

Lecture Notes in Civil Engineering

Tung Nguyen-Xuan ·  
Thanh Nguyen-Viet · Thanh Bui-Tien ·  
Tuan Nguyen-Quang ·  
Guido De Roeck *Editors*

# Proceedings of the 4th International Conference on Sustainability in Civil Engineering

ICSCE 2022, 25–27 November, Hanoi,  
Vietnam

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Thanh Bui-Tien · Tuan Nguyen-Quang ·  
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Editors

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*Editors*

Tung Nguyen-Xuan  
University of Transport  
and Communications (UTC)  
Hanoi, Vietnam

Thanh Nguyen-Viet  
University of Transport  
and Communications (UTC)  
Hanoi, Vietnam

Thanh Bui-Tien  
University of Transport  
and Communications (UTC)  
Hanoi, Vietnam

Tuan Nguyen-Quang  
University of Transport  
and Communications (UTC)  
Hanoi, Vietnam

Guido De Roeck  
Department of Civil Engineering,  
KU Leuven  
Leuven, Belgium

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# Preface

The construction industry has experienced fundamental changes in facilitating environmental-friendly infrastructure toward the sustainable development goals (SDGs) in recent years. Since the 1973 oil crisis, the green structures have ever improved and gained momentum across all industries. Green construction has become a popular norm in many new construction projects. Promoting green building principles in infrastructure is globally challenging for all stakeholders.

Green building is still in its infancy and constantly evolving. There are numerous principles applied to green projects: efficiency of structural design, energy distribution, water supply, material selection, waste, pollutant reduction, and so forth. Nowadays, the combination of economic development and advanced environmental management technology has paved the way for a sustainable built environment. At the country level, construction projects should be built to meet the green building standards, focusing on a priority for customers and communities.

The 4th International Conference on Sustainability in Civil Engineering—ICSCE 2022 was successfully held on November 25–27, 2022, in Hanoi, Vietnam. The local organizing committee (LOC) would like to greatly appreciate to all of you. Your participation contributes not only to the success of the conference itself but also to the innovation in green technologies. The ICSCE 2022 received 262 abstracts and 167 full papers from 15 countries and regions, including Algeria, Australia, Belgium, Brazil, Bulgaria, China, France, Japan, South Korea, Portugal, Russia, Taiwan, Myanmar, Cambodia, and Vietnam. The International Scientific Committee selected 81 papers for this proceedings, which is divided into eleven parts. These papers were presented at the conference and played an important role in promoting sustainable civil engineering infrastructures toward a green future.

The LOC would like to sincerely thank the International Scientific Committee, keynote speakers, session chairs, and reviewers for your support and cooperation for the success of the ICSCE 2022. We also gratefully acknowledge the sponsors for their valuable time and support.

Assoc. Prof. Thanh Bui-Tien  
Chairman of the LOC—ICSCE 2022  
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# Contents

## Keynotes

<b>The Use of New Tools and Technologies for the Management of Existing Infrastructures. Worldwide Perspective</b> .....	3
José C. Matos, Ngoc-Son Dang, Mário Coelho, and Sérgio Fernandes	

<b>Development and Characterization of Controlled Low-strength Materials as a Heat Transfer Medium for Horizontal Ground-Source Heat Pump System</b> .....	23
Young-Sang Kim and Ba Huu Dinh	

## Materials for Construction

<b>Experimental Investigation of Cs of Reinforced Concrete Structures in Sea Island Regions of Khanh Hoa (Viet Nam) Application on Service Life Prediction</b> .....	37
Thi Thu Hien Dang, Duy Huu Pham, Thi Bach Duong Nguyen, and Trong Chuc Nguyen	

<b>Performance Evaluation and Mix Proportion Design of Concrete Using Low-quality Recycled Aggregate in Vietnam</b> .....	45
Huynh Nguyen Van, Yasuhiro Dosho, Duc Nguyen Anh, and Sang Nguyen Thanh	

<b>Effects of Rejuvenators on Cracking Resistance of High RAP Asphalt Mixtures</b> .....	59
Van Quyet Truong, Ngoc-Lan Nguyen, Dong Van Dao, Kim Youngik, and Duc Trung Tran	

<b>Using Paper Production Industry Waste as Soil Stabilizer for Pavement Construction in Vietnam</b> .....	69
Nguyen Trong Hiep and Pham Huy Khang	

