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Ideas, perspectives, case studies
in the application of latest technological and
engineering practices in an urban landscape

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CONTENTS

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Editor's Note

The increasing rate of urbanization and our ever expanding cities have caused our communities, knowledge think-tanks, government institutions, and multilateral agencies to have a renewed focus on our cities and its infrastructure to be sustainable and resilient. Infrastructure is essential in powering businesses, generating innovative economic opportunities, as well as addressing economic and social cohesion in a city. Besides this, the tools and technologies that are applied for infrastructure development have profound effect on addressing the factors associated with environmental and economic sustainability.

Through this issue we have brought together ideas, perspectives, and case studies from authors actively involved in applying latest technological and engineering practices in an urban landscape, as well as application of innovative ways of enhancing the skill set of professionals involved in urban infrastructure projects. As you will read through this issue you will find reliable technologies that the authors have shared specific to the application in micro level assessment of conditions of buildings as well as macro level monitoring and assessment of damage and reconstruction of buildings and infrastructure in the city level. Also, the authors have addressed ways through which culture of innovation and creativity could be nurtured as a soft skill among the engineering professionals. Insights in understanding complex urban systems and community awareness systems in order to have a resilient urban environment, climate change adaptation measures for sustainable and resilient urban infrastructure, and non-engineering green infrastructural solution for sustainability of our water resources are some of the topics that have been covered in this issue.

I am thankful to all authors for sharing their knowledge and experience, as well as our editorial team for their efforts in editing and designing this issue.

This magazine is a knowledge product of AIT Solutions and a professional communication platform for experts and researchers and a window to its readers to the technologies, events, and developments.

We welcome your valuable feedback and opinions.

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Satellite-based Damage Assessment and Reconstruction Monitoring after the 2018 Earthquake and Tsunami in Central Sulawesi, Indonesia

Manzul K. Hazarika and Syams Nashrrullah

The Geoinformatics Center of the Asian Institute of Technology (GIC-AIT) and the Remote Sensing Technology Center (RESTEC) of Japan, with the support from the INDRA SISTEMAS S.A. and the Planetek Italia, have been conducting damage assessment and reconstruction monitoring using satellite data to provide information on ground movements, building stability, reconstruction status, and other information needed to support the post-earthquake reconstruction activities.

Satellite-based Damage Assessment and Reconstruction Monitoring after the 2018 Earthquake and Tsunami in Central Sulawesi, Indonesia

A magnitude of 7.5 earthquake struck the Central Sulawesi Province of Indonesia on 28 September 2018, triggering a tsunami of 3-meter-height, widespread landslides, and staggering liquefaction. This devastating event resulted in a loss of human lives, destruction of buildings, and severe damage to the public infrastructures. Palu city and its surrounding areas were the worst affected areas, including Donggala and Sigi regencies. To support the Government of Indonesia in the post-disaster recovery, rehabilitation, and reconstruction in Central Sulawesi, the Asian Development Bank (ADB) is implementing an Emergency Assistance for Rehabilitation and Reconstruction (EARR) project with a grant from the Japan Fund for Poverty Reduction (JFPR). Under this project, the Geoinformatics Center of the Asian Institute of Technology (GIC-AIT) and the Remote Sensing Technology Center (RESTEC) of Japan, with the support from the INDRA SISTEMAS S.A. and the Planetek Italia, have been conducting damage assessment and reconstruction monitoring using satellite data, to provide information on ground movements, building stability, reconstruction status, and other information needed to support the post-earthquake reconstruction activities.

We utilized both optical and radar satellite remote sensing data, employing visual image interpretation as well as advanced data processing techniques. All the outputs are available in a Geoportal developed according to the Open Geospatial Consortium (OGC) standards.

Ground motion and building stability using Synthetic Aperture Radar (SAR)

With its all-weather, all-day, and cloud-free operational capabilities, Synthetic Aperture Radar (SAR) has been increasingly used for wide area monitoring of disaster situations. The conventional Interferometric SAR (InSAR) and Differential Interferometric SAR (DInSAR) techniques can extract topographic information and detect possible ground surface movements in millimetric accuracy by measuring the changes of signal phase between two SAR images acquired over the same area at different time. The technological breakthrough in cloud computing and big data analytics led to the development of Multi-temporal InSAR (MTI) techniques in which a large number of SAR images from multiple acquisitions are taken overtime to estimate the ground motion through the time-

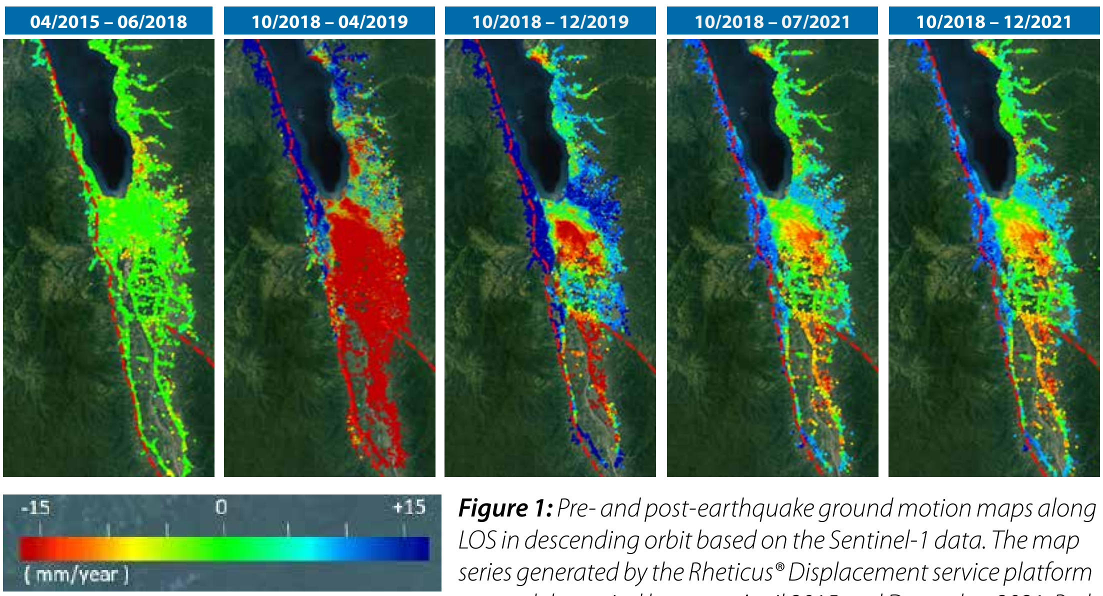

Figure 1: *Pre- and post-earthquake ground motion maps along LOS in descending orbit based on the Sentinel-1 data. The map series generated by the Rheticus® Displacement service platform covered the period between April 2015 and December 2021. Red dash-line is the Palu-Koro fault line.*

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Figure 2: *Building stability map based on the ground motion measurements that covered the period between October 2018 and December 2021. Red dash-line is the Palu-Koro fault line. Black dash-outline polygon is the liquefaction area (Balaroa).*

series displacement provided for each measured target. The MTI approach enables the study of temporarily extended and varying phenomena on the earth's surface while improving interferometric performance and measurement accuracy. Over the decade, numerous MTI processing techniques have been proposed, which can be grouped based on the type of measurement target: Persistent Scatterers (PS) approach, Distributed Scatterers (DS) approach, and the combination of both targets (hybrid approach). The PS approach, such as the popular Persistent Scatterer Interferometry (PSI) technique, utilizes strong, stable point-like scatterers over a long-time sequence and is often associated with man-made structures (buildings) in the urban area. Meanwhile, the DS approach, such as the Small Baseline Subset (SBAS) technique, utilizes distributed targets that often occur in natural environments (agriculture fields, grassland, bare soil). The hybrid approach combines the best of both worlds by maintaining the high measurement quality and density at full resolution from the PS approach and the possibility to identify unstable areas in low vegetated areas critically close to the structure of interest from the DS approach.

We used the time-series of the Sentinel-1 dataset, the C-band SAR satellite imaging that is freely available from the European Space Agency (ESA) through the framework of the Copernicus program. The period between April 2015 – June 2018 (pre-earthquake) and October 2018 – December 2021 (post-earthquake) have been processed using the cloud-based processing services Geohazard Exploitation Platform (GEP) and Rheticus® Displacement service platforms.

The GEP allows the processing of the time-series of Sentinel-1 data using the PSI and SBAS techniques, while the Rheticus® Displacement implements an automatic processing chain based on the hybrid MTI technique called SPINUA (Stable Point Interferometry even in Un-urbanized Areas). Figure 1 shows the ground motion maps along the sensor direction, i.e., Line of Sight (LOS) in descending orbit, which depicts the movement of the earth's surface observed in Central Sulawesi over the time. The maps reveal the general stability of the area before the earthquake, then became very unstable a few months after the earthquake. One year after, the ground motion decreased and continued till the last observed data acquired in December 2021. However, some areas still remain unstable, especially along the Palu-Koro fault line with an average velocity of about 1.5 cm/year with respect to the satellite LOS over the entire period.

