CDRI
Coalition for Disaster Resilient Infrastructure

CDRI Fellowship Programme

Cohort 2022-23

Project Abstracts

COALITION FOR DISASTER RESILIENT INFRASTRUCTURE

Launched by the Honourable Prime Minister of India, Shri Narendra Modi at the UN Climate Action Summit in New York on 23 September 2019, the Coalition for Disaster Resilient Infrastructure (CDRI) is a partnership of national governments, UN agencies and programmes, multilateral development banks and financing mechanisms, the private sector and knowledge institutions that aims to promote the resilience of new and existing infrastructure systems to climate and disaster risks in support of sustainable development.

CDRI FELLOWSHIP PROGRAMME

The CDRI Fellowship Programme was launched in September 2020 with the objective of investing in research and innovation to build back and build forward better as the world navigates through global transitions. The Fellowship Programme is a seed grant, providing financial support, capacity development and peer learning opportunities for individuals designing solutions for real-world problems related to the resilience of infrastructure.

For queries, contact: fellowship@cdri.world

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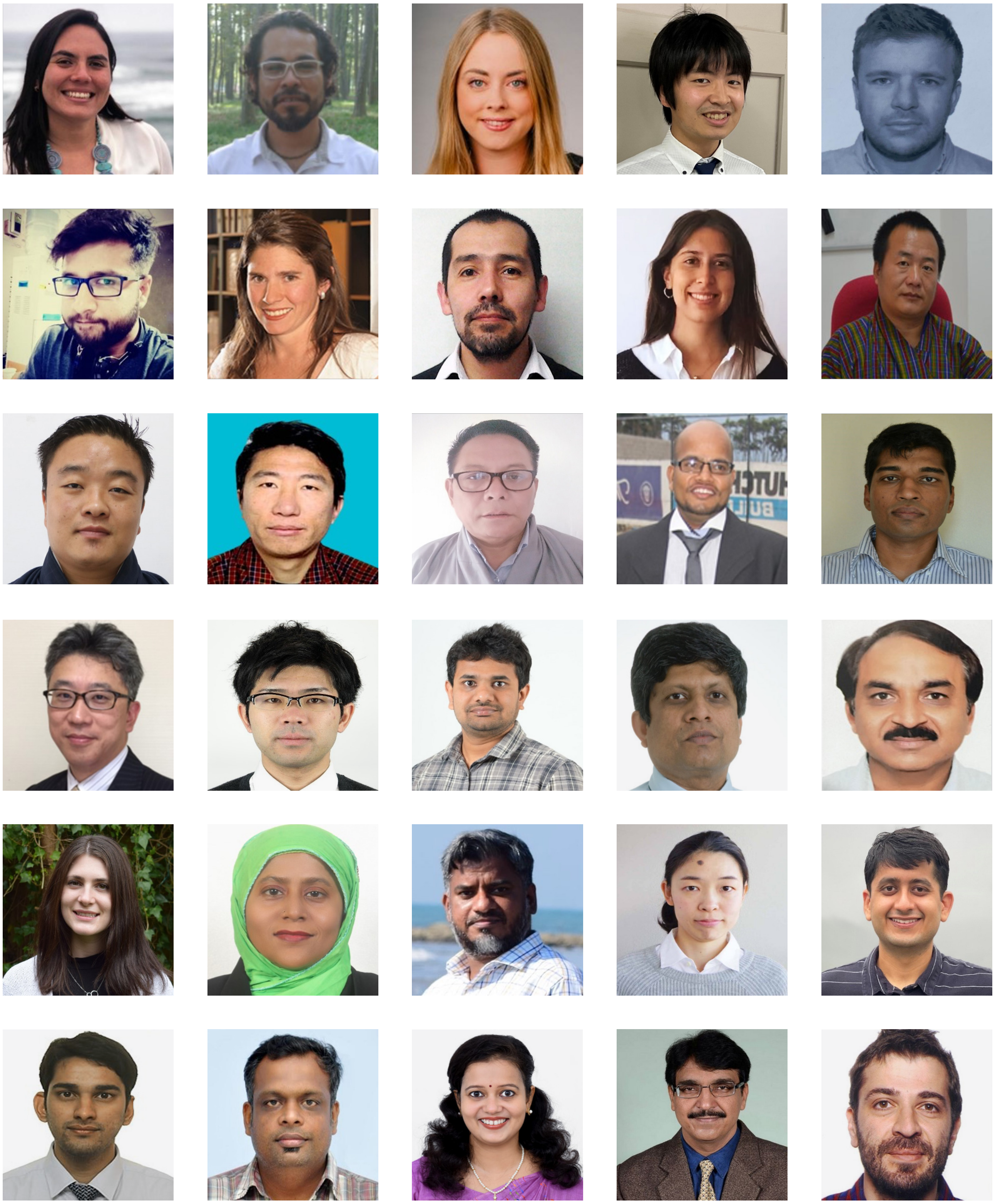
CDRI Fellowship Cohort 2022-23



Introduction

The Coalition for Disaster Resilient Infrastructure (CDRI) recognizes the need to invest in youth as a vital stakeholder group for a better future. The Coalition has designed knowledge initiatives targeting the youth, which foster cutting edge research and innovation towards resilience of infrastructure to climate and disaster risks.

The CDRI Fellowship Programme is one such initiative, launched in September 2020, a 12-month seed grant, providing financial support, peer learning and capacity development opportunities for individuals designing actionable solutions for real-world problems related to infrastructure resilience.

The second Cohort of CDRI Fellows comprises 14 teams from 11 countries, including Australia, Bangladesh, Bhutan, Canada, Chile, India, Japan, Peru, Sri Lanka, the United Kingdom and the United States of America, engaged in a variety of research projects covering diverse hazard conditions under the following themes: early warning & decision support systems; resilience standards; nature-based solutions; risk finance; and health infrastructure resilience. The teams have successfully completed their Fellowship, demonstrating considerable progress in their research projects.

