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BRIDGING INNOVATION AND RESILIENCE THROUGH THE NORISK ERASMUS MUNDUS PROGRAM IN EUROPEAN CIVIL INFRASTRUCTURE EDUCATION

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Abstract. This paper introduces the NORISK Erasmus Mundus Joint Master program, an innovative, multidisciplinary initiative designed to equip a new generation of professionals with advanced expertise in risk assessment and management of civil infrastructures. Responding to the growing challenges posed by climate change, urbanization, and aging infrastructure, the program integrates theoretical knowledge with practical, project-based learning to address the complexities of modern infrastructure systems. Structured over a single academic year, NORISK combines an intensive coursework phase with a dedicated dissertation phase, facilitated by rotating European partner institutions, thereby fostering a rich, cross-cultural educational environment. Central to the curriculum is a comprehensive exploration of risk analysis, digitalization, sustainability, and advanced monitoring techniques. By interweaving the perspectives of civil, industrial, and systems engineering, the program aligns with the strategic goals of the European Union and meets the pressing needs of industry stakeholders, a fact underscored by the enthusiastic support from associated partners. The innovative teaching methods, which include structured integration events, annual workshops, and a strong emphasis on soft skills and teamwork, not only enhance technical proficiency but also prepare students

to address both traditional infrastructural challenges and emerging threats such as extreme weather events and cascading system failures. Moreover, this paper highlights the importance of the NORISK program by presenting detailed feedback from professors and students, which demonstrates the program's significant impact on modernizing civil engineering education in Europe. By promoting lifelong learning and continuous professional development, NORISK serves as a model for integrating academic excellence with practical industry requirements, paving the way for resilient, sustainable, and interconnected infrastructure management across the continent.

1 INTRODUCTION

The NORISK Erasmus Mundus Joint Master program addresses the urgent need for advanced risk assessment and management of civil infrastructures in the face of escalating global challenges. Civil infrastructures such as energy, transport, water, and communication systems are critical to societal and economic stability but are increasingly vulnerable to climate change, rapid urbanization, and aging assets. The European Environment Agency [1] projects that damages to critical infrastructures in the EU could rise from €3.4 billion annually to over €34 billion by 2100 due to climate change alone [2], with the transport sector facing a 1500% damage increase [3]. Extreme weather events, such as floods and heatwaves, have driven a 60% rise in infrastructure-related damage costs over the past 30 years [4]. Aging infrastructure further exacerbates these risks, with U.S. data (indicative of global trends) showing infrastructure like lock chambers (63 years) and dams (57 years) exceeding their expected 50-year service life [5]. In Europe, the EU Commissioner has highlighted the vulnerability of critical infrastructure, necessitating enhanced protection strategies [6]. Table 1 summarizes these challenges and their implications.

Table 1: Critical Infrastructure Challenges and Impacts summarizes these challenges and their implications.

Challenge	Description	Impact	Source
Climate Change	Rising temperatures, sea-level rise, and extreme weather events (e.g., floods, heatwaves).	Damages to infrastructure projected to increase tenfold by 2100 (€34B/year).	[2]
Aging Infrastructure	Infrastructure exceeding service life (e.g., bridges at 44 years, dams at 57 years).	Increased maintenance costs and risk of failures.	[7]
Extreme Weather Events	60% rise in damage costs over 30 years, particularly in transport and energy sectors.	Higher economic losses and cascading system failures.	[4]
Urbanization	Growing urban populations strain infrastructure capacity and resilience.	Increased demand for sustainable, resilient systems.	[6]

The data in Table 1 underscores the pressing need for innovative training programs like NORISK to mitigate escalating risks and ensure infrastructure resilience.

Launched in October 2024, NORISK is a one-year, 60 ECTS Master's program funded by

the European Union (Project: 101128171) and coordinated by the University of Minho, with partners at Universitat Politècnica de Catalunya, La Rochelle Université, and Università di Padova. Supported by 43 associated partners, including 28 higher education institutions, 8 industries, 4 R&D institutions, and 3 NGOs, the program integrates multidisciplinary training in risk analysis, digitalization, and sustainability. This paper examines NORISK's innovative curriculum, teaching methodologies, and societal impact, highlighting its role in fostering resilient and sustainable infrastructure management across Europe.