The building stability analysis was performed using the Rheticus® Building Check service, which provides the level of concern of each monitored building based on the parameters extracted from the ground motion map and combined with the building footprints dataset. The Rheticus® Building Check classifies the buildings into three motion classes (Red: High Motion, Yellow: Medium Motion, Green: Low Motion) according to the normalized building motion score, called "Inspection Priority Score" [min: 0 – max:1], that is provided for each building. Based on Figure 2, the buildings characterized by the highest inspection priority are located on the western part along the fault line and close to the area affected by the liquefaction.

Damage assessment and reconstruction monitoring using Very High Resolution (VHR) Optical Data

VHR optical data are widely used for providing a quick review of the status of buildings and other physical assets when a disaster strikes, including monitoring the post-disaster damage and reconstruction status. The most common approach for damage assessment and reconstruction monitoring using remote sensing data is the visual interpretation of VHR optical images. The identification of the object condition is based on changes in spectral characteristics (textures, tones) and object shapes. In the case of buildings, other indications are roof condition (intact or not intact) and the presence or absence of debris

Figure 3: *Building reconstruction map, based on the interpretation of Pléiades image in March/April 2021. Red dash-line is the Palu-Koro fault line.*

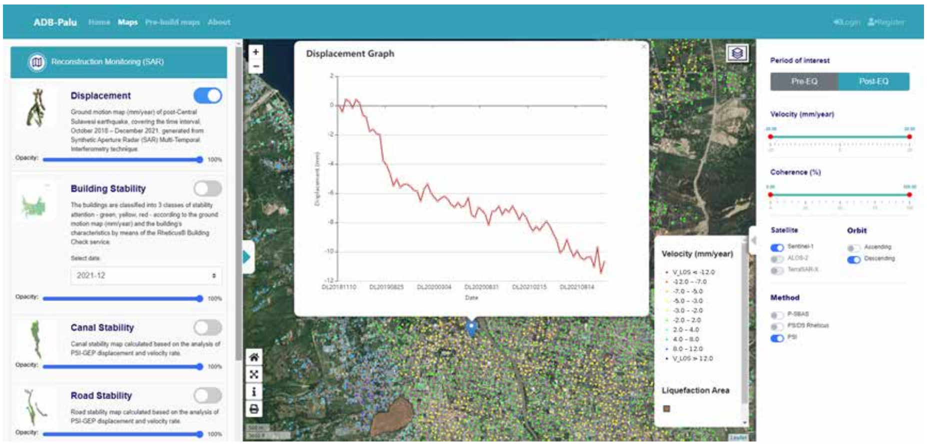

Figure 4: *User interface of the Project Geoportal, with available functionalities such as data layer selection, data filtering, map legend, time-series graph, etc. The map shows an overlaid of ground motion layer with a time-series displacement graph, liquefaction area, and building reconstruction layer.*

close to building walls. Wall condition should also be considered; however, the state of the façade of buildings in most cases cannot be distinguished because of the typical nadir-looking optical sensors.

We mainly assessed the damaged and reconstruction status of buildings and irrigation canal. Damage assessments for buildings and other infrastructures such as roads and bridges were done by the Copernicus Emergency Management Service Mapping and the International Charter Space and Major Disasters . Both of these international initiatives provide free satellite data and value-added products for an emergency response to a major disaster. We used the datasets as a baseline and continued the assessment to monitor the current reconstruction status using the 0.5cm resolution of Pléiades image in March/April 2021 (Figure 3). The analysis shows that the number of damaged buildings has significantly decreased, with only 3% of buildings remaining damaged thirty months after the earthquake event. Furthermore, more than twelve-thousand buildings have been constructed, of which a significant proportion of them contributed to the reconstruction efforts by the Government. Other than buildings, we also found that more than 50% of irrigation structures and canals of Gumbasa were damaged and destroyed based on the analysis using the combination of 0.31-0.46m resolution of WorldView-2/-3/-4 images in October 2018.

Project Geoportal

The Project Geoportal is developed as a user-friendly and interactive online platform to support the reconstruction monitoring activities and visualize the output of SAR and optical data processing. The output and maps are published through the platform, allowing the user(s) to display map layers individually or cascaded over another and view information according to their needs (Figure 4). The Geoportal can be accessed by the public and stakeholders with specific access levels specified by the system administrator.

The Project Geoportal is live and can be accessed here: https://pgeo.ait.ac.th/

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Climate Change Adaptation and Costing for Urban Infrastructure Development

Vilas Nitivattananon, Pyae Mon Naing, and Choen Krainara

The transport infrastructure and operations are seriously threatened and challenged by the existing variability in climate. It is imperative to implement climate change adaptive infrastructures in transportation sector, though adapting to more climate friendly infrastructure is neither cheap nor easy.

Climate Change Adaptation and Costing for Urban Infrastructure Development

The Intergovernmental Panel on Climate Change (IPCC)'s sixth assessment report (2021) clearly stated that humans have been the main cause of climate change, triggering many climatic extremes in all parts of the globe. Extreme climatic conditions caused by the results of human actions include heat waves, heavy precipitation, droughts, glaciers melting, and storms. Future global surface temperature will still be on the rise, exceeding the temperature rise of 1.5°C to 2°C during the 21st century until unless extreme actions are taken to reduce the carbon and Green House Gas (GHG) emissions. A comprehensive definition of infrastructure includes both traditional types of infrastructure (everything from energy to public transport, buildings, water supply and sanitation) and, critically, also natural infrastructure (such as forest landscapes, wetlands and watershed protection). Sustainability means ensuring that the infrastructure we build is compatible with social and environmental goals, for instance by limiting air and water pollution, promoting resource efficiency and integrated urban development and ensuring access to zero-or low-carbon energy and mobility services for all. It also includes infrastructure that supports the conservation and sustainable use of natural resources and contributes to enhanced livelihoods and social wellbeing.

According to The Global Commission on the Economy and Climate (2016), the world is expected to invest around US$90 trillion in infrastructure over the Years 2016-2030, more than is in place in our entire current stock today. These investments are needed to replace aging infrastructure in advanced economies and to accommodate higher growth and structural change in emerging market and developing countries. This will require a significant increase globally, from the estimated US$3.4 trillion per year currently invested in infrastructure to about US$6 trillion per year. The transport infrastructure and operations are seriously threatened and challenged by the existing variability in climate. Scholars have proposed adaptation measures and strategies to tackle the climate risks on ports, railways and roads, and applied them to different geographical locations and regions (Ng et al., 2018 and Wang et al., 2018). It is, therefore, imperative to implement climate change adaptive infrastructures in transportation sector. However, adapting to more climate friendly infrastructure is neither cheap nor easy. Adaptation costs by 2050 are likely to reach US$ 300 billion. Dollar per year, even with emission cuts with a smaller chance of US$ 500 billion per year. With no cuts, adaptation costs could be double these figures (UNEP, 2014).

In developing countries, improved road planning, maintenance and investment will manifest itself in improved access to social services and a more robust infrastructure, which both serve to increase community resilience to general development challenges and emerging issues such as climate change (Schweikert et al.,2014). The risks of climate change to roads threaten the associated economic growth, development, and social welfare benefits of infrastructure expansion. In most developing countries, there is a lack of information for estimating the cost incurred by climate change impacts. For example, the road infrastructure development process–planning, designing, construction, operation, and maintenance–is usually done through conventional methods by the government ministries. On a nationwide scale, there is also a lack of standard adaptation costing applicable for both public and private sectors. This has caused discomfort for decision-makers for making allocations the budget and making suitable adaptation measures. Therefore, there is a need for improved understanding of for climate adaptation and costing for urban infrastructure development where there are densely developed while incorporating the damages and losses caused by flood and other climate hazards.

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It is also important to quantify hazards and exposure because the costs are very much controlled by the spatial distribution, frequency, magnitude, and intensity of the hazard and the number of affected objects.

Role of Infrastructure in Urban Development

There are no uniform definitions of urban infrastructures. According to UNESCAP (2007), infrastructure is normally viewed as the physical assets that are defined as "fundamental facilities and systems serving country, city, or area, as transportation and communication systems, power plants, and schools". However, the non-physical aspects of infrastructure including management also play major role in achieving sustainability. Infrastructure can also be defined as hard utilities and the material networks that underpin their provision (Fay et al., 2011). It can further be connoted as people, practices, discourses, and imaginaries that shape urban services. Likewise, it can be determined as the term for the basic physical systems of a business or nation transportation, communication, sewage, water and electric systems. Infrastructure sector consists of power, roads, energy and urban infrastructures.

With the increasing population and urbanization rate, the role of infrastructure increases along with its complexity. Infrastructure plays an important role in economic development, reduction in poverty rate, improvement in environmental conditions, and urban growth. Infrastructures serve as an input into private sector production, hence improving output and productivity. They are the enabling tools for simulating development of the sustainable human settlements in the urban areas. However, the growth of infrastructure has negative impacts. They can cause the government high economic responsibilities for the maintenance and care. Once the economic life span of the infrastructure has ended, there are still expenses. When new buildings are built, they can cause damage to the existing infrastructures such as roads and sidewalks. In order to reduce the damages caused on the existing infrastructures, infrastructure corporations have to make excavations, causing extra charges (Turgut, 2016).