Innovative solutions that have emerged from this Cohort include guidelines for financing resilient rural road networks; water treatment systems; decision support tools to assess structural safety and health of bridges; framework to identify nature-based solutions for infrastructure resilience; and early warning system for collapses in road infrastructure.

This publication is a compilation of Project Abstracts of Cohort 2022-23 of the CDRI Fellowship Programme. For more details on these projects and the CDRI Fellowship Programme, visit www.cdri.world/fellowship

Managing and Financing Risk for Resilient Rural Road Networks: Standards Recommendations under a Multi-Hazard Approach

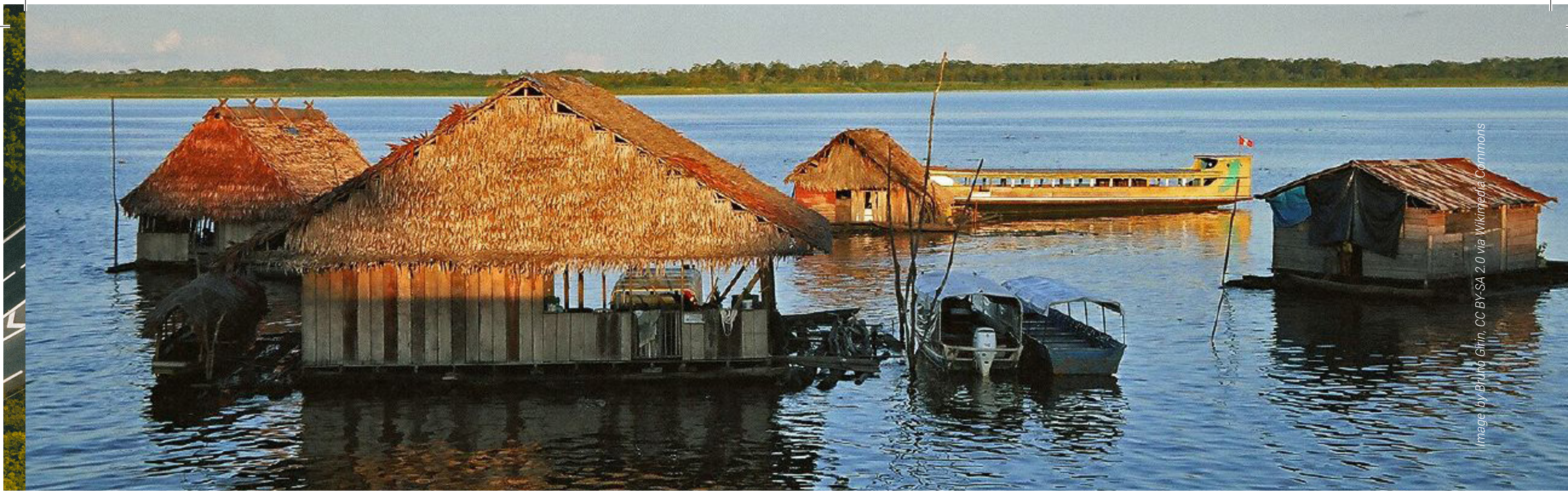
Alondra Chamorro, Tomás Echaveguren and Natalia Nieto
Pontificia Universidad Católica de Chile, Chile

Damages induced by natural events to transportation systems create significant socioeconomic impacts in vulnerable territories such as rural areas. Management and funding of rural roads are commonly centred on economic and technical dimensions under normal operational conditions, where the socioeconomic consequences of natural events are rarely accounted for in decision-making and guidelines. The guidelines proposed in this research are unique and novel, as they suggest a holistic approach where socioeconomic impacts and risk assessment under multi-hazard scenarios are considered for managing and financing risk reduction of rural roads. The methodology is applied to a case study from which guidelines will result.

The research aims to propose holistic resilience guidelines that account for the socioeconomic impacts caused by natural events and financial requirements for resilient rural road networks in vulnerable territories and populations exposed to multiple natural hazards.

First, a diagnosis of current standards for financing and managing the risk of rural roads was developed. Next, a methodology to assess risk considering socioeconomic impacts was proposed. Subsequently, the method was applied to a rural road network in central Chile. Finally, the resilience guidelines and financing recommendations were elaborated. The proposed methodology was applied to a rural road network in central Chile exposed to seismic and hydro-meteorological hazards. The case study considered geographical, social and environmental conditions typical of rural settings with limited accessibility. Based on this application and sensitivity analysis, resilience guidelines were proposed.

The analysis considered the simulation of seismic and hydro-meteorological hazards that have historically caused infrastructure damages and socioeconomic consequences in Chile. Economic losses were estimated regarding travel-time increase and agency costs, and social effects were included using social vulnerability of the exposed population in terms of the Social Vulnerability Index. As a result, the document “Guidelines for Managing Risk of Rural Road Networks” was developed. It consists of practical recommendations for risk management, including on parameters such as scalability, data sources and risk governance, among others.