<b>Experimental Investigation of Silica Fume Effect on Durability of High Performance Concrete (HPC)</b> .....	79
Thi Thu Hien Dang, Thi Bach Duong Nguyen, Thi Hong Bui, and Quang Trung Dinh	
<b>Leaching Mechanism of Metals from Recycled Concrete Aggregates (RCA) and Potentially Environmental Issues</b> .....	89
Vu Quoc Hung, Prasanna Egodawatta, Chaminda Gallage, and Les Dawes	
<b>Effect of Shape Memory Alloy Fibers on Volumetric Strain and Moduli of Concrete in Cyclic Compression</b> .....	99
Vinh-Ha Ho, Van-Minh Ngo, Eunsoo Choi, and Ngoc-Long Nguyen	
<b>Construction Engineering and Management</b>	
<b>Framework for Measuring Controlling Function Management of Vietnam’s Public Construction Works</b> .....	113
Ngo Anh Tuan and Nguyen Luong Hai	
<b>The Impact of Project Organizational Culture on Cost Performance of Construction Projects</b> .....	121
Do Van Thuan and Nguyen Luong Hai	
<b>Propose the Construction Orientation of Two Airports in Hanoi After Forecasting Airport Passenger Demand</b> .....	131
Quoc Van Nguyen, Trung Tien Trinh, and Thuy Anh Vu	
<b>An Overview of the Legislation on Sustainability and Strategy Accessing the Sustainability Performance of Road Construction Projects in Vietnam</b> .....	141
Ngoc Minh La, Trong Hung Dinh, and Thi Tuyet Pham	
<b>Constraints in Implementing Public–Private Partnerships (PPPs) in Vietnam: Private Sector’s Perspective</b> .....	151
Hang Vu and Quynh-Huong Pham-Nguyen	
<b>Assessing the Accuracy of Lidar UAV Technology Along with the Lidar Camera in Establishing the Terrain Map for Construction in Vietnam</b> .....	159
Tran Quang Hoc, Tran Duc Cong, and Do Van Manh	
<b>Bridge and Highway Engineering, Railway Engineering</b>	
<b>A Review of Methods for Protecting Highway Embankments from Overtopping Flow</b> .....	169
Huy Quang Mai, Tuan Anh Tong, and Phong Dang Nguyen	

**Applied Technology of Stay Cable with Saddle System in Song Hieu Bridge** ..... 177  
 Nguyen Dac Duc and Nguyen Tuan Ngoc

**Weight Evaluation of Criteria Influencing Road Flooding Using Multi-criteria Analysis** ..... 185  
 Thai Thi Kim Chi and T. T. K. Chung

**Equilibrium Local Scour Depth Under Live-Bed Scour for Cylindrical Piers with Their Width Greater Than Three Meters Based on Field Data** ..... 193  
 T. N. Doan and D. N. Tran

**Study on the Effect of Corrugated Webs in Steel I-Girder Bridge** ..... 201  
 Tran Viet Hung

**Evaluation of Dynamic Behaviors of Girders in High-Speed Railway Bridges Under Dynamic Impact of Electric Multiple Unit and Push–Pull Trains** ..... 209  
 Nguyen Duc Thi Thu Dinh

**Application of Mobile Road Profiler for International Roughness Index Monitoring in Hanoi** ..... 223  
 Hoang Kien Pham and Kazunari Hirakawa

**River, Estuary and Coastal Hydrodynamic Engineering**

**Numerical Simulation of Submarine Landslide-Induced Tsunami Using Two-Layer Extended Boussinesq Equations** ..... 235  
 Van Khoi Pham, Van Nghi Vu, and Changhoon Lee

**Selecting Optimal Marina Configuration with Regard to Mooring Safety and Port Area Water Exchange** ..... 243  
 Izmail Kantarzhi, Alexander Gogin, and L. G. Tran

**Wave Reflection from Typical Sloping Dike in the North of Vietnam** .... 253  
 Thi Phuong Thao Nguyen

**The Mechanism of Large-Scale Flow Circulation at Asymmetric Sand Spit Inlet: A Case Study in Degi Estuary, Binh Dinh Province** .... 263  
 Vu Van Ngoc, Tran Thanh Tung, and Nguyen Quang Duc Anh

**A Mathematical Model of Two-Dimensional Vertical Flow Based on the Dual Approach** ..... 271  
 The Hung Nguyen

**Analysis on Feasibility Study of PE Material Buoys for Vietnam Inland Waterways and Maritime Channels** ..... 287  
 Nguyen Xuan Thinh and Bui Minh Thu

**Research on Verification of the Pile Types of a Port Structure by Using Impact Vibration Test in Vietnam** ..... 295  
 Thi Bach Duong Nguyen and Thanh Dat Pham

**Prediction of Water Setup and Wave Crest Heights on Submerged Coral Reefs with Steep Slopes** ..... 305  
 Tao Nguyen Quang, Ha Thi Thu Nguyen, Bau Nguyen Van, and Cuong Dinh Quang

**A Study of Wave Attenuation Through Vegetation** ..... 313  
 Phan Khanh Linh, Pham Lan Anh, Truong Hong Son, and Le Hai Trung