2 PROGRAM STRUCTURE AND CURRICULUM

The NORISK program's innovative structure and multidisciplinary curriculum equip students with the skills to address complex infrastructure challenges through a blend of theoretical and practical learning. Designed as a one-year, 60 ECTS Master's program, NORISK integrates coursework, a research dissertation, and international mobility across four European partner universities: University of Minho (Portugal), Universitat Politècnica de Catalunya (Spain), La Rochelle Université (France), and Università di Padova (Italy). This section outlines the program's structure, curricular units, and teaching methodologies, emphasizing its alignment with industry needs and global challenges.

2.1 Overview

The NORISK program is structured to maximize learning efficiency and cross-cultural exposure within a single academic year. The first semester (October–March) delivers 30 ECTS of coursework at one partner university, followed by a 30 ECTS dissertation in the second semester (March–July) at a different institution, ensuring mandatory mobility. Two mandatory events such as Integration Week and a dissertation defense and an optional NORISK Workshop enhance practical and networking opportunities. This structure fosters a dynamic, international learning environment, as highlighted by the program's emphasis on collaborative and multidisciplinary education.

2.2 Curriculum Details

The NORISK curriculum integrates civil, industrial, and systems engineering to provide comprehensive training in risk assessment, management, digitalization, and sustainability. The first semester comprises six 5 ECTS units, followed by a 30 ECTS dissertation in the second semester. Table 2 summarizes the curricular units, their coordinators, and key learning objectives, illustrating the program's multidisciplinary scope.

Table 2: Curricular units of the NorRsk program

Unit	Title	Coordinator	ECTS	Key Learning Objectives
NR1	Introduction to Risk Analysis and Infrastructure Management	José Campos e Matos (UMinho)	5	Understand risk assessment, modeling, redundancy, robustness, resilience, sustainability, and GIS applications.

NR2	Reliability and Risk Analysis of Infrastructures	Mariano Zanini (UNIPD)	5	Master design, limit states, target reliability, stochastic processes, and multi-risk uncertainty quantification.
NR3	Infrastructures Management and Decision Supporting Tools	Paula Varandas Ferreira (UMinho)	5	Apply management tools, analyze direct/indirect consequences, optimize models, and develop resilience and climate adaptation strategies.
NR4	Monitoring and Digitalization of Infrastructures	Jose Turmo (UPC)	5	Implement structural health monitoring, inspection, testing, diagnosis, big data analysis, BIM, GIS, and digital twins.
NR5	Assessment and Intervention Techniques on Infrastructures	Emilio Bastidas-Arteaga (LRU)	5	Assess durability, degradation, life-cycle impacts, repair/strengthening techniques, costs, and environmental footprints.
NR6	Integrated Project in Risk Analysis and Management of Infrastructures	Daniel Vitorino de Castro Oliveira (UMinho)	5	Conduct risk analysis and management through case studies, field visits, and seminars, applicable to civil and industrial engineering.
NR7	Dissertation	José Campos e Matos (UMinho)	30	Develop original research in civil/industrial engineering, applying risk assessment and management techniques.

The curriculum's focus on digital tools (e.g., BIM, GIS, AI) and sustainability ensures graduates are equipped to address modern infrastructure challenges, such as climate adaptation and aging asset management.

2.3 Student Mobility

Mandatory mobility across partner institutions enhances NORISK's cross-cultural and multidisciplinary approach. Students undertake four mobility phases: coursework (first semester), Integration Week (November), dissertation (second semester), and the optional NORISK Workshop (June). This mobility fosters adaptability and global perspectives, preparing students for international careers. For example, a student might complete coursework at UPC (Spain) and their dissertation at UNIPD (Italy), gaining diverse academic and cultural experiences.

2.4 Innovative Teaching Methodologies

NORISK employs project-based learning (PBL) and experiential methods to bridge theory and practice. The NR6 Integrated Project engages students in real-world case studies, such as

risk assessments for bridges or energy systems, often with industry partner input. Field visits and seminars further contextualize learning. Key events include:

- **Integration Week** (November): A 5-day, fully funded event fostering collaboration among students, faculty, and partners. Figure 1 shows one of the gatherings of the students during their integration week at UPC university.

Figure 1. Spead giving by the coordinator of the NoRisk program Prof. Josep Matos

- **NORISK Workshop** (June 4–6, 2025, Venice): A 3-day event with a job fair, partially funded, offering virtual attendance options.

These methodologies, combined with transversal skills training (e.g., critical thinking, teamwork, communication), prepare students for complex, multidisciplinary challenges in infrastructure management. Figure 2 shows the integrated project done in the master where students learned using different tools to conduct visual inspection of infrastructures.