Water Collection, Storage and Treatment System in Floating Community Space in the Peruvian Amazon

Belen Desmaison and Kleber Arturo Espinoza
Pontificia Universidad Católica del Perú, Peru

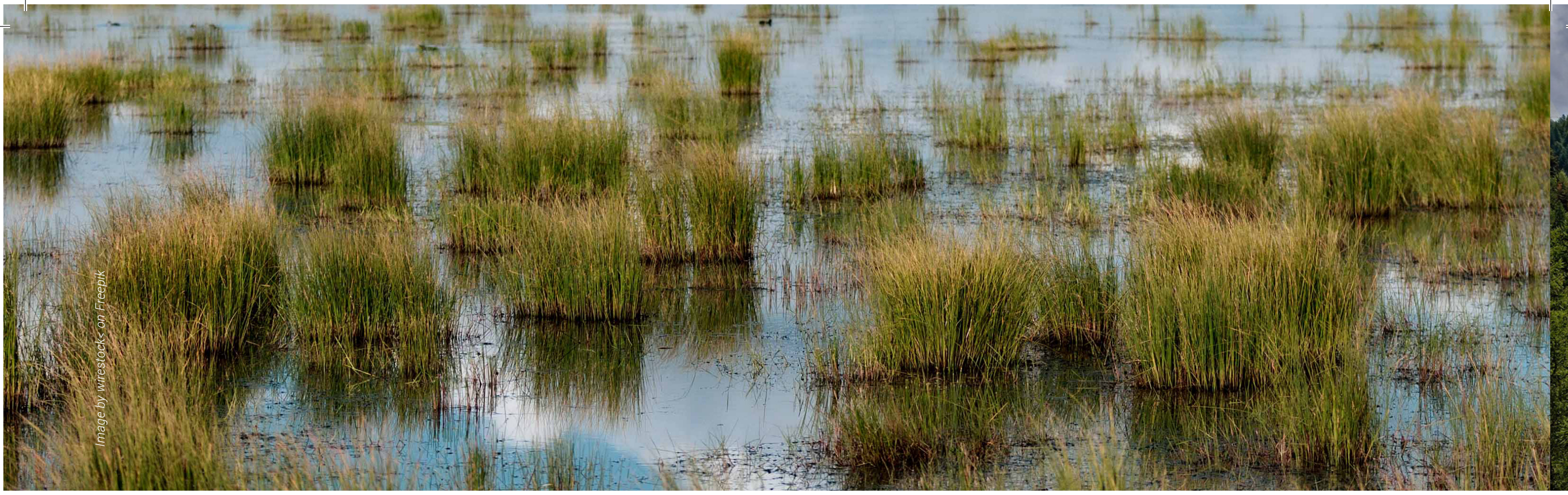
Over 40 percent of the inhabitants of the Amazonian region of Peru do not have access to clean water. In a region with one of the largest sources of fresh water in the world, the population does not have constant access to quality drinking water. The research team works in Iquitos, the capital of Loreto, which is the largest region in Peru. Loreto covers more than 30 percent of the country and records the highest levels of annual precipitation.

The proposal seeks to provide technological alternatives for access to water that do not depend on a conventional network and are designed for easy installation and maintenance. The proposal also integrates water treatment to reduce pollution after usage. The team works closely with the residents in co-production processes, not only in the design and construction of the infrastructure but also in the creation of a management committee for the use of space. The aim is to generate alternative forms of governance for the city and promote more active participation by its inhabitants.

The team previously worked on a system in which the rain is captured by the roof and solar panels are used to provide energy for pumping water. Once used, it goes through a phytodepuration system and a grease trap for cleaning. The water is stored in pipes that can be modulated and adapted to different needs. For the current research project, the team focused on amphibious settlements that are either floating or on stilts and inhabited by 20 percent of the population of Loreto to explore development of infrastructures that deliver water, sanitation and collective spaces in this context.

The replicability of the proposal occurs in two dimensions: the first is the technique since the built system is modular and flexible, so it can be adapted to different situations, spaces and capacities. On the other hand, there is the experience of co-production itself, which integrates technical aspects together with social and cultural ones, generating relevant solutions that reinforce and improve relationships between citizens, local government and the academia.

The project presents the methodology itself as a fundamental aspect to be integrated in the planning and management of the cities of the future.



Constructed Wetlands for Wastewater Treatment Plant Resilience

Cayla Anderson
The University of British Columbia, Canada

The increasing frequency and intensity of extreme storms and flooding events due to climate change threaten traditional wastewater treatment infrastructure capacity. In the North American Pacific Northwest, large flooding events have resulted in untreated and partially treated municipal wastewater bypassing treatment infrastructure and polluting local water bodies. As a result, there is a need to improve the resilience of wastewater treatment infrastructure. Constructed wetlands for wastewater treatment are an attractive addition to traditional wastewater treatment trains as they can provide additional treatment capacity during high-intensity storm and rain events. Vertical flow constructed wetlands have been used successfully to treat shock loads of wastewater from combined sewer overflows.

To further investigate the resilience of vertical flow constructed wetlands against shock loads of partially treated wastewater, nine model wetland columns were constructed in the laboratory that were fed with synthetic, secondary municipal effluent wastewater. Twice over the four-month experimental duration, three columns were subjected to high-intensity flooding events, modelling a one-in-100-year extreme rain event for the city of Vancouver, British Columbia. Under baseline conditions (i.e. not flooding flow rates), the column wetlands operated with an average hydraulic retention time of 2.35 days. During the high-loading simulations, the retention time was decreased to 0.24 ± 0.1 days in the three high-load columns. Under baseline conditions, the wetlands removed 85 ± 14% of the influent ammonia concentration.

All other parameters measured remained relatively constant with no observable removal of other nutrients like phosphates and sulphates. The high-loading events produced no observable effect on pH measurements, dissolved oxygen, electrical conductivity, dissolved organic carbon and phosphates and sulphates measured in the effluent. Ammonia removal efficiency decreased to 78 ± 14% during the high-loading events. However, treatment performance resumed shortly after the shock event.

Results from the study indicate that vertical flow constructed wetlands are resilient to changes in influent-loading due to flooding and high-intensity storm events. Mass removal rates of ammonia based on the column data were calculated per square metre to estimate treatment performance during a high-load event in a larger, full-size system. However, caution is advised when extrapolating data. The vertical flow constructed wetland systems studied are a resilient technology that can potentially improve the resilience of municipal wastewater treatment trains.