**Effects of Beach Slope on Wave Characteristics in the Surf Zone Over Fringing Reef** ..... 321  
 Pham Lan Anh, Phan Khanh Linh, and Truong Hong Son

**A New Framework for Estuarine and Coastal Modeling to Monitor Water Security in a Changing Climate** ..... 329  
 Truong Hong Son and Phan Khanh Linh

**Hydrodynamic Modelling of New Segment Channel to Navigation Channel in Hau River, Vietnam** ..... 337  
 Nguyen Viet Thanh, Le Vinh An, Thai Thi Kim Chi, Nguyen Dang Phong, Hoang Nam Binh, Nguyen Duy Tien, Bui Vinh Phuc, and Trinh Dinh Lai

**Numerical Model of the Impact of Submerged Breakwater on Shoreline Evolution of Bona Beach, France** ..... 347  
 Vu Minh Tuan and Yves Lacroix

**Wave Transmission Through Pile–Rock Breakwater to Protect the Mekong Delta Coastal and Develop an Empirical Formula** ..... 357  
 Nguyen Hai Duong, Dinh Cong San, Nguyen Nguyet Minh, Vu Van Nghi, and Le Duy Tu

**An Empirical Prediction of  $T_{m-1,0}$  on the Reef Flat of Atolls** ..... 369  
 Thi Thuy Pham, Hai Trung Le, and Thanh Tung Tran

**Overview of Coastal Protection Structures in the Mekong River Delta** ..... 377  
 Le Vinh An, Nguyen Viet Thanh, Pham Van Hai, and Trinh Dinh Lai

**Geotechnical Engineering**

**Thermo-Hydro-Mechanical Behavior of the Rock Mass Surrounding Wellbore in Deep Saturated Geological Layer** ..... 399  
 Nam Hung Tran, Thi Thu Nga Nguyen, Duc Tiep Pham, and Duc Tho Pham



**Numerical Study on Behaviors of EPS Geofom Embankment on Soft Ground** ..... 409  
 Quoc-Bao Truong, Anh-Tuan Vu, Hoang-Kien Pham, and Duy-Canh Nguyen

**Investigation of Slope Protection Using Vegetation: A Case Study in Ninh Thuan Province, Vietnam** ..... 417  
 Tuan-Nghia Do and Lan Chau Nguyen

**Rockfall Mitigation for Highway in Vietnam: A Case Study on the Hoang Sa Road, Da Nang City** ..... 427  
 Cho Thu Thu Naing, Lan Chau Nguyen, and Tien Dung Nguyen

**Volume Loss During the TBM Construction of Metro Line 1, Ho Chi Minh City, Monitoring Data Assessment and New Analytical Model for Prediction** ..... 439  
 Nguyen Phuong Duy, Nguyen Thach Bich, and Tran Duc Nhiem

**Proposing an Analytical Equation to Evaluate the Maximum Surface Settlement Due to TBM Construction Based on the Monitoring Data from Ho Chi Minh City Metro Construction** ... 447  
 Nguyen Thach Bich, Nguyen Phuong Duy, and Tran Duc Nhiem

**EPS Geofom Embankment on Soft Ground—A Full-Scale Test** ..... 455  
 Quoc-Bao Truong, Hoang-Kien Pham, Anh-Tuan Vu, Satoshi Kobayashi, and Duy-Canh Nguyen

**Earthquake Resistance of Caisson-Type Quay Wall Renovated by Grouting and Deepening: Geo-Centrifuge Test** ..... 463  
 Anh-Dan Nguyen and Young-Sang Kim

**Remedy Solutions for a Deep-Seated Landslide on Road No. 155, Section Km 12 + 667.85–Km 12 + 711.57, Sapa Town, Lao Cai Province, Vietnam** ..... 473  
 Thu Zar Aung, Lan Chau Nguyen, and Tien Dung Nguyen

**Water Resource and Environment Engineering**

**Uses Field-Scale Data to Modify the HEC-18 Scour Model** ..... 487  
 Huy Quang Mai and Nghien Dinh Tran

**Identifying the Reasonable Rainfall Intensity Formula and Intensity–Duration–Frequency Curve for Tan Son Hoa Station, Ho Chi Minh City** ..... 495  
 Dong Nguyen Dang and Thi Hoa Binh Le

**Use of Disdrometer Dataset to Detect Kinetic Energy Expenditure and Rainfall Intensity Relationships** ..... 503  
 Linh Nguyen Van, Xuan-Hien Le, Giang V. Nguyen, Minho Yeon, Younghoon Kim, and Giha Lee

**Evaluating the Performance of Light Gradient Boosting Machine in Merging Multiple Satellite Precipitation Products Over South Korea** ..... 513  
 Giang V. Nguyen, Xuan-Hien Le, Linh Nguyen Van, Sungho Jung, Chanul Choi, and Giha Lee