Urban Infrastructure in the Context of Climate Change in Developing Countries

Urban infrastructure is quite associated with development and climate change, especially in developing countries. For example, roads are the heart of the economic development with high expenditures of a country. Poorly designed roads, and lack of roads and highways can cause an increase in transportation cost and time to reach to the destination place. This has several cascading impacts on the education, health, social impact, and economic development. Despite being important in daily lives, road infrastructures are facing serious impacts from climate change. Increase in temperature has resulted in pavement deterioration which is caused by the liquidation of bitumen. Increased intensity of rainfall leads to floods which affect the drainage system, road pavements, and driving conditions and visibility. Furthermore, it causes damage to bridge and culverts foundation due to scouring. Heavy rainfall can also cause landslides and mudslides which can cause road and traffic blockages. Sea level rise can contribute to realignment of roads or in the worst-case scenario–abandonment of the roads. Figure 1 provides an example of losses and damages on road due to flooding in Cambodia in 2020.

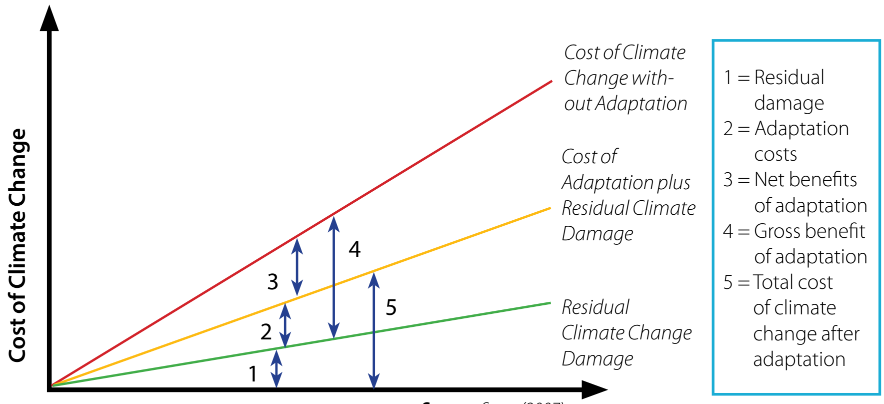
Figure 1: *Losses and damages on road due to flooding in Cambodia in 2020*

Economic Analysis of Climate Change Adaptation on Urban Infrastructures

Costing of Climate Change Impacts and Responses

The costing of climate change adaptation consists of two steps. Before climate change risks can be valued, they must first be identified and measured. Only once they have been quantified it is possible to determine their relative economic importance by expressing them in the monetary term. The identification and measurement of quantification of risks is therefore a prerequisite for their valuation. When conducting climate risk assessment and implementing the climate change adaptation plans, it is important to take the costing from the aspects of economy, societal, and environment. It is also important to quantify hazards and exposure because the costs are very much controlled by the spatial distribution, frequency, magnitude, and intensity of the hazard and the number of affected objects. In particular, quantifying the inputs of risk assessment allows the risk to be quantified and comparable to the risks in other regions (Clarke et al., 2018).

There are also the costs of climate change, as shown in Figure 2. The residual climate change damage is the unavoidable damage that results from climate change. No matter how much adaptation measures are taken, there will be residual damage. When adaptation measure is taken to combat climate change, the cost of climate change will be higher than just the cost of residual damage. However, if there is no adaptation measure taken, the cost of climate change will be the highest because there are no adaptation options to combat the changing climate and the loss and damage will occur every time the hazard happens. The total cost of climate change after adaptation is the combination of residual climate change damage and the cost of adaptation measure. The gross benefit of adaptation is the damage avoided. The net benefit of adaptation is the damage avoided with less the cost of adaptation.



Source: Stern (2007).

Figure 2: *Costs of Climate Change*

Different Methods and Tools of Economic Analysis

There are no explicit rules for choosing the economic tools as each method and tool have its own strengths and weaknesses. Figure 3 summarizes the main groups of methods in adaptation economics ranging from traditional economic decision support, uncertainty framing, and economic decision making under uncertainty with corresponding approaches, potential uses, strengths, challenges and dealing with uncertainty.

	Approach	Summary	Potential use	Strengths	Challenges	Dealing with Uncertainty
Traditional Economic Decision Support	Cost-benefit analysis	Values all costs and benefits to society for all options, and estimates the net benefits/costs in monetary options	To identity low and no-regret options in the near future. As a decision support tool within Iterative climate risk management	Most of useful when climate risk probabilities are known and sensitivity is small. Also where clear market values can be used.	valuation of non-market sectors/non-technical options. Uncertainty limited to probabilistic risks/sensitivity testing	Does not explicitly deal with uncertainty, but can be combined with sensitivity testing and probabilistic modeling
Traditional Economic Decision Support	Cost-effectiveness analysis	Compares cost against effectiveness (monetary/non monetary) to rank, then cost curves for targets/resources	As above, but For market and non-market sectors where benefits are not motioned.	As above, but for no-monetary sectors and where pre-defined objectives must be achieved	Single heading metric difficult to identify and less suitable for complex or cross-sectional risks. Low consideration of uncertainty	Does not explicitly deal with uncertainty, but can be combined with sensitivity testing and probabilistic modeling
Traditional Economic Decision Support	Multi-criteria analysis	Allows consideration of quantitative data together for ranking alternative options	As above, but for scoping options. Can complement other tools and capture qualitative aspects	When there is a mix of quantitative and qualitative data	Relies on expert judgment or stake holders, and is subjective, including analysis of uncertainty	Can integrate uncertainty as an assessment criterion, However usually relies on subjective expert judgment or stakeholder opinion
Uncertainty Framing	Iterative risk management	Uses iterative framework for monitoring research, evaluation and learning to improve future strategies	For appraisal medium-longer term. Also applicable adds a framework at policy level	Useful where long-term and uncertain challenges, especially when clear risk thresholds	Challenging when multiple risk acting together and thresholds are not always easy to identify	Deals explicitly with uncertainty by Promoting iterative analysis, monitoring, evaluation and learning
Economic Decision making Under Uncertainty	Real-option analysis	Allows economy analysis of future option value and economic benefit of waiting/information/flexibility	Economic analysis of major capital investment decisions over the medium term. Analysis of flexibility within major projects.	Large irreversible decisions, where information is available on climate risk possibilities	Requires economic valuation probabilities (see CBA) and clear decision points	Deals explicitly with uncertainty by analyzing the performance of adaptation for different potential futures
Economic Decision making Under Uncertainty	Robust decision making	identities strategies which are optimal (robust)against a large number of plausible scenarios	identifying combination of strategic (long-term scenario independent) and operational (short-term scenario dependent) decisions	When uncertainty and risk are large. Can use a mix of quantitative and qualitative information	Requires high Computational analysis and large number of runs	Explicitly Incorporates uncertainties and risks, in particular, systemic dependent risks, to derive robust solutions
Economic Decision making Under Uncertainty	Portfolio analysis	Economic analysis of optimal portfolio of options by trade-offs between return (net present value) and uncertainty (variance)	Project based analysis of future combinations. Designing portfolio mix as part of iterative pathways	When number of complementary adaptation actions and good information	Requires economic data and probabilities. Issues of interdependence	Deals explicitly with uncertainty by examining the complementarity of adaptation options for dealing with future climates

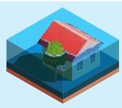
Figure 3: *Summary of main groups of methods in the adaptation economics*

Loss and Damage

According to ISDR (2003), risk is expressed by the equation: Risk (R)=Hazard (H) x Vulnerability (V)/ Capacity (C). Hazards (H) include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) and/or induced by human processes (environmental degradation and technological hazards). Vulnerability (V) is considered as a set of conditions and processes resulting from physical, social, economic and environmental factors, which increases the susceptibility of a community to the impact of hazards (ISDR, 2003). Loss and Damage (L&D) are defined as "adverse effects of climatic stressors resulting from inadequate efforts to reduce greenhouse gas emissions and insufficient capacity to reduce the risks associated with climatic stressors, to cope with impacts of climatic event to adapt to climatic changes".

L&D can be often time be avoided or reduced through adaptive measures although there are always residual damages and losses. Better risk management, reduction of greenhouse gases, and more effective climate change adaptation measures can minimize L&D. L&D research can display the actual effects of a natural disaster, what kind of post-disaster measures need to be reinforced more, and acts as a valuable tool to measure the amount of compensation an affected household may claim from a climate insurance plan. In terms of practical climate change risk assessment, Noi and Nitivattananon (2015) conducted an assessment of vulnerabilities to climate change for urban water and wastewater infrastructure management with a case study in Dong Nai river basin of Vietnam (sample results provided in Figure 4). They found that applying risk vulnerability assessment in three cities: Dalat, HCMC and Vung Tau, followed by vulnerability assessment at community level, provides an innovative and practical approach for conducting climate change risk assessment of urban water and waste water infrastructure at city to community levels.