Risk Assessment and Hazard Mapping of Bhutan's Power System Infrastructure

Cheku Dorji, Namgay Tenzin and Nima Dukpa
Royal University of Bhutan, Bhutan
Sangay Wangdi
Bhutan Power Corporation

Human endeavours are subject to risks due to unforeseen uncertainties and hazards posed by natural forces, ecosystems and various human and technological hazards. Therefore, effective risk assessment and management are crucial components of any undertaking. This investigative research attempted to assess the impact of climate change on the power infrastructure and networks of the Bhutan Power Corporation, identifying probable hazards and suggesting a framework for risk management through careful planning, preparedness, prevention and mitigation. The methods employed in this research were both qualitative and quantitative and were carried out in phases, each of which built upon findings from precedents.

The first phase involved understanding the historical and current status of the power system infrastructure, networks and operations to establish a foundation for investigative questions. In the second phase, the probing questions generated from the first phase were used to assess risks and potential impacts of hazards in relation to the past and present management processes of the power system. The third phase emphasized evaluating the hazards to Bhutan's power system by using a hazard probability matrix.

The major outcomes of the analysis were: (i) climatic variables, particularly temperature and precipitation, pose potential risks to the power system infrastructure through lightning, flash floods, landslides and windstorms; (ii) Bhutan Power Corporation requires well-defined policy and coherent procedures regarding the operation and maintenance of power systems, which can effectively address hazards and implement prevention and mitigation techniques; (iii) infrastructure such as power stations, transmission lines, towers and substations are vulnerable due to ageing and climate change-exacerbated hazards; (iv) plans and resources are not optimally integrated in the operation and management of the power system; and (v) hazards related to climate change need to be considered to improve the reliability and sustainability of electricity supply.

Ultimately, this research emphasizes the need to develop comprehensive risk management strategies to combat the challenges posed by climate change, upgrade the resilience of power infrastructure, and ensure reliable and sustainable electricity supply.

Real-Time Scour Detection and Prediction for Structural Performance and Safety

Daigo Kawabe, Kyoto University, Japan
Vasilis Sarhosis, University of Leeds, UK

Scour is the localized erosion that undermines bridge foundations during flooding and is considered to be one of the most critical threats for bridges crossing rivers around the world. Nearly 21,000 bridges are reported to be susceptible to have their foundations undermined during extreme storm events. It is particularly difficult to visually determine the scour risk of a bridge over a river, as the condition of the ground beneath the water surface of a pier cannot be directly visualized. Heavy rainfall disasters, especially in recent years due to climate change, have led to the need to address scour risk in more areas.

The study aims to propose a real-time scour depth estimation method through long-term vibration monitoring and eigenvalue analysis of a numerical model of an in-service railway bridge pier as a case study. Many bridge authorities make decisions on the occurrence of scour by using direct measuring methods or indirect methods after a high-flood event has occurred. In particular, the Japanese Railway Company has applied a vibration-based assessment method to identify frequency changes to evaluate the bridge piers' stability. However, it is time-consuming, laborious and inapplicable during swollen river water periods.

Therefore, a remote-sensing system was developed that deploys accelerometers on top of the pier across a river and identifies natural frequency in real time during a swollen river water period. To enhance a fast and easily understandable condition of the pier, this study investigated a way of estimating scour depth in real time using eigenvalue analysis of the Finite Element Model of the pier. To deal with the uncertainty of identified frequency due to signal noise derived from weak signal, a novel sampling method was introduced to model the uncertainty of interaction with soil. A scour depth estimation method was applied to the time series of identified frequencies during the swollen river water period, and the feasibility of the method discussed.

The proposed scour assessment system has high performance but can be expensive; it can be used to assess the safety of bridges easily and inexpensively using smartphones although the accuracy and real time detection would be reduced. Scalability of the proposed tool is high given the generic anomaly detection scheme. The replicability of the solution would depend on sensitivity of the sensors built in smartphones that could identify the vibration characteristics of bridge piers. The alternate solution can benefit developing countries.

Evaluation of Cyclonic Disaster Resilience of Coastal Healthcare Infrastructure in Bangladesh: A Special Comparison with Japan

Gulsan Ara Parvin and Nina Takashino, Ritsumeikan University, Japan
Md Anwarul Abedin, Bangladesh Agricultural University, Bangladesh

Efforts to understand cyclonic disaster resilience of critical infrastructure, especially healthcare infrastructure, are rare in Bangladesh and Japan – the two most cyclone-vulnerable countries in the world. This study evaluates the cyclonic disaster resilience of Bangladesh's coastal healthcare infrastructure through a special comparison with Japan.

An intensive and systematic literature review was done to determine cyclonic disaster resilience evaluation's dimensions, parameters and indicators. Incorporating all these selected dimensions, parameters and indicators, a structured questionnaire was prepared, where a three-point Likert scale (poor, moderate and good) was used to assess the level of resilience of the healthcare infrastructure. Cyclonic disaster resilience was evaluated using the Weighted Mean Index method; the Cyclonic Disaster Resilience Index was developed for five studied healthcare infrastructures. In Bangladesh, three Upazila Health Complexes (UHCs) in the coastal district of Satkhira and in Japan, two coastal hospitals of Miyagi Prefecture were studied.

The Cyclonic Disaster Resilience Index scores indicate that all five healthcare infrastructures have moderate (2 out of 3) levels of cyclonic disaster resilience. However, the resilience levels vary in dimensions and parameters. In the case of Bangladesh, occupational safety of all UHCs has a poor score (ranging from 1 to 1.67) in resilience evaluation, while this is in moderate condition in Japanese hospitals. Debhata UHC of Bangladesh has the highest Cyclonic Disaster Resilience Index score in overall resilience (2.5) and structural resilience (2.7) among the five studied healthcare infrastructures. Conversely, this UHC has relatively low (1.9) resilience in the non-structural dimension.

These outcomes reveal that cyclonic disaster resilience varies in structural and non-structural dimensions and even in different parameters. Therefore, this type of study is essential for precise resilience evaluation of healthcare infrastructure to allow effective budget allocation and action planning for disaster preparedness, risk reduction and, finally, building resilient critical infrastructure to serve during and after disaster.