**Multiple Methods for Homogeneity Analysis of Precipitation Series in Vinh Phuc Province** ..... 523  
 Phan Manh Hung and Chien Pham Van

**Impacts of the Threshold Value of the Enhanced Vegetation Index on Surface Water Area and Extent in MODIS Imagery** ..... 535  
 Chien Pham Van

**Extracting Water Depth from Landsat-8 Multispectral Satellite Imagery in Coastal Waters** ..... 545  
 Tran Duc Phu

**The Novelty of Extreme Natural Drought Trend Using the Statistical Approach** ..... 553  
 Tuong Vo

**Proposed Adaptation Measures for Saltwater Intrusion in the Vietnamese Mekong Delta** ..... 563  
 Nguyen Phuong Mai, Sameh Kantoush, Sumi Tetsuya, and Tang Duc Thang

**Structural Modelling and Analysis**

**Evaluation of Partial Safety Coefficients in the Concrete Tank Design by a Semi-Probabilistic Approach** ..... 575  
 Hocine Hammoum, Karima Bouzelha, and Amar Aliche

**Multi-Criteria Optimization of the Quality Indicators of Steel Foundry Ladles, Based on Priorities and Weighting Coefficients of the Indicators** ..... 583  
 Dimitar Borisov

**Research on Construction of Prefabricated Precast Concrete Columns Combined with S-VRO Foam Core Slab** ..... 593  
 Thang Hoang Duc

**Influence of Cohesive Interface on the Flexural Behavior of Textile-Reinforced Concrete** ..... 605  
 Nguyen Thi Thu Nga, Dang Thi Thu Hien, and Tran Nam Hung

**Nondestructive Mechanical Characterization by Small Punch Test and Statistical Fractography for the Determination of the Residual Lifetime of Old Steel Bridges** ..... 615  
 Bholah Bhimal, Delgado Julien, Depale Bruno, Auvray Nicolas, and Ponson Laurent

**Evaluating Damping Model Applied for Cable Tension of Cable-Stayed Bridge** ..... 623  
 An Huynh-Thai, Toan Pham-Bao, Hung Nguyen-Quoc, and Luan Vuong-Cong

**Investigating Seismic Response of Container Crane Subjected to Near-Field Ground Motions** ..... 631  
 Van Bac Nguyen and Van Hung Nguyen

**Structural Damage Detection and Health Monitoring**

**Mechanical Reliability Analysis of an RC Storage Tank Considering Pitting and Uniform Corrosion** ..... 641  
 Karima Bouzelha, Nassima Miloudi, Hocine Hammoum, Lysa Benaddache, and Serine Bennabi

**Study to Apply Artificial Neural Network for Establishing Displacement Models of a Cable-Stayed Bridge** ..... 649  
 Thuy Linh Nguyen and Van Hien Le

**Filtering Outliers in GNSS Time Series Data in Real-Time Bridge Monitoring** ..... 657  
 Ngoc Quang Vu and Van Hien Le

**Safety Warnings for Technical Status of Port Structure by Automatic Monitoring in Vietnam** ..... 665  
 Thi Bach Duong Nguyen, Van Hien Le, and Duc Cong Tran

**Opportunities and Challenges of Digital Twins in Structural Health Monitoring** ..... 673  
 Minh Quang Tran, Helder S. Sousa, Nhung Thi Cam Nguyen, Quyet Huu Nguyen, and José Campos e Matos

**Damage Detection in Structural Health Monitoring Using a One-Dimensional Convolutional Neural Network—The Z24 Bridge Case Study** ..... 683  
 Hieu Nguyen-Tran, Dung Bui-Ngoc, Dung Pham-Tuan, Lan Ngoc-Nguyen, Hoa Tran-Ngoc, and Thanh Bui-Tien

**The Effect of the Cut on the Power Spectral Density of the Beam** ..... 693  
 Toan Pham-Bao and Luan Vuong-Cong

**Building Information Modelling and AI in Civil Engineering**

**Application of FARO Focus 3D S350 Terrestrial Laser Scanner in Building 3D Models of Potential Areas of Landslides and Rocks—Case Study in Ha Giang Province, Vietnam** ..... 703  
Hanh Hong Tran, Hung Quoc Vu, and Anh Van Tran

**Risk Identification and Prediction for Highway Bridge Projects Using an Artificial Intelligence Model** ..... 711  
Dao Duy Lam, Le Duc Anh, Luu Truong Giang, and Hoang Ha

**Integrating Terrestrial Laser Scanning Technology and Unmanned Aerial Vehicles in Establishing a Database for the Preservation of Ancient Constructions** ..... 721  
Do Van Manh, Le Quang, and Vu Ngoc Phuong

**Pavement Crack Segmentation Using an Attention-Based Deep Learning Model** ..... 727  
Hieu Dao, Tung Khuc, Quan Truong, Cang Dinh, and Andy Nguyen