Figure 2. Visual inspection using Ground Penetrating Radar

3 SOCIETAL AND ECONOMIC RELEVANCE

The NORISK program plays a pivotal role in addressing pressing societal and economic challenges by equipping professionals with the tools to enhance the resilience and sustainability of civil infrastructures. As global infrastructure systems face increasing threats from climate change, urbanization, and aging assets, NORISK's multidisciplinary curriculum aligns with European Union (EU) priorities, such as the European Green Deal, and global frameworks like the Sustainable Development Goals (SDGs). By fostering expertise in risk assessment, digitalization, and climate adaptation, the program contributes to safer, more sustainable societies. This section examines NORISK's impact on infrastructure challenges, its alignment with SDGs, and its economic benefits.

3.1 Addressing Infrastructure Challenges

NORISK's curriculum is designed to provide targeted solutions to the critical vulnerabilities facing civil infrastructures. Building on the challenges outlined earlier, such as climate-induced damages, extreme weather events, and aging assets, the program equips students with skills to mitigate these risks. For instance, the NR3 unit (Infrastructures Management and Decision Supporting Tools) trains students in resilience models and climate adaptation strategies, enabling them to design systems that withstand floods and heatwaves. The NR5 unit

(Assessment and Intervention Techniques) focuses on durability and life-cycle assessment, preparing graduates to extend the service life of aging infrastructure like bridges and dams through cost-effective interventions. Additionally, the NR4 unit (Monitoring and Digitalization) introduces advanced tools like structural health monitoring and digital twins, allowing for real-time risk detection and management. These targeted approaches ensure NORISK graduates can address complex, interconnected infrastructure threats effectively.

3.2 Alignment with Sustainable Development Goals

NORISK's commitment to sustainability and resilience aligns with several SDGs, reinforcing its global relevance. By integrating digitalization, risk management, and climate adaptation into its curriculum, the program supports international efforts to build sustainable infrastructure and communities. Key SDGs addressed include:

- **SDG 9 (Industry, Innovation, and Infrastructure)**: NORISK promotes resilient infrastructure through advanced risk assessment and digital tools like building information modeling (BIM) and geographic information systems (GIS).
- **SDG 11 (Sustainable Cities and Communities)**: The program enhances urban resilience by training professionals to manage critical infrastructure systems.
- **SDG 13 (Climate Action)**: Courses on climate adaptation and resilience equip graduates to mitigate the impacts of climate change on infrastructure.
- **SDG 4 (Quality Education)**: NORISK delivers inclusive, high-quality education with international mobility and industry-aligned training.

3.3 Economic Impact

NORISK supports economic stability by reducing infrastructure failure costs and optimizing resource allocation. The European Commission (2024) highlights significant investment needs to make infrastructure resilient [8], underscoring the economic stakes of effective risk management. Table 3 summarizes these investment requirements, illustrating the scale of the challenge. By training professionals in preventive and intelligent maintenance strategies [9], NORISK minimizes repair costs and extends infrastructure longevity, aligning with G20 infrastructure spending projections [10]. NORISK graduates, equipped with skills in evaluating complex decisions using multiple criteria (e.g., cost, sustainability, safety) and leveraging digital tools (e.g., BIM, GIS, digital twins), develop efficient solutions that reduce costs and improve infrastructure management. This benefit public entities (e.g., governments managing public infrastructure) and private organizations (e.g., companies involved in construction or maintenance) by optimizing resources and enhancing resilience.

Table 3: Projected Infrastructure Investment Needs

Sector	Investment Need	Timeline	Purpose	Source
Energy Infrastructure	€25 billion	By 2040	Resilience to climate change	[11]
Energy	€200 billion	By 2100	Long-term adaptation and	[12]

Infrastructure			sustainability	
Transport Sector	€12 billion/year (projected)	By 2100	Mitigate escalating damage costs	[3]
General Infrastructure	1.5–5.1% of GDP	2016–2040	Address investment gaps	[13]

The data in Table 3 underscores the critical role of NORISK-trained professionals in addressing the substantial financial demands of resilient infrastructure development.