Development of a Distributed Optical Fibre Sensor Network-Based Condition Monitoring System to Alert Road Collapses

Madhubhashitha Herath, Uva Wellassa University, Sri Lanka
Jayantha Ananda Epaarachchi, University of Southern Queensland, Australia

Road infrastructure is a crucial public asset that contributes to economic development and growth while bringing critical social benefits. It connects communities and businesses and provides access to education, employment, social and health services. Heavy rains, floods and hurricanes cause roads to collapse, resulting in life-threatening catastrophes and road closures. Emergency repair costs are estimated to be ten times that of planned maintenance. Therefore, condition monitoring and preventive maintenance will have significant cost and safety advantages for road infrastructure. The rapid rise in pore water pressure can be adduced as the key root cause of road collapse.

This research introduces a monitoring technique based on distributed optical fibre sensors to facilitate early warning for road infrastructure. Laying subterranean distributed optical fibre sensors along a road offers unique advantages for spatially distributed measurements for hundreds of kilometres. By analyzing the dynamic strains, road conditions can be measured in real time. The evolution of the strain fields can relate to road collapse dynamics with an unprecedented resolution for early warning.

The proposed sensor system is designed in segments to measure the pore water pressure, and vertical and horizontal ground movements. The concept and the mechanical design were developed with the aid of computer simulations and Computer-Aided Design software. Initially, the first version of a pore water pressure sensor array was tested under laboratory conditions to investigate the water pressure-measuring performance by measuring strain readings through an Optical Backscatter Reflectometer. Afterwards, the second version of a pore water pressure sensor array was tested systematically to calibrate and build the relationship between water pressure and strain readings. The third version of the sensor consisted of all three components including the pore water pressure sensor, and vertical and horizontal ground moment-sensing components. The performance of the entire sensor system will be demonstrated in a physical model that has been constructed to date.

It was proven that the proposed sensor has the potential to precisely measure pore water pressure, and it was revealed that the measured strain readings were proportional to the applied hydrostatic pressure. The real-time measurements indicating the combined subterranean conditions of the roads can be obtained frequently from a remote location as the optical fibres can transmit the measured data over long distances. The established system will be introduced to road development authorities for condition monitoring and to alert about road collapses at an early stage. A model combined with water pressure sensing and land properties can be developed in the future to address any developing geohazards in water-prone areas. The developed condition monitoring and early warning system will be proposed for implementation in a high-risk road section in Sri Lanka and Australia.

Resilience of Power Grid Infrastructure with Renewables to Extreme Events in a Changing Climate

Prateek Arora
New York University, USA

Strong hurricane winds damage power grids and cause cascading power failures, resulting in critical service disruption and major economic losses. A resilient power system should minimize the extent of prolonged power disruptions. In this project, two different aspects of enhancing power grid resilience against power disruptions from hurricanes have been presented: (a) predicting the extent of power outages before the arrival of a hurricane to allow utilities to prepare for an emergency response and rapidly recover, and develop a probabilistic method to understand the expected performance of power systems to future hurricanes; and (b) investigating the potential of solar power to sustain electricity supply amid power outages during a hurricane.

Statistical and machine learning models have been proposed to predict the extent of power disruptions due to hurricanes. Existing outage models use inputs including power system information, environmental and demographic parameters. Existing models were developed and validated with data from a few utility companies and regions, limiting the extent of their applicability across geographies and hurricane events. These existing outage models were trained and validated using power outages from multiple regions and hurricanes, including Hurricanes Harvey (2017), Michael (2018) and Isaias (2020), in 1910 US cities.

The project discusses the limited ability of state-of-the-art machine learning models to: (1) make bounded outage predictions; (2) extrapolate predictions to high winds; and (3) account for physics-informed outage uncertainties at low and high winds. The findings suggest that further development is needed for power outage models for the proper representation of hurricane-induced outages. Additionally, utilities must make risk-informed decisions to prioritize their limited resources (e.g. for grid hardening) in cities expected to experience larger and longer hurricane-induced outages.

Flood Disaster Resilient Hydraulic Design of Bridges Exposed to Climate Change

Rakesh Kumar
Sharda University, India

India is expanding its highway and railway networks for better connectivity and to give a boost to its infrastructure facilities and economy. For this purpose, the safe and optimal design of the bridges incorporating the impact of climate change is of primary importance. Inadequate hydraulic design of bridges leads to their failure whereas over-design results in excessive cost of construction.

A comparative study of the conventional approach in practice and the L-moments-based flood frequency analysis has been carried out, and the superiority of the L-moments over the conventional approach has been demonstrated. Based on the |Zidist|-statistic criteria as well as the L-moment ratio diagram, the Generalized Logistic distribution is selected as the suitable frequency distribution for the study area and design floods are estimated using this frequency distribution. The effect of climate change on the design floods and the resulting hydraulic variables of the river reach for the bridge site were simulated using the downscaled projections of climate scenarios and the defined increases in the design floods. Hydraulic modelling for the bridge site was carried out using the design floods for various scenarios to incorporate the impact of climate change in the hydraulic design of the bridge.

The floods of 50 and 100-year recurrence intervals computed by the L-moments method are 16.70 percent and 22.74 percent higher than the conventional method, respectively. The hydraulic modelling of the river reach of about 1.70 km is carried out using the HEC-RAS package for 24 river cross-sections obtained from the topographic survey. Based on the L-moments approach, the simulated water levels at the bridge are estimated to be 255.88 m and 256.40 m for 50-year and 100-year recurrence interval floods, respectively. Flow velocities are estimated to be 3.70 m/s and 3.90 m/s for 50-year and 100-year recurrence interval floods, respectively. The top width and hydraulic depth are also estimated by the hydraulic modelling approach. For 15 percent increase scenarios of 50 and 100-year recurrence intervals, water levels are estimated to be 256.31 m and 256.90 m. For the downscaled climatic projections, the water levels are estimated to be 253.48 m and 255.38 m for 2050 and 2100, respectively.