**Hindrances to the Application of Building Information Modeling (BIM) in the Construction Field in Vietnam** ..... 739  
Nguyen Tai Duy

**AI Solutions for Innovation of Pavement Crack Analysis on Images Taken from Specialized Road Surface Survey Vehicles in Vietnam** ..... 747  
Thao Dinh Nguyen and Nhung Thi Hong Nguyen

**Traffic Engineering, Transportation and Logistics Engineering**

**An Investigation of Cargo Handling Equipment Performance in Vietnam Container Terminals** ..... 757  
Pham Huy Tung and Nguyen Luong Hai

**Assessment of Traffic Safety Between Pedestrians and Vehicles Using Traffic Conflict Technique** ..... 763  
Tuan Thanh Nguyen and Phuong Thao Cao

**Vehicle Speed Analysis Toward Traffic Safety at School Zones Considering Roadside Activities—Case Study in Vietnam** ..... 771  
Dang Minh Tan and Vu Quang Huy

**Impact of COVID-19 on the Inland Waterways and Review Recovery Solutions** ..... 781  
Nguyen Viet Thanh, Nguyen Dinh Thao, Dang Tuyet Ly, and Pham Van Hai

**COVID-19 Impact on the Operations of Road Transport Enterprises and Green Recovery Solutions** ..... 793  
Thao Dinh Nguyen, Ly Tuyet Dang, and Quyen Van Nguyen

**Correction to: Proceedings of the 4th International Conference  
on Sustainability in Civil Engineering** ..... C1  
Tung Nguyen Xuan, Thanh Nguyen Viet, Thanh Bui Tien,  
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# About the Editors

**Dr. Tung Nguyen-Xuan** has been working at Civil Engineering Faculty, University of Transport and Communications (UTC), Vietnam, since 2008. He got Bachelor's and Master's degrees at UTC and Ph.D. degree at Tokyo Metropolitan University, Japan, with his main research topic about corrosion monitoring on steel truss bridges. Dr. Tung's research interests are concrete structure including concrete using recycled aggregates, structure engineering, advanced material, and structural health monitoring. Dr. Tung has published 20 scientific papers (in national and international journals) and 4 scientific books and is a principle investigator for 3 research projects.

**Dr. Thanh Nguyen-Viet** obtained his engineering and master's degrees from the National University of Civil Engineering (Vietnam) in 2001 and 2006 and his Ph.D. degree from Hohai University (China) in 2012, respectively. He joined the University of Transport and Communications in 2005 as a lecturer and is now a vice dean and an associate professor in the Faculty of Civil Engineering at the University of Transport and Communications, Hanoi, Vietnam. Dr. Viet Thanh Nguyen is a specialist working in the field of the harbor, coastal, and offshore engineering. Practical knowledge and experience help a lot in his research as well as inspire students and researchers. Dr. Nguyen's research areas are hydrodynamics, sediment transport, port, coastal and offshore engineering, and inland waterways. He has 26 publications in Web of Science and Scopus. He has obtained an Outstanding Ph.D. Candidate Award at Hohai University in 2013.

**Assoc. Prof. Dr. Thanh Bui-Tien** is an expert in Civil Engineering, specializing in structural health monitoring, AI, digital twin, intelligent transportation, and structural damage diagnosis of bridges. He is currently the dean of the Faculty in Civil Engineering at the University of Transport and Communications in Vietnam. He obtained his Bachelor of Engineering degree in Bridge Engineering from the University of Transport and Communications (UTC) in Vietnam in 2000 and his Ph.D. in Civil Engineering from the University of New South Wales (UNSW), Australia, in 2007. He has held academic positions at various institutions, including lecturing at UNSW and UTC and postdoctoral research at Université de Liège and KU Leuven. Assoc.

Prof. Dr. Bui Tien Thanh has published numerous papers in peer-reviewed prestigious journals and has contributed to many conferences and seminars around the world. He has a citation count of 1048, an h-index of 18, and an i10-index of 26. His current work involves developing new methods based on optimization and AI for structural health monitoring and structural damage detection.

**Assoc. Prof. Tuan Nguyen-Quang** is currently the vice dean of Faculty at Civil Engineering, University of Transport and Communications in Vietnam. His research domain is on the behavior of materials and structures, new materials, and technologies in construction. He graduated from University of Transport and Communications, Vietnam, in 2006. Then, he received a master's degree in 2007 and a Ph.D. in 2011 from Ecole Nationale des Travaux Publics de l'Etat (ENTPE) in France. Until now, he has more than 10 years of research in the field of materials in transport construction, especially asphalt materials. He is a member of the editorial board of Road Materials and Pavement Design Journal since 2016. He has published 60 scientific papers (in national and international journal) and 2 scientific books. His total number of citations is 750 (according to Google scholar). His h-index is 13 (according to Google scholar) and is 10 (according to Scopus). He chaired and participated in more than 10 ministerial and state-level projects in Vietnam as well as participated in the international RILEM project (RILEM TC 237 SIB, Testing and characterization of sustainable innovative bituminous materials and systems).

