peer-reviewed journals), acquisition and management of funds for basic and applied research, and technology transfer.
- Training of the teaching skills through the involvement in tutorship and assistant teaching activities for bachelor and master students.

To achieve these objectives, the DICI Board seeks to involve doctoral students in complex and current scientific problems since the first year, to help them become progressively independent from a scientific point of view, to stimulate their critical capacity through frequent comparison with other scholars, especially at international conferences/workshops and seminars, and to promote training periods abroad at institutions of recognized prestige in the field of Civil and Industrial Engineering.

### 3. Expected impact on the career development perspectives of the PhD students

In Western countries, the growth of human capital skills is now recognized as one of the main elements for achieving competitive growth. In current industrial system development models, success factors are not only sought in maximizing production capacity but especially in innovation capacity and the quality of products produced. Therefore, the establishment of the Doctorate and its specific educational aspects has been conceived and implemented to train professionals with greater specialized knowledge, capable of developing methodologies useful for promoting and managing both product and process innovation activities and research projects in various fields of Civil and Industrial Engineering.
The educational offer, characterized by interdisciplinarity and sustainability of the proposed activities, will provide doctoral researchers with the opportunity to conduct research activities in research institutions and organizations, as well as to carry out specialized professional activities in the public and private sectors, in the design and management phases of works, utilization, and commercialization of the final product. In particular, reference is made to infrastructure, defence of the territory and artefacts from natural events, territorial management, and planning for the civil curriculum, and to technologies and production control for the industrial curriculum.

Many alumni who have obtained the title of Doctor of Civil and Industrial Engineering work in the research sector at Italian and foreign universities, European and non-European, at prestigious international research institutes (such as CERN in Geneva, ENEA), and at industrial research centres both in Italy and abroad.
Considering the professionalism of the doctoral researchers, demonstrated by the high levels of employment achieved, it is believed that the training provided by the doctoral program is adequate for the challenges of the labour market, both nationally and internationally.
Although no systematic investigation has been completed on the level of satisfaction regarding professional and economic gratification, as well as the level of acquired skills, it is considered positively to assess the career prospects and social satisfaction of DICI doctoral researchers.

## 4. Consistency of the PhD course with the objectives of the Italian National Recovery Plan (PNRR)

The research themes that characterize the DICI are fully consistent with almost all the thematic areas considered in the six Missions articulated in the National Recovery and Resilience Plan (PNRR).
Regarding Mission 1, several studies have been conducted in the areas of digitization, innovation, and public administration security (M1C1), and in the productive system (M1C2), as well as in the tourism and culture sector (M1C3). These studies include the development of new organizational and technological models, experimentation with innovative materials and techniques for the requalification of built environments, optimization of production processes in terms of product quality, system efficiency, and sustainability, 3D optical measurement techniques for historic and monumental buildings, and the design of prototypes for the underwater detection of submerged cultural heritage.
All thematic areas of Mission 2 (Green Revolution and Ecological Transition) are of great importance to the DICI. Various researches have focused on the use of renewable energy sources and bio-resources for sustainable energy vector production, proposal of robotic solutions and innovative gripping mechanisms to increase the sustainability of specific agricultural applications (M2C1, M2C2), energy efficiency of buildings with renewable sources, their seismic requalification through the use of dissipative and non-dissipative exoskeletons (M2C3), sustainable water resource management, and mitigation of natural and anthropic risks for territory protection, also employing low environmental impact green technologies and designing smart systems for calamitous event prediction (M2C4). Also, within Mission 2, the component "Renewable Energy, Hydrogen, and Sustainable Mobility" is of interest to the DICI, with objectives including encouraging the reduction of polluting transport modes through the shift to collective mobility systems and further development of light mobility.
The theme of sustainable mobility (Mission 3) also fully aligns with the interests of the DICI. Main topics include railway infrastructure management, use of digital models for sustainable mobility and in support of logistic systems, road safety, and energy recovery from vibrations induced by passing trains to power small electronic devices and sensors in remote environments.
Mission 4 is of interest to the DICI in relation to both Component 1 (M4C1 - Strengthening the provision of education services: from nurseries to universities) and Component 2 (M4C2 - From research to business). Specifically, regarding M4C1, research themes and educational activities implemented by the DICI align with the objectives of Investment 3.4 (Teaching and advanced university skills), Investment 4.1 (Expansion of the number of research doctorates and innovative doctorates for public administration and cultural heritage), and Measure T1 (Assignment of new three-year doctorates in programs dedicated to digital and environmental transitions). Concerning M4C2, it is highlighted how the DICI contributes to achieving the objectives pursued by the Mission and especially Investment 3.3 (Introduction of innovative doctorates that respond to companies' innovation needs and promote the hiring of researchers by companies).
Components M5C2 (Social infrastructure, families, communities, and the third sector) and M5C3 (Special interventions for territorial cohesion) of Mission 5 are also of interest to the DICI. Finally, some mechatronic solutions for rehabilitation and tele-monitoring of patients' health status at home, and activities for the design of new medical devices, fall within the two Components of Mission 6 (Health). Several doctoral theses, patents, and a large number of scientific publications have been produced on these themes, involving doctoral students and researchers from the DICI.