a) Hazards & Vulnerabilities

Cities		Dalat	HCMC	Vung Tau
Hazard	**Vulnerable sectors**			
 **Flood**	Overall	+	+++	+
	Most Vulnerable	Agriculture	Water supply and drainage systems	water supply and services
 **Storm**	Overall	++	++	++
	Most Vulnerable	Agriculture	Water supply and drainage systems	Settlements near the along estuaries
 **Drought**	Overall	+++	+	++
	Most Vulnerable	Water irrigation agriculture	Water supply	Water supply

b) Urban infrastructure losses in selected districts

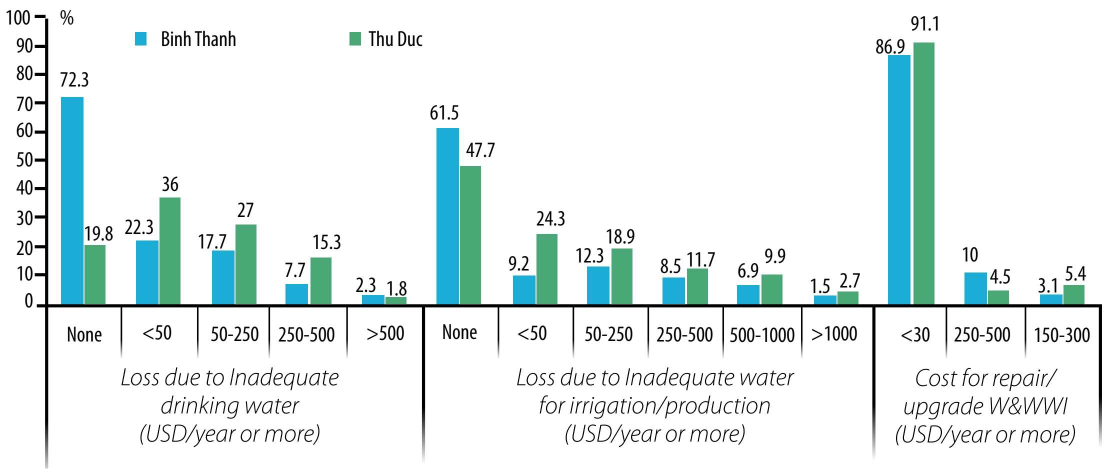


Figure 4: *Sample results of climate change impacts and associated infrastructure losses from a study of selected cities in Vietnam*

Source: Noi and Nitivattananon (2015).

Climate Change Adaptation Options

The IPCC (2022) illustrates linkages between mitigation, adaptation, and sustainable development. Accelerated and equitable climate action in mitigating and adapting to climate change impacts is critical to sustainable development. Climate change actions can also result in some trade-offs. The trade-offs of individual options could be managed through policy design. The Sustainable Development Goals (SDGs) adopted under the UN 2030 Agenda for Sustainable Development can be used as a basis for evaluating climate action in the context of sustainable development. Climate change adaptation can be defined as "the adjustments that are made in ecological, social, and economic aspects concerning the effects and impacts caused by climate change". The adjustments can either be in processes, practices, and structures which can reduce the potential damages and increase the benefits from the opportunities associated with climate change.

There are several types and approaches for climate change adaptation measures. Anticipatory adaptation is adaptation that takes place before the climate change are observed. Autonomous adaptation refers to spontaneous acts driven by local experience to reduce risks from any specific environmental changes and enhance opportunities for wellbeing in the absence of official intervention and external support (Limthongsakul et al., 2017). Planned adaptations are adaptations that are made before the event occurs and before the impact. Planned adaptations are made up of deliberate policy decision on the part of a public agency, based on an awareness that conditions are about to change or have changed. Public adaptation is the adaptation that is initiated and implemented by the government at all levels. Also, there is maladaptation. Maladaptation occurs when the adaptation measures increase vulnerability instead of decreasing it. In relation to practical adaptation measures, Nitivattananon and Srinonil (2019) conducted a study on analyzing the relationships between tourism, coastal areas, the environment, and climate change in the context of tourism urbanization in three popular coastal tourism destinations in the Eastern region of Thailand namely Koh Chang, Koh Mak, and Pattaya. They found that most of the current adaptation practices are autonomous or general with economic incentives and significantly required additional measures.

Possible Adaptation Measures for Urban Infrastructure

Although some adaptations and environmental protection as well as mitigation measures are with synergies to improve environment and increase climate resilience, some strategies also pose negative consequences to the environment. In addition, the main gaps are also related to planned adaptation and mitigation measures requiring improved capacities of and collaborations with local and regional governments together with other tourism stakeholders, especially for long-term and investing public infrastructure and services. With the increase in the intensity and frequency of the natural disasters, it is important to find suitable adaptation measures. Building underpasses, replacing traditional concrete roads with porous pavements, and improving the drainage systems are some of the measures that been done to accommodate the impacts of climate change on road infrastructure. Table 1 highlights possible adaptation measures for the transport network in which climate change-induced hazards are mean annual temperature rise, changing precipitation pattern, and changing wind speed.

Building underpasses, replacing traditional concrete roads with porous pavements, and improving the drainage systems are some of the measures that have been done in accommodating to the impacts of climate change on road infrastructure.

Table 1: Possible Adaptation Measures for the Transport Network

Climate change-induced hazards	Possible adaptation measures for the transport network
Mean annual temperature rise	• Consider the use of asphalt with modified binders that raise the softening point • Paint train tracks in white reflective paint to reduce rail temperatures • Improve the energy efficiency of air conditioning/fridge storage on trains and ships to reduce costs • Review operational procedures for workers operating in hot conditions • Review or introduce firebreaks next to road and rail
Changing precipitation patterns	• Upgrade drainage systems • Upgrade or install flood defence systems • Review and revise design standards for road, rail, bridges, tunnels and port systems • Review land stability and erosion control given increased flooding impacts • Increase maintenance regimes
Changing wind speed	• Assess implications of increased wind on operational efficiencies of railways • Increase the storage capacity of ports to account for weather delays

Sources: *Fisk (2017); Moretti and Loprencipe (2018).*

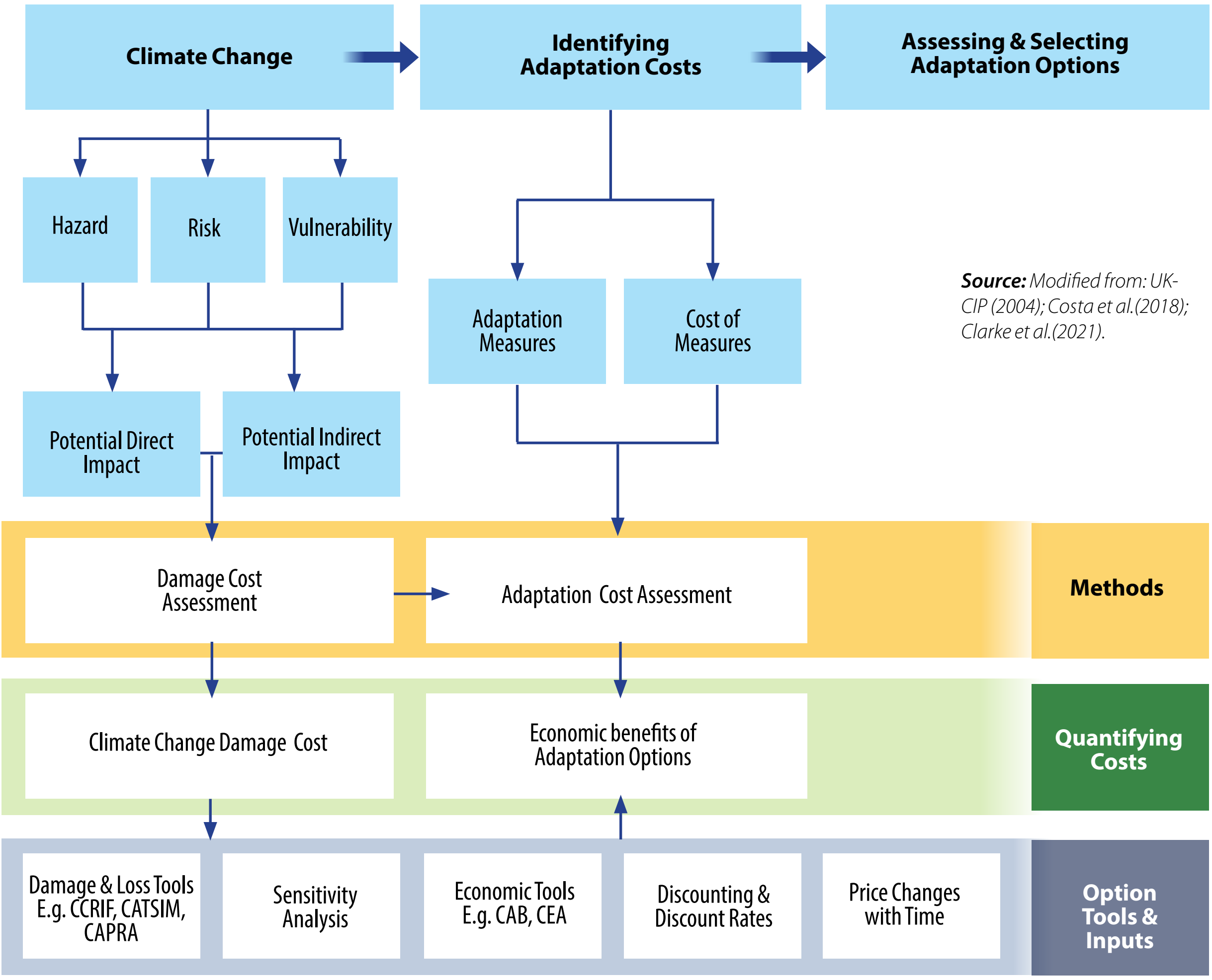


Figure 5: *Conceptual Framework for Economic Analysis on Climate Change Adaptation for Urban Infrastructures*

Box 1: The Roads of Cambodia

The 2011 flood in Cambodia had devastating effect, resulting in fatalities of 250. 18 out of 24 provinces were affected with more than 1.7 million people affected. Several infrastructures were impacted with 363 Km of roads damaged and 177 bridges/culverts damages. Over 180 Km of rural roads were damaged. The damage for road infrastructure alone cost over 340 million U.S. Dollar which contributed 57% of total damage. Such damage and loss incurred due to several reasons. Firstly, there is a lack of refined sector policy and effective legislative implementation. Secondly, in order to meet national and regional demand of infrastructure, there is no sufficient investment. Thirdly, when planning and developing road infrastructure, there is lack of sustainability in social, environmental, and financial aspects.