**Emeritus Prof. Dr. Guido De Roeck** is a highly respected figure in the field of civil engineering, with a distinguished career spanning several decades. He is currently affiliated with the Department of Civil Engineering, Section Structural Mechanics at Katholieke Universiteit Leuven (KU Leuven), Belgium. With expertise in fuzzy finite element method, dynamic analysis, soil mechanics, and fracture mechanics of composite materials, he has contributed extensively to research in these areas. Professor De Roeck obtained his Bachelor of Engineering Science in 1968, followed by his Master of Science in Civil Engineering in 1971, both from KU Leuven. He earned his Ph.D. in Structural Mechanics from the same institution in 1975 and his Doctor of Science degree in 1981. As a top professor at KU Leuven, Prof. De Roeck has published thousands of international articles, with a citation count of 22609, an h-index of 74, and an i10-index of 220. His notable achievements include being a senior specialist in the field of structural health monitoring with the output-only method of determining damage from vibration measurement. Professor De Roeck leads multiple research activities, covering a broad spectrum of domains such as static and dynamic analysis of mechanical structures, damage detection by vibration monitoring, dynamic system identification, soil-structure interaction, non-linear constitutive soil models, fracture mechanics of composite materials, fuzzy finite element method, and so on.

# Keynotes



# The Use of New Tools and Technologies for the Management of Existing Infrastructures. Worldwide Perspective



José C. Matos, Ngoc-Son Dang, Mário Coelho, and Sérgio Fernandes

**Abstract** The development of modern society heavily relies on existing infrastructures. In particular, transport infrastructures are crucial to moving people and goods around the world, thus materializing globalization. In recent years, awareness has been raised on the necessity to maintain the existing infrastructures and aspects such as sustainability are nowadays the top priorities of infrastructures' stakeholders. Accordingly, the future infrastructures will be those already existing and properly maintained rather than new ones to be built to replace them. The success of this huge compromise on maintaining existing infrastructure depends on the development of more accurate, efficient, cost-effective and sustainable tools and technologies to support all the lifecycle management. The present work provides an overview of some relevant efforts that are being conducted worldwide in this regard, highlighting the current trends of technological development, identifying some existing opportunities, and anticipating some of the most relevant tools that will be used in the near future to support transport infrastructures' management.

**Keywords** Transport infrastructures · Management · Technology

## 1 Introduction

During the last decades of the twentieth century and the start of the twenty-first century, significant investments were made in the transport industry in most developed nations. In the past, the main emphasis was on finding a design that would result in the lowest investment cost for various assets, including bridges, viaducts, and highways, while merely considering the functional requirements. This strategy

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J. C. Matos (✉) · N.-S. Dang · M. Coelho · S. Fernandes  
ISISE, University of Minho, Guimarães, Portugal  
e-mail: [jmatos@civil.uminho.pt](mailto:jmatos@civil.uminho.pt)

N.-S. Dang  
e-mail: [sondn@civil.uminho.pt](mailto:sondn@civil.uminho.pt)

produced an infrastructure design with high maintenance costs. An innovative life-cycle cost analysis (LCCA) method was developed to buck this tendency and seek the best balance between maintenance and investment [1].

The fact that a portion of Portugal's transportation system traverses several geological and environmental concerns enhances its sensitivity to climatic risks. Due to their crucial role in socioeconomic growth, one of the difficulties for transport decision-makers is ensuring the transportation networks' resilience to extreme events and climate change [2]. The Strengthening Infrastructure Risk Management in the Atlantic Area (SIRMA) project was suggested to create, validate, and implement a comprehensive framework for effectively managing and mitigating natural hazards in terrestrial transportation modes. According to the Transport White Paper (2011), SIRMA significantly increases the resilience of transportation infrastructure. The SIRMA idea, which uses multiplatform remote sensing and crowdsourcing to monitor big data, is at the forefront of the adoption of predictive maintenance [3, 4]. The primary goals of SIRMA are to lower maintenance and retrofitting costs through long-term recovery and risk mitigation. To achieve this goal, existing deterministic models of infrastructure resilience under the current climate will be modified to incorporate probabilistic models that take into account the uncertainties of future climate and change on land use and how it affects the impact of hazards on specific mode components [5, 6].