Taking the results of the various scenarios into consideration, the project authorities may make appropriate decisions for flood-resilient design and construction of the bridge. The methodology developed in the study will serve as a guideline/manual for the organizations involved in planning, designing and constructing bridges for their optimal hydraulic design. The departments involved in the construction of highway, railway and other bridges may apply this methodology for the construction of flood-resilient bridges exposed to climate change.

Nature-Based Solutions for Resilient Infrastructure Systems

Robyn Alison Haggis
University of Oxford, UK

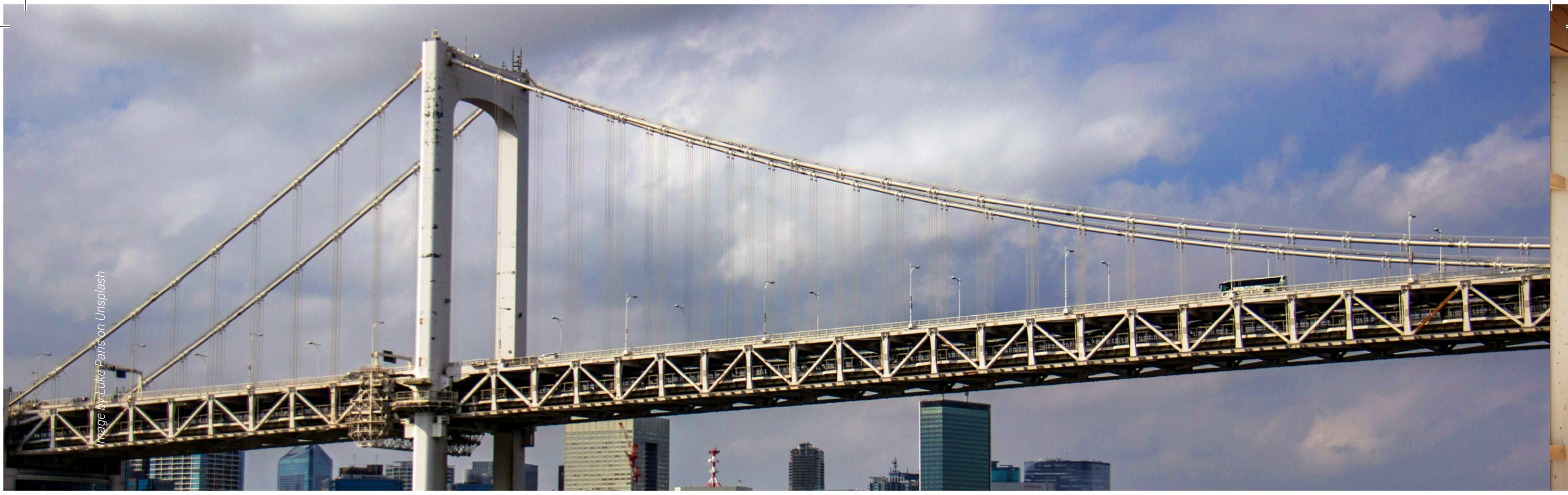
Climate change hazards, such as floods, droughts and landslides, threaten infrastructure systems and the services they provide. There is a need to increase the resilience of existing infrastructure systems and embed resilience into the design of new infrastructure. Traditionally, decision-makers have focused on built infrastructure options for providing services, including adaptation. However, there is increasing recognition that nature-based solutions (NbS) can provide services relevant to infrastructure, including increased resilience to climate change.

The project aims to support the scale-up of NbS in decision-making for infrastructure resilience, focusing on the energy, transport and water sectors. Three outputs are developed through the Fellowship: (1) a conceptual framework to identify which NbS options can increase the resilience of different infrastructure sectors to a range of climate change-driven hazards; (2) a database of key metrics for evaluating the costs and benefits of different NbS options, created from an extensive literature review of academic and policy documents; and (3) a pilot interactive decision-making tool which decision-makers can use to identify and evaluate relevant NbS options to increase the resilience of their chosen sector to their relevant climate hazards, populated with data from existing studies.

Through the project, numerous data gaps relating to NbS were identified, including effectiveness of service provision, monitoring and maintenance costs. Key informant interviews suggest that the data gaps result from factors including a lack of funding for monitoring, a lack of technical and human capacity, and reporting requirements of funders. These gaps pose a challenge to the comparison of NbS options in infrastructure decisions and scaling the uptake of NbS through infrastructure planning and investments.

As part of the Fellowship, the pilot decision-making tool is applied to the case study of Jamaica to identify NbS options for increasing the resilience of road transport infrastructure to two fluvial (river) flooding scenarios: one of 2 m flood depth and another of 1.3 m flood depth. The results show that NbS may have greater requirements in terms of space and time than built infrastructure but can help to reduce economic damages from climate impacts, potentially reducing requirements for built adaptation infrastructure. At the same time, they can lead to multiple additional benefits for policy agendas such as the Paris Agreement, Sustainable Development Goals and the Convention on Biological Diversity.

NbS should be considered part of standard practice in infrastructure decisions to maximize their broad potential benefits. The outputs developed through this Fellowship provide a starting point for identifying NbS options, assessing the various costs and benefits, and defining the key metrics which should be reported upon to inform robust decision-making.



Framework for Evaluating Bridge Network Resilience by Considering Socio-Technical Attributes

Rubel Das, Masaaki Nakano and Tetsuro Goda
Nippon Koei Co Ltd, Research and Development Centre, Japan

Transportation bridges are the weakest element among all the components of the transportation infrastructure system. Recent experiences with natural and man-made water-related disasters indicate that the current transportation systems cannot protect and prevent all disruptive events. The focus is gradually shifting from critical infrastructure protection to critical infrastructure resilience because the former does not address all the aspects of securing a country's critical infrastructure.