To reduce and avoid such damage and losses in the future, it is important to conduct risk assessment before conducting economic analysis. Developing several scenarios ("Do Nothing" scenario and scenarios with different adaptation options) help in evaluating what might happen in the future under different circumstances. Cost-benefit analysis is often used while considering the socio-economic and environmental impacts of the road improvement projects. Direct and indirect costs and benefits would be key element in the decision-making process for choosing the most appropriate adaptation measures.

Source: Asian Development Bank (2012)

Methods for Economic Analysis for the Climate Change Adaptation of Urban Infrastructures

The framework with supporting methods and tools for economic analysis on climate change adaptation for urban infrastructure development is as presented in Figure 5, compromising of climate change factors and impacts, adaptation costs, and selecting adaptation options. Climate change causes hazards which create risk and vulnerability. The risk imposed potential direct and indirect impacts. To identify adaptation cost, it is necessary to identify the adaptation measures and the cost of application of the measures. Several inputs are required to determine the most appropriate costing methods. The components are overlapping and interrelated, requiring an iterative process of costing and decision making. For example, adaptation cost assessment methods need to take account of damage costs in the absence of adaptation in order to estimate averted losses. For these reasons, the above-mentioned framework should not be regarded as a linear process, but one with feedback loops across the components. Box 1 also presents an example of economic analysis of climate change on the roads of Cambodia.

Addressing the Challenge of Creating and Maintaining Sustainable and Resilient Urban Infrastructure

Delivering the right kind of urban infrastructure requires an understanding of what cities need today and anticipating what they might need in the future. Infrastructure projects must maximize both their mitigation and adaptation potential, combining hard infrastructure and nature-based solutions, and addressing physical constraints together with community needs. This will lead to infrastructure that is built to improve daily life, ensure survival, and support continued growth in the face of increasingly hazardous climate events (Yee and Fairholme, 2019). Most of the challenges in creating resilient cities lie in the lack of sufficient infrastructures. This is caused by housing deficit, high levels of housing informality, poor planning, lack of availability of services, and migration.

Regarding examples of resilient urban infrastructure in Asian countries, Bangkok Metropolis in Thailand has set the goal to improve resilience to floods. As a flood-prone city facing a changing climate, Bangkok looks at different approaches for 'living with water'. These approaches represent a more integrated and holistic way to manage different city water systems, rather than solely depending on flood protection via hard infrastructure. Initiatives to deliver this goal focus on conservation and development of the city's blue and green infrastructure, primarily by improved catchment management, open space, and green areas to maximize natural infrastructure for water management. These actions will be underpinned by community participation for integrated socio-economic, environmental and flood protection benefits. This will be combined with specific flood defence actions such as upgrading drainage and testing the use of a flood resilience index in an urban area. This goal is supported by three initiatives consisting of catchment management strategy and vision for the Chao Phraya Basin, community water resource management programs and urban flood defences. Likewise, green infrastructure such as Chulalongkorn University Centenary Park is helping add more "green lungs" to Thailand's capital, one of the places most at risk from worsening storms, flooding, and sea-level rise (Wei and DeRidder, 2021) In Vietnam, cities located along long coastline face hazards from the sea. Dong Hoi and Hoi An are important tourist destinations. Strong tourism revenues fuel rapid urban growth, which in turn adds strain to the wastewater management system. Left unchecked, wastewater can leak and pollute beaches and seawater while unsustainable buildings can damage natural features. Currently, both cities are threatened by typhoons, flooding, and saltwater intrusion. To address these challenges, Dong Hoi and Hoi An are rolling out efforts to help urban infrastructure keep up with development. A project initiated to run until 2023 aims to promote climate-proof new and existing structures, focusing on improved stormwater and flood management, erosion prevention, and salinity control. The initiative focuses on Dong Hoi's Bao Ninh Peninsula and Hoi An's Coco River. Measures against flood risk include building vegetated buffer zones to hold back water surges and prevent the erosion of sand dunes. The project also established a forecasting and early warning system and an evacuation route for locals. Meanwhile, Hoi An is reinforcing its water supply by protecting the Lai Nghi Reservoir from saltwater intrusion. To protect the coastal dunes, planners are defining a coastal zone where vegetation will be planted as a buffer against erosion (UNDRR, 2022).

Similarly, Singapore and Chinese cities like Wuhan and Shenzhen have adopted "sponge city" concepts and practices, such as permeable pavements, rain gardens, grass swales, and artificial ponds and wetlands, to reduce flooding and improve both water quality and water supply.

Sri Lanka's capital city, Colombo, also implemented wetland protection and restoration to retain water during storms and safeguard urban communities against climate impacts (Wei and DeRidder, 2021). Box 2 additionally highlights selected urban infrastructure projects integrating climate-resilience in OECD and G20 countries.

Photo credit: *Dsign Something*

Box 2: Selected Urban Infrastructure Projects Integrating Climate-Resilience in OECD and G20 Countries

Photo credit: South Australia

Eyre Peninsula (Australia): a strategy was developed to address climate impacts, including increasingly frequent inundation of coastal infrastructure. A plan was developed using participatory techniques for decision-making under uncertainty to produce sequenced pathways combining management and structural measures to adapt to increasing risks.

Photo credit: Tokyo Cheapo

Japanese Railways (JR) (Japan): Extreme heat can cause railroad tracks to buckle, as heat causes steel to expand putting stress on ties, ballasts, and rail anchors that keep the tracks fixed to the ground. To achieve "zero accidents" due to track buckling, JR has raised the standard for estimated maximum performance temperature of its railroads from 60°C to 65°C to guide future investments. JR has also developed maintenance vehicles that detect potential joint openings.

Photo credit: Radii China

Sponge City (Hong Kong, China): Prone to tropical cyclones and with an average annual rainfall of 2400mm, Hong Kong is one of the world's wettest cities. Considering future climate impacts, the Drainage Services Department (DSD) of Hong Kong, China is implementing a nature-based drainage system with the aim of building up flood resilience and improving public spaces, instead of constructing flood resistance infrastructure. A future project is a flood retention lake that will become an open green space for public use on dry days, and operate as a flood retention site during the wet season (Leung, 2017).

Photo credit: State of the Planet | Columbia University

Hurricane Sandy Rebuilding Strategy (USA): In August 2013, the Hurricane Sandy Rebuilding Task Force issued the "Hurricane Sandy Rebuilding Strategy" to support the rebuilding of the region affected by the 2012 hurricane. The report contains policy recommendation on ensuring a regionally coordinated and resilient approach to infrastructure investment. It aimed to build back smarter and stronger infrastructure by: aligning federal funding with local rebuilding visions; reducing excessive regulation; coordinating the efforts of the federal, state, and local governments, with a region-wide approach to rebuilding; and ensuring the region's climate change and disaster resilient rebuilding (OECD, 2014a).

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Conclusions and Ways Forward

Several relevant climate change adaptation practices are discussed, taking the urban infrastructure development as the focal point of interest. Several measures such as raising road levels, adjusting the side slope, improving drainage, replacing or building permeable roads, building retaining walls, retention and detention pond, as well as improving management system, can be done to aid as adaptation measures to the changing climate. The cost of climate change varies based on whether level adaptation measures are taken or not, as well as on residual damage. The suitable (or optimum) level and type of adaptation measures are required in order to ensure to ensure lowest possible total climate change cost. Urban infrastructure projects must maximize both their climate mitigation and adaptation potential, combining hard infrastructure and nature-based solutions, as well as addressing physical constraints together with local and community needs.

In order to strengthen climate change adaptation and costing for urban infrastructure development, following consideration should be made:

- It is pivotal to investigate the underlying causes of L&D–independent of physical impacts. Monitoring the trend of L&D should be as important as the trends in vulnerability and resilience to climate change. Vulnerability and resilience are the starting point for effective hazard mitigation and climate change adaptation strategies.
- It is important to improve the data collection for L&D analysis. Most L&D databases utilize secondary data reported by humanitarian organizations, the media, and other sources. Such estimates are often crude estimates and inadequately discern between the different types of loss (e.g., direct or indirect costs, etc.). Therefore, more in-depth study needs to be done for measuring the intangible indirect and direct cost.
- Investments in the urban infrastructure sector must be protected by a thorough operation and maintenance program that extends the asset's life. This will also secure the sector's long-term viability. The government should establish and maintain a sufficient infrastructure repair budget, with the involvement as well as contributions from the private and other sectors.