On the other hand, recently, the bridge management system (BMS, hereafter used by the acronym GOA—Gestão de Obras de Arte in Portuguese) has evolved to meet the needs of various clients and to reflect the features of their bridges. GOA has been modified into a product owned by Betar, Lda. Betar discovered a void in the domestic market and began developing the first Portuguese bridge management system in 1997, 29 years after establishing the first bridge management system in the USA [7]. Estradas de Portugal, a public transportation company, was also acquired and used the GOA system in 2004. By establishing GOA as a national standard, these facts helped private and public transportation agencies in Portugal, and practically, all bridge owners create a consistent language and framework. Continuous advancements in GOA have been made possible by more than 20 years of research and experience. It led to expansion outside the Portuguese market, specifically in Mozambique and China. More recently, opportunities to implement it in other countries have also arisen. The specification of the fundamental modules that allow storing various data types has mostly undergone revisions during the past few years (LABSE Symposium Report 91). In this sense, GOA.BI is a project built on modern technology and digital trends that focuses its efforts on addressing the issues with the highway and railroad infrastructures that were previously mentioned. Due to the large number of assets involved, this project seeks to develop a smart interface to assist stakeholders (owners, transportation authorities, and inspectors, among others) in the lifecycle management of complex systems, such as transportation infrastructures (bridges, viaducts, tunnels, acoustic barriers, buildings, retaining walls, slopes, pavements, rail tracks, telematics equipment, sign gantries, high mast columns, among others). The first step is to create an integrated asset management system framework based on the

bridge management system (BMS), which offers flexibility to apply and extrapolate its concepts for different types of infrastructure.

Building information modelling (BIM), which can cover integrated management of entire asset networks like motorways, railways, or bridges, has recently assumed a crucial position in the infrastructure sector. The state of the art of BIM implementation in this field, including an overview of the BIM domains, BIM applications, data schemas, and BIM uses, has been presented through the thorough review and critical analysis of 198 publications in the field of building information modelling for transportation infrastructure [8]. For transportation infrastructure in general, and particularly for highways and bridges, it demonstrates better BIM research and application development. Additionally, it draws attention to the state of research at the moment, how emerging technologies are being used, and the considerable research gaps that still need to be filled.

Depending on the originator's source, the 3D geometrical model for an existing infrastructure can be generated in various ways. The IFC model, which aims to link the geometric representations with the semantic objects in a flexible manner, is the geometric representation of each structural member. In this context, several types of bridge structures have lately been widely launched using the bridge digital information model (BIM method) [9–14]. An improved version of the alignment-based object-oriented design philosophy appears to be the key to building a bridge information model. The entire bridge model can be delivered without discontinuity using a set of parameter definitions and suitable algorithms. Because of the flexibility afforded by the parametric design idea, the model's creator can alter any input variables to satisfy the desired objectives. The digital bridge model greatly aids the engineer in effectively controlling the flow of information for various goals throughout the project's lifecycle. Collaboration between multiple project stakeholders and stages is made possible by the design platform's interoperability.

## 2 Methodology and Framework

Managing the existing infrastructure is challenging regarding interoperability among different BIM solutions, different BIM uses, or difficulties in integrating other BIM models. Therefore, the prototyping methodology and case study are strongly recommended. This method includes the prototype creation, application and curating to a specific infrastructure asset, then reworking when needed until an acceptable prototype is achieved. It allows engineers to deal with any project when the requirements come from multiple disciplines and aspects, a crucial challenge that needs to be overcome.

During the prototyping research, the expertise and methods from different disciplines will be integrated into pursuing objectives. According to the management purposes for existing infrastructure, the following concept and framework works can be introduced:

## 2.1 Risk and Resilience-Based Decision-Making

Extreme natural occurrences and the robust corrosion processes brought on by closeness to the water directly impact how well railway and transportation infrastructure performs in the service, particularly in the Atlantic Area. To increase the resilience of transportation infrastructure, a robust framework for managing and mitigating extreme natural occurrences must be developed and put into place. Figure 1 suggests a framework for risk- and resilience-based decision-making intended to lessen the effects of extreme natural hazards, such as floods and fires, on people and local and global economies.

The main actions and deliverables following the proposed framework can be considered as follows:

- Risk-based predictive model (algorithm) for transportation infrastructures (includes climate change effects on the impact and return period of extreme events).
- Relational database with risk mitigation measures for transportation infrastructures, their effects, and costs.
- Framework (user-friendly software) for multi-criteria decision-making, i.e. by maximizing resilience and minimizing the risk mitigation costs.

Noteworthy, the risk definition here is associated with the consequences of an asset’s failure in case of a hazard’s occurrence. While a holistic methodology was defined, its implementation was only done for specific parameters. Risk management involves monitoring the factors that influence these three risk components and defining mitigation actions to keep the network risk within acceptable levels. This framework enables forecasting transportation infrastructure performance to multiple hazards, comprising the likelihood of such extreme events and their impact on the infrastructures. Moreover, it is expected to create the premise for the creation of a database with the most relevant risk mitigation measures, including their description, when they should be used, and with what time frequency, effects, and costs (direct and indirect).