In this study, structural properties are considered explicitly while the interdependency of bridges is being analyzed. The failure of one bridge may not significantly influence the network-level performance. Other bridges will have users. However, the disruption of another bridge may produce a substantial hindrance. In that case, a collapsed bridge's frequent users have no alternatives to reach their destination. Therefore, it is necessary to evaluate the interdependency and importance of each network section. Certain destinations can be reached via multiple routes, whereas others have only one route.

Therefore, this study assesses resilience through a network-level analysis. Structural and traffic factors were combined into a single framework by utilizing structural assessment for each bridge and the operational performance of transportation networks. The concepts presented were applied to a real transportation network in Yamaguchi, Japan, to illustrate the mathematical procedures. The proposed method is based on the concept of 4R (robustness, redundancy, rapidity and resourcefulness). In this study, the location data for Yamaguchi city was used, which contains many transportation bridges. A return period of 475 years is utilized to estimate the bridge damage levels. The damage level of bridges owing to earthquakes can be estimated using the flowchart proposed by Kobayashi and Unjoh (2005). According to that study, the condition of bridges can be categorized into three damage levels. The result for a return period of 475 years has two bridges with damage level "A," 17 bridges with damage level "B," and eight bridges with damage level "C". Meanwhile, the result for a return period of 2,475 years has six bridges with damage level "A," 14 bridges with damage level "B," and seven bridges with damage level "C".

For the project, the bridge with the largest number of users was selected, thus reducing the travel cost. Here, three restoration strategies were analyzed: (1) road-user priority scenario; (2) road-type priority scenario; and (3) damage-type priority strategy. In scenario 1, the average speed after the restoration of bridges increased. The average speed for scenario 2 on the 10th day was higher than that for the other periods. The average speeds on the fifth and 15th days were lower than in the base case. Without a variation in scenario 3, the average speed after the restoration of bridges was higher than the base level, except on the 30th day.

The findings reveal that scenario 1 has the lowest area above the resilience curve. Although the areas above the curves for scenarios 2 and 3 are significantly close, for scenario 3, they are the largest. Based on the area, the pre-disaster user-based scenario (scenario 1) produced a more resilient system. Based on the above results, pre-disaster maintenance results in less severe damage and post-disaster recovery becomes faster. Thus, it can result in a trade-off between pre- and post-disaster costs.

Robust Approach to Assessing Post-Fire Structural Behaviour of High-Rise Mass Timber Buildings

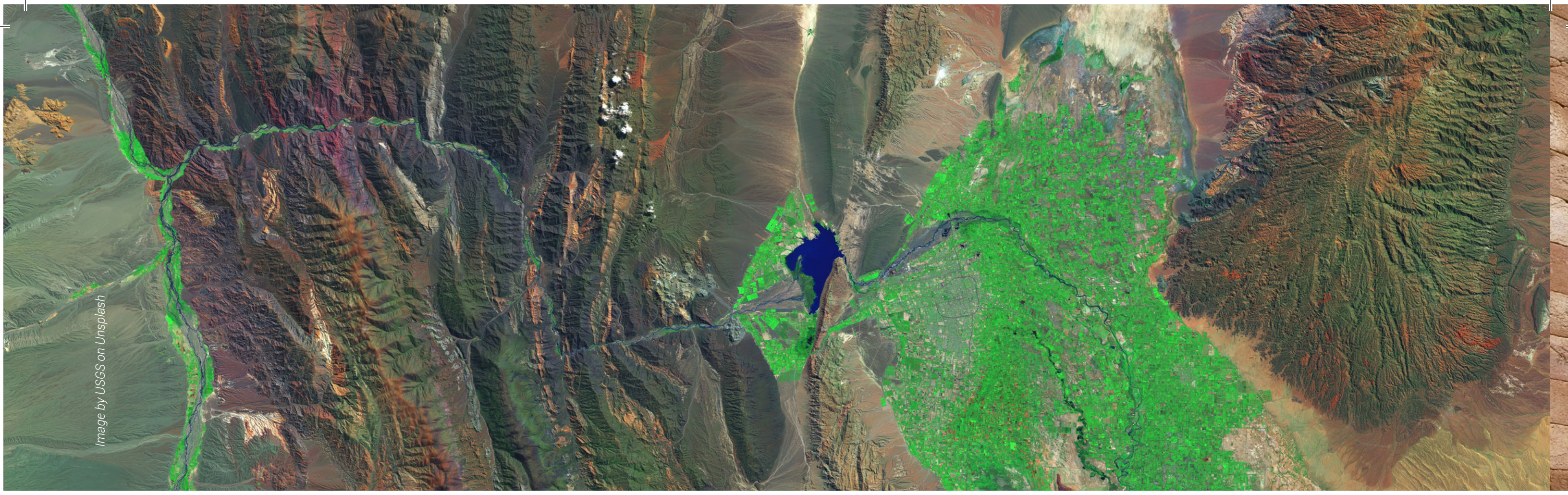
Satheeskumar Navaratnam
RMIT University, Australia

Mass timber buildings offer a competitive and innovative sustainable construction alternative to steel-framed and concrete buildings. This robust approach to mid-rise construction offers a number of environmental benefits such as reducing embodied carbon impacts and construction waste. However, there has been a significant barrier preventing the implementation of mass timber buildings including concerns over structural fire performance and tighter legislation on the fire design of buildings induced by the Lacrosse fire in Melbourne.

This project aims to understand the fire reaction, post-fire performance and collapse mechanisms of floor panels (cross-laminated timber) and mass timber buildings. The fire performance of cross-laminated timber depends significantly on the strength and behaviour of the adhesive. At elevated temperatures, the adhesives could fail and create severe delamination due to changes in the moisture content and thermal degradation.