Continuation

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Teaching Idea Creation to Next-gen Engineers: Reflections from a Crash Course Experience

Daniel Del Barrio Alvarez and Kensuke Yamaguchi

Innovation and creativity are two intrinsic components of engineers' education and professional development. Engineering projects of any particular speciality require finding new solutions for existing and new problems.

Teaching Idea Creation to Next-gen Engineers: Reflections from a Crash Course Experience

Innovation and creativity are two intrinsic components of engineers' education and professional development. Engineering projects of any particular speciality require finding new solutions for existing and new problems. In today's world engineers need to consider both the technological and social systems to develop adequate solutions to, what in many cases, are wicked problems. These are "a class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision-makers with conflicting values, and where the ramifications of the whole system are thoroughly confusing" (Buchanan, 1992). In this context, the ability to come out with ideas that are "new, surprising, and valuable" (Borden, 2004) is essential for a successful engineer. This ability may be nurtured through a combination of high-level and deep scientific and technological knowledge, and tacit wisdom obtained through the actual practice and sharing with colleagues. The current common engineering curricula do not properly incorporate these abilities, so can creativity be introduced in engineering education programs? And if so, how? This article presents the experience of the authors organizing an idea creation workshop within a broader course. On urban innovations this type of exercise is novel not only in teaching creative thinking but also in aiming to serve for students to put into practice the knowledge acquired in the previous lessons from the same course.

An immediate question is whether creativity is an inherent ability or skill of certain persons, or it is a skill that can be learned. Certain people are more talented than others in creative and artistic activities. But it is also not less true that creativity is also nurtured and improved, even the greatest artists need to practice and make efforts to improve ("practice makes perfect"). Researchers have been able to "teach" or program intelligent systems, able of certain kinds of creativity. Boden (2004) describes three types of creativity: combinational, the result of unfamiliar combinations of familiar ideas; exploratory, new ideas within an established conceptual space; and transformational, a deliberative transformation of the conceptual space and rejection of constraints and assumptions. For our matter, the main lesson is that creativity is a mental process (Beccone, 2020) that can be described and therefore teachable. Furthermore, there is a growing consensus on the importance of incorporating creativity as one of the core skills for students to learn (in and outside engineering fields). The Organisation for Economic Co-operation and Development (OECD), which also conducts the well-known PISA tests, includes creativity as one of the cognitive and meta-cognitive core skills that should be included in educational programs (Taguma & Barrera, 2019) (see Figure 1).

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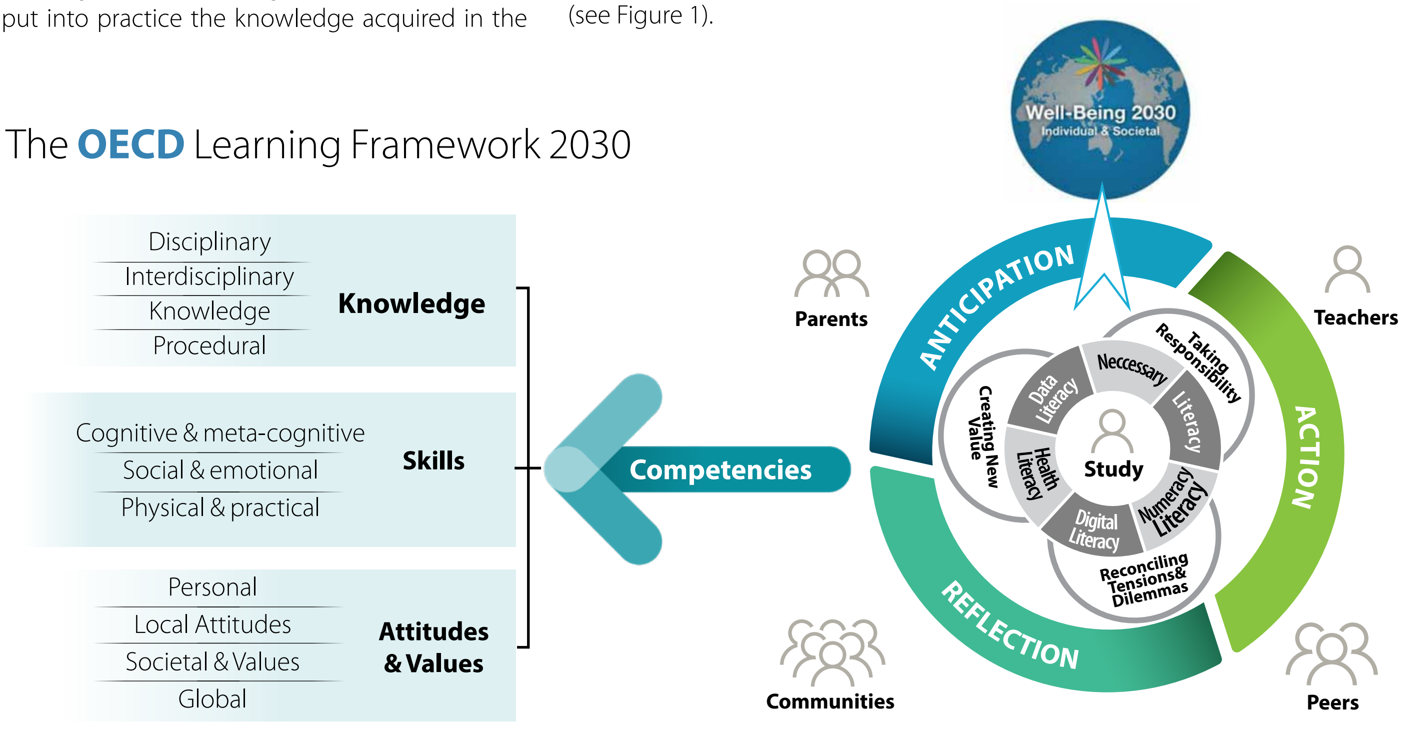

Figure 1: *Preliminary version of the OECD Learning Framework 2030*

Source: *OECD, extracted from (Taguma & Barrera, 2019)*

Indeed, many universities across the world are incorporating creativity as one of the transdisciplinary elements of their education curricula. Stanford University's d.school established by Prof. David Kelley, who also funded the innovation firm IDEO and was an early proponent of design thinking, is one of the most well-known examples. Numerous universities across the world have also introduced innovation programs and schools combining design, entrepreneurship, and engineering, such as the InnovationRCA of the United Kingdom's Royal School of Arts. In Japan, the i.school was initially established as a program of The University of Tokyo by Prof. Hideyuki Horii in 2009, and continued as an independent entity since 2017 under his leadership and linked to the Japan Social Innovation Center (JSIC). The i.school aims to "develop human resources who can generate ideas for new products, services, business models, social systems". The departments and schools introducing these creative or innovative programs are becoming more in demand both by students and employers. Professors also can find them useful as another education tool that includes more active engagement from students and provides flat platforms for discussion between students and experts.

Piloting an idea creation workshop to consolidate course learnings

This paper describes the experience of incorporating an idea creation workshop within a broader course. As such, it aims to share the findings from the instructors and the feedback from students to discuss some implications for the development of similar programs. The idea creation workshop was incorporated as part of a broader course on urban innovations conducted online at AIT during the Fall semester of 2021. Previous lessons in the course were given by several other instructors. The classes were facilitated online, with the instructors being based in Tokyo (Japan), and the majority of the 19 students were based in Bangkok (Thailand) also joining online and separately (e.g. not from a big seminar room). The scope of the idea creation workshop was on "innovative energy usage for sustainability". The workshop process followed a common division into divergent, convergent, divergent, and convergent thinking. In the "idea creation journey" (see Figure 2) as "analysis and exploration + Group brainstorming" for the first divergent thinking stage, "ideation I and II)" for convergent, and refining idea in which new divergent and convergent thinking were conducted.