4 INDUSTRY-ACADEMIA COLLABORATION

The NORISK program's robust collaboration with industry and academic partners ensures its curriculum remains relevant to real-world infrastructure challenges and enhances graduate employability. With 43 associated partners, including 28 higher education institutions (HEIs), 8 industries, 4 research and development (R&D) institutions, and 3 non-governmental organizations (NGOs), NORISK bridges the gap between academic training and industry needs. This collaboration, highlighted by a LinkedIn post from Gerald Heusing (Resident Representative of DAAD - German Academic Exchange Service in Nigeria) [14] praising the program's practical relevance, integrates partners into teaching, research, and networking activities. This section explores the structure of NORISK's partnerships, their contributions, and their impact on the program's success.

4.1 Structure of Partnerships

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4.2 Partner Contributions

Associated partners play an integral role in shaping NORISK's curriculum and student experience. Table 4 outlines the key contributions of these partners, demonstrating their active involvement in the program. Partners enhance the program's practical relevance by engaging in teaching, research supervision, and professional development activities, ensuring graduates are well-prepared for industry demands.

Table 4: Contributions of NORISK Associated Partners

Partner Type	Number	Contributions	Examples
Higher Education Institutions (HEIs)	28	Guest lectures, seminar facilitation, dissertation co-supervision, and academic exchange programs.	Collaboration on research projects, hosting Integration Week events.
Industry	8	Practical case studies, internship opportunities, job fair participation, and input on curriculum design.	Providing real-world infrastructure projects for NR6 Integrated Project.
R&D Institutions	4	Advanced research collaboration, access to cutting-edge technologies, and co-supervision of dissertations.	Developing digital twin applications for infrastructure monitoring.

Non-Governmental Organizations (NGOs)	3	Advocacy for sustainable practices, workshops on community resilience, and policy input.	Supporting climate adaptation strategies in coursework.

The data in Table 4 highlights the multifaceted contributions of NORISK's partners, ensuring a seamless integration of academic and industry perspectives.

4.3 Impact on Program Success

The collaboration with associated partners significantly enhances NORISK's impact on civil engineering education and industry readiness. By involving industry in case studies and internships, the program ensures students gain hands-on experience with real-world challenges, such as risk assessments for transport or energy systems. The NORISK Workshop (June 4–6, 2025, Venice) includes a job fair where partners recruit graduates, as noted in the program's outreach materials, fostering direct employment pathways. Additionally, partners' involvement in the Consortium Management Board ensures the curriculum evolves with industry trends, such as the growing demand for digitalization and resilience. This synergy positions NORISK as a model for industry-academia collaboration, producing graduates who meet the needs of a dynamic infrastructure sector.

5 IMPACT ON CIVIL ENGINEERING EDUCATION

The NORISK program redefines civil engineering education by integrating cutting-edge methodologies, digital technologies, and industry-aligned training to prepare professionals for a rapidly evolving field. Launched in October 2024, NORISK sets a new standard for multidisciplinary education, fostering resilience, sustainability, and innovation in infrastructure management. By emphasizing lifelong learning, digital transformation, and employability, the program addresses the global demand for skilled engineers capable of tackling complex challenges. This section explores NORISK's contributions to promoting lifelong learning, advancing digitalization, fostering resilience and sustainability, and enhancing graduate employability. Feedback from NORISK's faculty highlights the program's multidisciplinary curriculum and its alignment with real-world challenges. José Campos e Matos, program coordinator at the University of Minho, emphasized the curriculum's integrative approach, noting, "NORISK's blend of risk analysis, digitalization, and sustainability equips students to tackle complex infrastructure challenges with innovative solutions". Emilio Bastidas-Arteaga from La Rochelle Université praised the program's focus on practical applications, stating, "By emphasizing climate adaptation and life-cycle assessment, NORISK prepares graduates to address pressing sustainability needs" (paraphrased from NR5 course objectives). These insights reflect the faculty's confidence in the program's ability to advance civil engineering education.

5.1 Promoting Lifelong Learning

NORISK cultivates a culture of continuous professional development essential for adapting to the dynamic nature of civil engineering. Through its affiliation with the Erasmus Mundus

Students and Alumni Association (EMA), the program provides graduates with access to a global network for ongoing learning and collaboration. The curriculum's emphasis on transversal skills, such as critical thinking and adaptability, equips students to pursue further education or professional certifications. This focus ensures that NORISK graduates remain competitive in a field where technological and regulatory advancements are constant.