Therefore, this study conducted several experimental and numerical model analyses to evaluate the fire performance of adhesive bond strength and compressive strength of cross-laminated timber at elevated temperatures and proposed advanced modified adhesive to improve the fire performance. Next, this study developed a numerical model for a 10-story mass timber building subjected to localized fire.

Results showed that the fire performance of cross-laminated timber and mass timber buildings could be improved when the floor panel is made with the proposed modified fireproof adhesive. Further, the proposed finite element and analytical models can be used to predict engineered timber's post-fire residual strength. However, further experimental tests are needed to ensure the capability of modified fireproof adhesives to improve the robustness of mass timber buildings.



Financial Decision Framework for Infrastructures Based on Disaster Damage Rating Models for Financial Decisions Using Machine Learning Approaches

Saurabh Gupta
Indian Institute of Technology Kanpur, India

Disaster damage assessment plays a vital role in understanding the extent of destruction caused by a catastrophe and in making informed financial decisions. Traditionally, this assessment has been a manual and time-consuming process. However, this study focuses on automating the process using remote-sensing technologies and advanced computational methods to facilitate efficient and timely damage assessment. Additionally, this study highlights the significance of this work in supporting finance framework decisions. Automating the damage assessment process eliminates the need for manual data collection and analysis, saving valuable time and resources. Real-time damage assessment becomes possible, providing up-to-date information on the scale and severity of the disaster. This timeliness is crucial for making finance framework decisions, as it allows policymakers and financial institutions to quickly assess the financial implications of the disaster and allocate resources accordingly.

The approach in this study for disaster damage assessment uses a segmentation model capable of classifying and localizing different levels of damage, namely, "destroyed," "major damage," "minor damage" and "no damage". The first task of the study involved building a localization model to accurately identify the regions within a satellite image that were affected by the disaster. A model capable of precisely delineating the boundaries of damaged areas is developed by leveraging advanced computer vision techniques. This localization step provides essential information for subsequent damage assessment and aids in targeted relief efforts. The second task focused on the actual assessment of the damage levels. A multi-class segmentation model that could classify the affected regions into one of the four predefined categories — "destroyed," "major damage," "minor damage" or "no damage" — is employed. This classification enables decision-makers and disaster response teams to prioritize their efforts, allocate resources effectively and plan appropriate recovery strategies.

Different segmentation models and backbones were trained and experimented with as combinations on a large dataset of annotated disaster imagery. The dataset included various types of disasters and encompassed various damage scenarios. State-of-the-art deep learning techniques and architectures were leveraged to ensure the model can generalize and handle real-world disaster scenarios effectively. The experimental results demonstrate the approach's effectiveness in accurately localizing and assessing disaster damage.

Overall, the research contributes to disaster management by providing an automated and efficient method for damage assessment. Combining localization and multi-class segmentation techniques enables rapid and accurate identification of affected regions and detailed evaluation of damage severity. This information can aid decision-making processes, facilitate targeted resource allocation and ultimately expedite recovery in the aftermath of disasters.

Machine Learning-Based Unified Seismic Vulnerability Prediction Model for Heritage Minarets of India

Vinay Shimpi, Madappa VR Sivasubramanian and Nidhi M, National Institute of Technology, Puducherry, India
Shamsher Bahadur Singh, Birla Institute of Technology and Science, Pilani, India
Nikolaos Nikitas, University of Leeds, UK

Preservation of architectural heritage plays a critical role in safeguarding historical structures, particularly in countries like India. Masonry minarets in India, such as the Qutub Minar, Hiran Minar and Char Minar, have been designated as UNESCO World Heritage sites. However, these iconic minarets have experienced significant deterioration due to past earthquakes and other natural calamities. The structural stability of minaret structures depends on various factors, including their construction methods, structural information and seismicity of the region. The uneven shape and mass distribution of these structures along their heights increase their susceptibility to damage from earthquakes. Despite their historical importance, many monumental structures, including minarets, were constructed without considering horizontal actions such as those induced by earthquakes. While heritage structures are vital for attracting tourists and contributing to the economy, their preservation necessitates strict controls and maintenance efforts to ensure their safety and conservation.

This study introduces a novel machine learning-based approach for predicting the seismic vulnerability of heritage minarets in India. The methodology employs vibration-based structural condition assessment to identify dynamic properties such as natural frequencies and curvature mode shapes. A three-dimensional numerical model of the minarets is developed using finite element analysis software, incorporating nonlinear material and geometric behaviour. To ensure the accuracy of the proposed modelling techniques, the dynamic characteristics of real minaret structures are compared with their corresponding numerical models. Material and boundary stiffness parameters are adjusted to match numerical dynamic parameters with experimental response. Nonlinear dynamic analysis is performed using various ground motions with Peak Ground Acceleration ranging from 0.10g to 0.30g. A vulnerability assessment method is established to identify the vulnerability of the structure, and these results are used as input data for the development of a prediction model using a random forest algorithm. The data collected from several nonlinear dynamic analyses is split into two subsets: a training set for building the prediction model and a test set for assessing its performance.

The results show that the random forest model is effective in evaluating the seismic vulnerability of masonry minarets and can be relied upon for future predictions. The developed methodology and prediction model can be applied to evaluate the seismic safety of existing minarets and inform decisions on retrofitting or preservation measures. This approach has the potential to contribute to the preservation of cultural heritage in India by providing a tool for assessing and mitigating seismic risks to historical structures, with potential applications for other structures.

Coalition for Disaster Resilient Infrastructure

4th & 5th Floor, Bharatiya Kala Kendra, 1, Copernicus Marg, New Delhi 110001, India | +91 11 40445999 | www.cdri.world
info@cdri.world @cdri_world @coalition-for-disaster-resilient-infrastructure @cdri.world