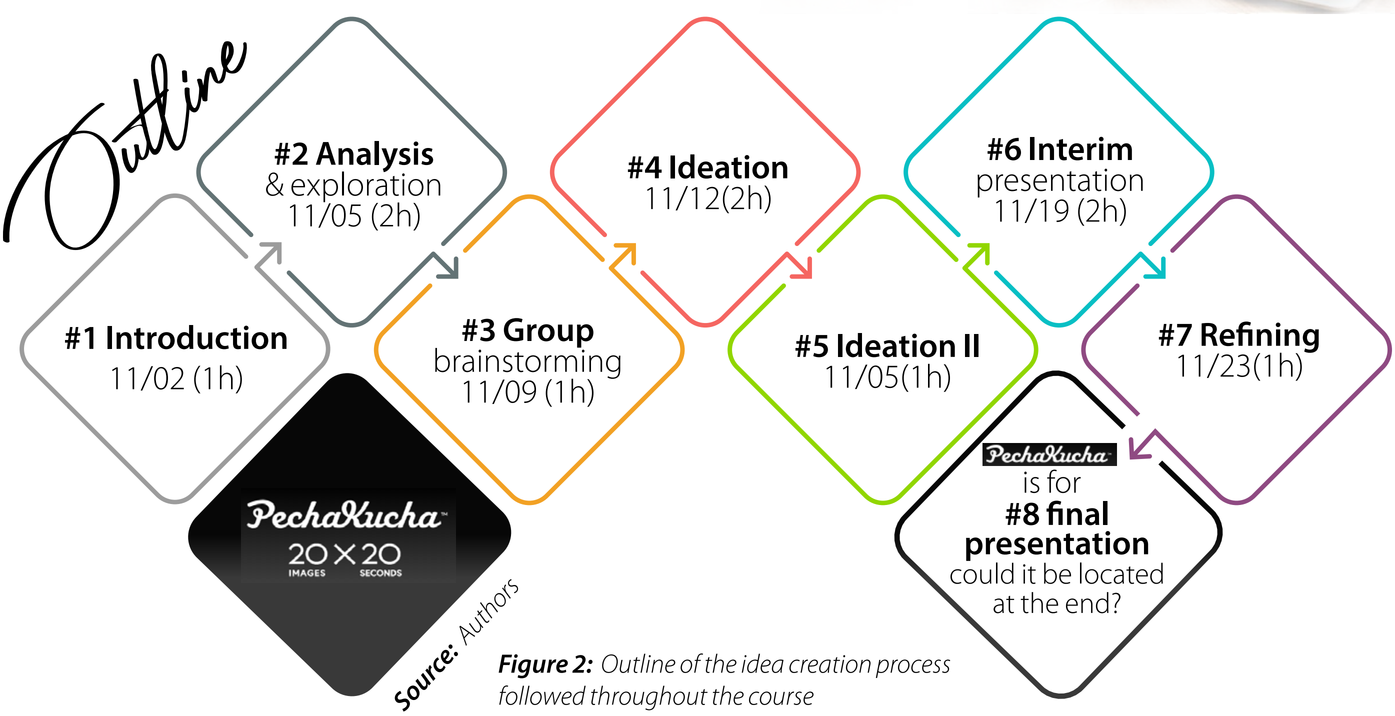

***Figure 2:** Outline of the idea creation process followed throughout the course*

The idea creation process proposed was based on the use of "analogical thinking". This aims to develop new ideas by fostering insights into new domains (Kim & Horii, 2016). In a nutshell, it is considered that services or products may have similarities among them at "superficial" and "structural" levels. The first is commonly self-evident and is more difficult to bring newness (for example between two online communication tools). In contrast, structural similarities will be between two services or products from very separated conceptual frameworks, fostering the creation of more novel ideas. The first day of the course served to explain and practice these concepts. In addition, students were introduced to concepts such as human-centered innovation.

For the analysis and exploration, students were provided with a set of innovative cases and tasked with analyzing them individually. Each of them also searched for additional cases following the same structure. To facilitate the group work, APISNOTE (https://www.apisnote.com/), an online application developed by the i.school, was utilized. In the following class, they classified those to identify some common mechanisms for value creation (see Figure 3).

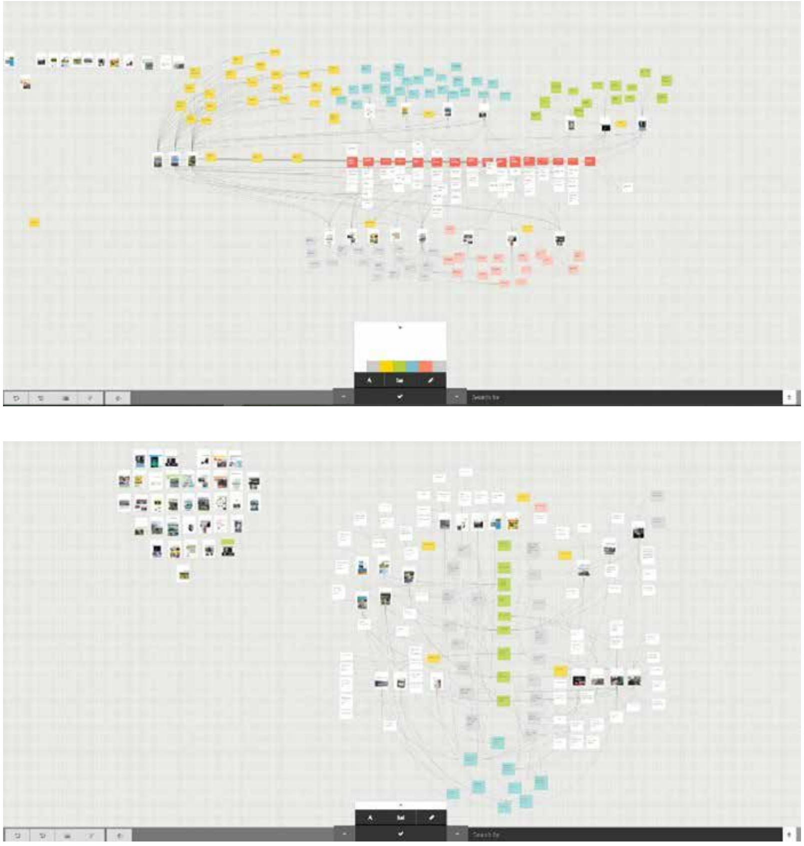

Figure 3: *Examples of the analysis of cases conducted by students utilizing online collaborative tool APISnote*

Source: *Authors (APISNOTE worksheets created by students participating in the course)*

Then, they selected one of those mechanisms and used those to develop new ideas to address social problems related to or to satisfy new uses of energy systems in urban contexts. This represents one of the major challenges for students. Since it is likely to be the first time for them to utilize such an approach, many of them may feel "lost". Their natural tendency may be to brainstorm more focused on their understanding of the issue or on ideas they hold before. There can be others who may put more emphasis on the management of the idea. For that, the introduction and close guidance from instructors is required. It is important to notice that this needs to start with a divergent thinking phase, so students may be guided in that direction with different tactics.

For that, it is also important to prepare for one session in which students will be challenged on their ideas. The goal is for them to reconsider their initial prototypes and initiate a new divergent thinking process. Ideally, they will challenge their fundamental ideas, while selecting what to remain and what to discard. This revision and refinement of the first proposals are an opportunity for students to practice once more a creative thinking process. As they gain experience, this process becomes more agile, what not necessarily mean faster. As this is the last stage in the course, it is more important a positive, rather than critical, support from facilitators. This brings also an opportunity to reinforce the main lessons to be derived from the course, that is, to understand the idea creation process and the approach applied. By doing so, students will be able to adapt it to their expertise and projects.

The final lesson includes presentations of the final ideas and a reflection. In our experience, it is important to make the final presentation as engaging or new as possible. In some cases, this can include preparing small sketches or performances. On this occasion and considering the limitations of the online setting of the class, students did their final presentations in the format of a "Pecha-Kucha". This format started in Japan and is being adopted globally, consists of presentations of 20 slides with a set time of 20 seconds for each (https://www.pechakucha.com/). This format is more engaging and dynamic for students (Beyer, 2011), which coincides with our experience. Finally, the idea creation workshop concludes with a group reflection on the process and the different steps throughout the course.

Reflections on the experience

How to teach creative thinking to students of different engineering backgrounds? What should be highlighted? How to examine them? These are some of the many questions that come to all of us. Experts in creativity and innovation workshops have been searching for the answers. We see at least two paths for this, traditional engineering courses adopting idea creation workshops as an educational tool, and faculty at engineering schools engaging in creative thinking research and education.

The goal of the workshop is to foster a culture of innovation and creativity for the students/participants to apply later in their specialities. In that sense, it is required a departure from more traditional teacher-student dynamics. In some cases, some students may tend to "praise the professor". Indeed, many students pointed out this as a unique and attractive element of the course. In that sense, the professor needs to become more of a facilitator and imply instructions indirectly. There are many tactics for that, such as playing a role similar to devil's advocacy (by continuously challenging ideas and propositions) or, as one student called it, a psychologist (in which there are many questions as to why or how you think so?)

This experience also brought lessons on doing the activity online. Certain limitations are difficult to address in an online environment, such as group formation and opportunities for more casual interactions that help to build the atmosphere for a more productive idea creation process (which ultimately must come out naturally). But there are also other advantages in making innovations with the use of other tools, such as dynamic breakout rooms; as well as being able to connect students from different schools, cities, and even countries. Ultimately, a combination of both online and physical would be more preferred. The use of digital tools, such as APISNOTE, can be of great support to build continuation between the two contexts.

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Integrating Technologies in Civil Engineering

Naveed Anwar, Ashish Sapkota

Like everything else, civil engineering must continue to change and advance. Upgrading the technology being used in the industry is one strategy to stay current with the ever-changing times. The purpose of technology adaption is to make the process easier and efficient, helping to create a better system or solutions, and addressing the problems that couldn't be addressed otherwise.

Integrating Technologies in Civil Engineering

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Technologies in the present context can be categorized broadly as being a core technology in respective field, profession, or disciplines and other being hardware and software tools or applications helping to facilitate our routine work by integrating them into solutions. In civil engineering, there are many branches such as construction and management engineering, geotechnical engineering, structural engineering, earthquake engineering, transport engineering, water engineering, environmental engineering, and so on. Some of the disciplines are a little bit more adaptive or adapting the technologies whereas some are less progressive. However, the development depends on choosing the effective technologies in almost all these disciplines.