**Fig. 1** Configuration for the risk and resilience-based decision-making framework

## 2.2 BIM-Based Bridge Management System

A desktop web-based and intelligent interface platform should be available and supported by the new bridge management system (GOA.BI). The earlier system is a full version with all its modules because it is designed for the central management team. In situ inspectors will use this GOA.BI, which they will access through mobile devices. There should be a lighter version with less functionality in fewer modules.

Figure 2—Flowchart of the new system architecture summarizes the new system architecture. On top and bottom extremities are represented the two main ways to access the new system referred to before. In the middle, the significant modules to be developed are shown. They are beginning with the system’s core, GOA. BI module will be essentially based on the existing GOA system, which will be upgraded considering the interoperability between the current system and the new modules. Remark that this is the central module through which all other modules communicate.

Besides the objectives directly related to developing a new bridge management system, other important goals are associated with the recent acquisition tools and the exchange of information between all modules. The following list summarizes all the main objectives of the project:

- Development of a new web-based platform, modular, and scalable that can be continuously upgraded with new features and modules.
- Development of an intelligent interface platform to be used in the field by the in situ inspectors’ team.
- Development of new inspecting equipment taking advantage of existing commercial tools (e.g. commercial drones, cameras, etc.) and algorithms/methods in the computer vision and deep learning field.
- Development of mixed reality tools to manage bridges information with visual analytics and augmented reality techniques.

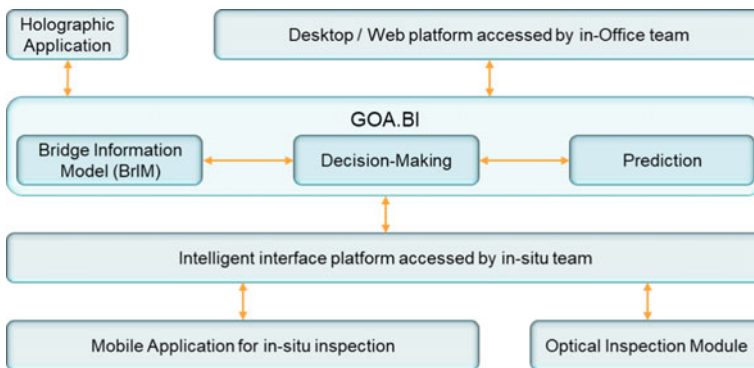


Fig. 2 Flowchart of the new BIM-based bridge management system architecture

- Development of algorithms to be used in information exchange between new inspecting equipment sensors and BrIM models.
- Development of digital image correlation algorithms to post-process inspection measurements.
- Development of a predictive maintenance management module, which will help in defining priorities for maintenance works.
- Development of a decision-making module will help define the type of intervention to be taken, considering the associated cost–benefit ratio.

### 3 Case Study 1: Strengthening Infrastructure Risk Management (SIRMA)

To achieve the project’s aims, the distribution of different Work Packages (WPs) was proposed and subdivided into specific actions that interact with each other (see Fig. 3). The technical WPs are listed: WP4—Climate change and natural hazards in Atlantic Area; WP5—Instrumenting transportation infrastructure for extreme natural hazards; WP6—Risk and resilience-based decision-making procedure for transportation infrastructure; WP7—Testbed.

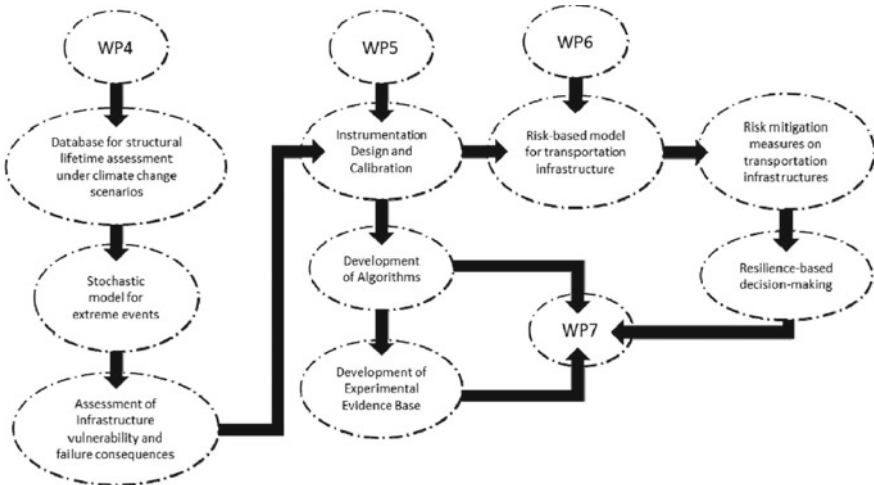


Fig. 3 Interaction graph between WPs