## 5. Short description of the Ph.D. Curricula

1. CIVIL ENGINEERING

The curriculum in Civil Engineering is based on the core areas of civil engineering and architectural engineering, including hydraulics and hydraulic constructions, infrastructure and transportation systems, geotechnics, construction science and technology, technical architecture, architectural composition, and restoration, urban planning, and territorial planning. Each of these areas develops themes related to the transformation of works, revisiting classic themes of civil engineering and architecture and proposing them in light of new sustainability and safety requirements. In particular, the course promotes original and innovative research on criteria and methodologies aimed at architectural design, surveying and restoration of cultural heritage, sustainable construction techniques, protection of constructions and territory in relation to natural risks, especially hydrogeological and seismic, design, management, and maintenance of hydraulic and maritime works, infrastructures, and transportation systems, territorial planning, and urban regeneration.

2. INDUSTRIAL ENGINEERING

Regarding the curriculum in Industrial Engineering, the course promotes original and innovative research on topics specific to the various scientific-disciplinary sectors competing with the profile of the Industrial Engineer, particularly in the fields of technical physics, machines and systems for energy and the environment, mechanics applied to machines, industrial design, mechanical construction, processing technologies and systems, mechanical industrial plants and management engineering, materials science and technology, systems, methods, and technologies of chemical and process engineering. In these areas, research will be conducted aimed at advancing the state of the art through the development of innovative methodologies, as well as overcoming technological gaps that limit the use of such methodologies in industrial contexts. In this way, the research conducted by doctoral students will have implications not only for their own training but also for the scientific community and the industrial world, towards which the curriculum aims to serve as a harbinger of potential lines of development and innovation.

## 6. Programme for scientific and transferrable skills training

The attendance of courses and workshops organized by the DICI is crucial in the training path of doctoral students, which consists of a third-level educational offer dedicated to its own students and open to the participation of doctoral students from other doctoral courses. Doctoral students will be able to build, with the support of their supervisor and upon approval by the DICI Board, their own training path, drawing on the courses listed in the following tables. In particular, personalized training plans will consist of a number of scientific courses (Table A) and cross-cutting courses (Tables B-D), chosen by the doctoral students based on their background and the scientific objectives of the proposed research project. Training plans must be designed to allow the doctoral student to acquire at least 30 ECTS over the three years, of which at least 18 are related to scientific teachings (Table A) and at least 6 to cross-cutting teachings (Tables B-D). Doctoral students may, if necessary, acquire up to 6 ECTS by taking specific courses for doctoral students provided by the educational offer of other doctoral courses at Unical. The admission to subsequent years is decided by the Doctoral Board based on the level of achievement of the research and training objectives set out in the individual research project and the personalized training plan. Admission to the next year will be decided by the doctoral board based on the scientific and training progress achieved by the student, as illustrated in a progress report,

The PhD students will have the opportunity to spend a period abroad (minimum 90 days), and apply for the recognition of the European and International PhD label.

**Table A. List of the scientific courses**

| N. | Formation activity | Year | Curriculum | Language | Hours/ECTS |
|---|---|---|---|---|---|
| 1 | Advanced scientific programming applied to process optimization and signal processing using Matlab | First | Civil and Industrial | EN/IT | 20/5 |
| 2 | Introduction to stochastic and mathematical modelling of discrete systems | First | Civil and Industrial | | 12/3 |
| 3 | Random Utility-Based Discrete Choice Models | First | Civil and Industrial | | 12/3 |
| 4 | Introduction to Python | First | Civil and Industrial | | 16/4 |
| 5 | Computational Fluid Dynamics: Principles and Applications | First | Civil and Industrial | | 12/3 |
| 6 | Design and analysis of experiments | First | Civil and Industrial | | 12/3 |
| 7 | The Material Point Method for civil and industrial engineering | Second | Civil and Industrial | | 12/3 |
| 8 | Verification and validation procedures for CFD simulations | Second | Civil and Industrial | | 12/2 |
| 9 | Energy performances and design of sustainable buildings | Second | Civil and Industrial | | 12/3 |
| 10 | Sustainability and hydrogen: from Waste to Hydrogen and Energy (W2H&E) | Second | Industrial | | 12/3 |
| 11 | Nature-based solutions to address environmental challenges | Second | Civil | | 12/3 |
| 12 | Integration between Urban Regeneration Processes and Advanced Geospatial Techniques and Artificial Intelligence (GeoAI) | Second | Civil | | 12/3 |
| 13 | Copernicus: Programme and Earth observation from satellite | Third | Civil | | 12/3 |
| 14 | Membrane Engineering in the Green Deal: innovation in the generation, separation and storage of Hydrogen | Third | Industrial | | 8/2 |

**Table B. List of courses on Research management and funding systems**

| N. | Formation activity | Year | Language | Hours/ECTS |
|---|---|---|---|---|
| 1 | How to conduct a Systematic Literature Review: design, methods and supporting tools | First | EN/IT | 16/4 |
| 2 | Introduction to Responsible Research and Innovation: Open Science and Scientific Integrity | First | | 4/1 |
| 3 | DICI Workshop: Foresight and megatrend analysis in Civil and Industrial Engineering | First | | 4/1 |
| 4 | Introduction to Horizon Europe with focus on funding schemes for Post-doctoral Research Fellows | Third | | 4/1 |

**Table C. List of courses for the valorization of research and intellectual property**

| N. | Formation activity | Year | Language | Hours/ECTS |
|---|---|---|---|---|
| 1 | Spin-off creation: key fundamentals for a good plan | Second | EN/IT | 8/2 |
| 2 | Principles on IP, patents and valorization strategies | Terzo | EN/IT | 4/1 |

**Table D. Language skills training**

| N. | Formation activity | Year | Language | Hours/ECTS |
|---|---|---|---|---|
| 1 | English for Academic Skills B2 | First | EN | 32/8 |