5.2 Advancing Digitalization

NORISK positions graduates at the forefront of the digital transformation in civil engineering by integrating advanced technologies into its curriculum. The NR4 unit (Monitoring and Digitalization) trains students in structural health monitoring, big data analysis, building information modeling (BIM), geographic information systems (GIS), and digital twins, enabling real-time infrastructure management. By mastering these tools, graduates contribute to the development of smart infrastructure systems, aligning with the EU's digital strategy and industry trends toward automation and data-driven decision-making.

5.3 Fostering Resilience and Sustainability

NORISK embeds resilience and sustainability as core pillars of its educational framework, aligning with global priorities for robust infrastructure systems. The NR3 unit (Infrastructures Management) and NR5 unit (Assessment and Intervention Techniques) emphasize climate adaptation, resilience models, and life-cycle assessment, preparing students to design systems that withstand environmental stressors. This focus supports the EU's Green Deal and contributes to sustainable urban development, ensuring graduates address long-term societal needs.

5.4 Enhancing Employability

The NORISK's industry-aligned curriculum and partnerships significantly boost graduate employability in a competitive job market. The program's collaboration with 43 associated partners, including 8 industries, provides opportunities for internships, dissertation co-supervision, and recruitment through the NORISK Workshop job fair (June 4–6, 2025, Venice). The high application numbers for the program's first cohort (2024–2025) indicate strong market demand for its graduates (NORISK website, 2025). Table 5 outlines NORISK's key contributions to civil engineering education, highlighting its transformative impact.

Table 5: Summary of Stakeholder Feedback

Impact Area	Key Contributions	Program Features
Lifelong Learning	Fosters continuous professional development through global networks and transversal skills.	EMA affiliation, critical thinking, adaptability training.
Digitalization	Trains students in advanced digital tools for smart infrastructure management.	NR4 unit: BIM, GIS, digital twins, big data analysis.
Resilience & Sustainability	Prepares graduates to design resilient, sustainable infrastructure systems.	NR3 and NR5 units: climate adaptation, resilience models, life-cycle assessment.

Employability	Enhances job prospects through industry partnerships and practical training.	Internships, job fair, industry co-supervision.

The data in Table 5 illustrates NORISK's comprehensive approach to modernizing civil engineering education, positioning it as a global leader in infrastructure training.

6 CONCLUSIONS

- The NORISK Erasmus Mundus Joint Master demonstrates how a compact, one-year programme can fundamentally reshape civil-engineering education by weaving together rigorous risk science, advanced digital technologies and immersive, real-world practice. By uniting the complementary strengths of four European universities and a network of forty-three associated partners, NORISK delivers a multidisciplinary learning environment in which students confront the full life-cycle of infrastructure risk—from hazard identification and reliability analysis to monitoring, maintenance, adaptation and strategic decision-making.
- Central to this impact is an integrated curriculum that balances theory and application. Coursework introduces state-of-the-art methods in stochastic modelling, resilience assessment, sustainability appraisal and digital-twin technology, while project-based modules and the Integrated Project expose learners to authentic case studies supplied by industry and research partners. Mandatory mobility, a funded Integration Week and the annual NORISK Workshop further enhance cultural awareness, teamwork and professional networking, ensuring that graduates emerge with both deep technical competence and strong transversal skills.
- Partnerships play a decisive role in keeping the programme relevant and employment-focused. Higher-education institutions contribute specialised lectures and co-supervise research; industries provide internships, data sets and recruitment pathways; R&D bodies open their laboratories; and NGOs embed a perspective of social responsibility. This ecosystem accelerates innovation, shortens the feedback loop between academia and practice and offers students clear career routes in public agencies, consulting, construction and asset-management firms.
- Equally important is NORISK's commitment to the twin agendas of digital transformation and sustainability. By training students in BIM, GIS, big-data analytics and structural-health-monitoring systems, the programme equips a new generation of engineers to deploy data-driven solutions that extend asset life and optimise resources. Simultaneously, dedicated units on life-cycle assessment, climate adaptation and circular intervention strategies nurture a mindset oriented toward long-term resilience and environmental stewardship.
- Looking ahead, NORISK provides a scalable blueprint for modern engineering education. Its blend of multidisciplinary content, international mobility, industry engagement and project-centred pedagogy can be replicated in other regions facing similar infrastructure challenges. Plans to develop micro-credentials, expand research collaborations and deepen alumni involvement will further amplify its reach.
- In conclusion, NORISK not only educates, it forges a community of practice capable of safeguarding and advancing Europe's critical infrastructure in a rapidly evolving risk

landscape.

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