Engineering Related

Engineering technology is the branch of engineering that deals with the practical applications. The primary responsibility of the technologist is to turn an idea into a practical reality once a project engineer has decided that it is theoretically possible by improving existing processes or developing entirely new technologies. For example, self-healing concrete is one of the new things that is being sort of developed and used. It is a concrete that heals by itself using biological or chemical process. The photovoltaic glaze is an innovative technology that, apart from electricity production, can reduce energy consumption in terms of cooling, heating, and artificial lighting. Kinetic footfall and kinetic roads are a few areas for sustainable energy source in generating electricity without consuming any natural resources. Advanced materials like shape memory alloys, nanofiber-based materials, and prefabrications are also gaining more popularity along with modular construction and 3D printed dwellings. Similarly, we can make an advanced usage of Global Positioning System (GPS), effective scanning solutions, drones, Unmanned Aerial Vehicles (UAVs), robotics and exoskeletons, wearable technology, and autonomous vehicles. Moreover, there is a technology for volumetric construction that comprises the entire parts of the buildings which are constructed first and then transported and assembled at the site. This technology has become quite significant in countries like Singapore and China.

Using drones to reach inaccessible locations, capture photos and videos, and then use the data to create models.

Computing and Software Shift

In the past, computer programs were essentially created to automate and speed up the manual tasks' humans were performing. But it is not necessarily the best use of computers and computing technologies. Nowadays, the processes are developed that are based on computing technologies. So, it's a complete reversal of the paradigm that unlocks the possibility of solving the problems uniquely and innovatively. This might be the key to using the computers and software more effectively.

Many engineering software traditionally use the Finite Element Methods (FEM), Finite Element Analysis (FEA), etc. The application of such software is in almost every field within civil engineering like geotechnical, structural, transportation, and water engineering; it can be applied to many of the challenges or the field problems. Similarly, Computational Fluid Dynamics (CFD) is now becoming quite useful in replacing some of the experiments that previously required lab work. The CFD development has helped to model many physical phenomena which otherwise would take long time and cost in labs.

Similarly, there is a development in Boundary Element Methods, Finite Volume Methods, etc. Automated meshing and discretization are becoming mainstream. Having said that, integration of Building Information Modeling (BIM), Bridge Information Modeling (BrIM), GIS, surveys, etc. with many of the traditional computing methods can produce a comprehensive solution when put together.

Information and Digital Technologies: Application to Engineering

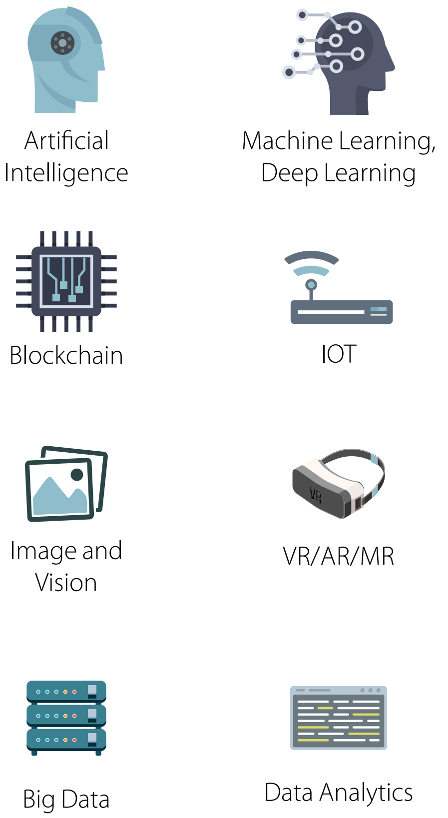

Figure 1: *Information and digital technologies*

Information and digital technologies encompass a very broad range. Artificial Intelligence (AI), machine learning, deep learning, blockchain, Internet of Things (IoT), image and vision, Virtual Reality (VR)/Augmented Reality (AR)/Mixed Reality (MR), big data, and data analytics are just a few to mention. The significance of them is not in their isolated use but rather in putting them together to solve a bigger problem in a way it was not possible earlier.

Figure 2: *Cloud-based access to models. ETABS Cloud Viewer is a mobile and web application for viewing ETABS models*

For example, Figure 2 shows a way to access the same information from structural models (using SAP-2000 or ETABS) through mobiles, tablets, iOS, and PC/Mac and then add more functionality through apps.

This simple example illustrates that, what we used to do traditionally (i.e. limiting ourselves within desktop/mainframe to view the finite element models) is no more a constraint these days since the data or the models are available to us anywhere on our devices. This gives the freedom to collaborate and at the same time present to the people who want to see them but are not structural engineers. The use of cloud-based access to models of any kind is a very useful tool and an important development that we can take full advantage of.

Arguably, AI is probably the biggest disrupter of the future having both positive and negative impacts. There are concerns regarding the negative effects that people are worried about and obviously, that is good because then we will be more careful with the application. But the potential of usefulness and valuable application of AI is already apparently in many areas and civil engineering is no exception. Some of the applications of AI in civil engineering are-

- Estimating the percentage of soil moisture content.
- Detecting damages by applying machine learning in the structural engineering field.
- Predicting maximum dry density and optimum moisture content in concrete.
- Using image recognition for proper site monitoring.
- Integrating with BIM for better prediction.
- Predicting properties of concrete mix designs
- Monitoring the construction site and predicting changes in the costing based on raw material market rates.

- Analyzing settlement of foundation and slope stability.
- Monitoring the real-time structural health of the building, giving warnings on when and where repair is required.
- Developing site layouts and predicting risks as part of project management.
- Finding a better solution for pile driving in foundation engineering.
- Making decisions in the design field.
- Expert monitoring and optimization of costs in the work system.

These are some other areas in civil engineering where AI can be applied, a general tool as an assistant.

Let's discuss one such system that uses AI to predict the outcome as shown in Figure 3. AI was utilized in the structural design process where one can possibly go directly from architectural plans to the structural design outcome. We skipped the modeling, analysis, and preliminary sizing, and based purely on architectural parameters we can go to the final design on code-based design procedure or performance-based design. This process operates entirely on experience by looking at many designs of similar buildings and training the AI so that it can predict the final design quickly. It may not seem practical to be used in the field as the final or detailed design, but it could be used to do a quick check in the design more like an experienced engineer by looking at many designs. This inspires the data-driven structural design rather than the process-driven design. Because when we have enough data and is stored on servers/cloud, we can use that data to make a design decision more quickly.

AI helps to make decisions in many systems and situations, and it is becoming a part of life. In civil engineering, we have so much work that can be done more effectively based on AI systems.

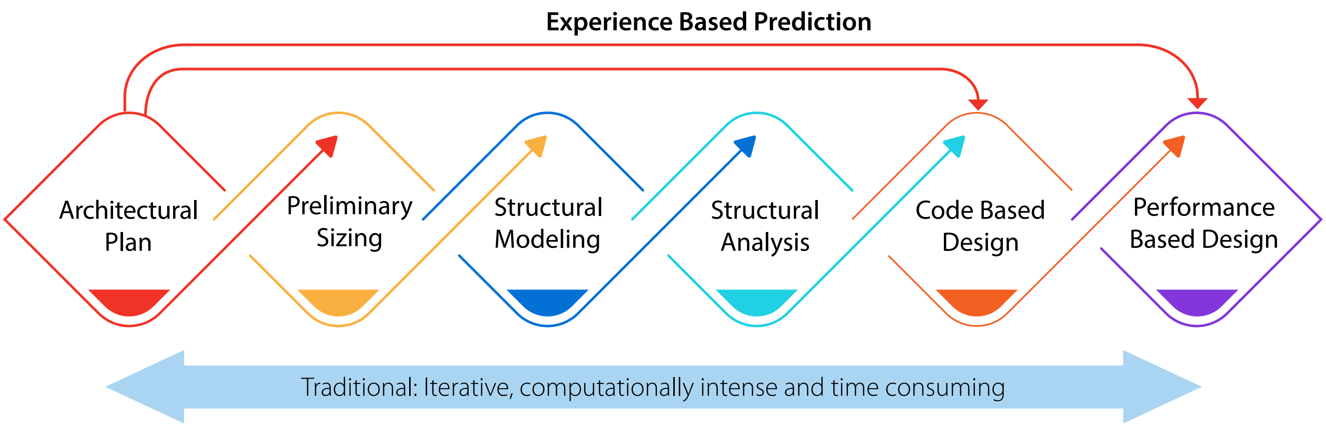

Figure 3: *Using AI in the structural design process as an alternative to traditional design process*

The Changing Design Paradigms

Design paradigms are changing from intuitive design to code-based design, performance-based design, risk-based design, resilience-based design, and to future-proof design. These are some of the terms people are using to define how the design is carried out, not only in structural engineering but in other disciplines too.

Futureproofing means the process of anticipating the future and developing a method of minimizing the effects of shocks and stresses of future events, including effects of climate change.

Figure 4: *Changing structural design paradigms*

However, it's hard to explicitly make structures and systems futureproof because that involves certain decisions to be taken that are beyond engineering. To make a built environment future-proof requires the structure to remain serviceable, safe, resilient, flexible, adaptive, sustainable, and dismantlable. Structural engineering is trying to catch up with all necessary technologies to meet the requirements to achieve the future proof design.

Another new paradigm that is quite buzz word and is gaining a lot of popularity and importance is the Bio Circular Green (BCG) economy. BCG is becoming an important player in the way the countries are developing or cities are being developed and once again civil engineering has a lot to do about the infrastructure, how it is developed, used, and finally disposed of. It also involves transportation networks, bridges, roads, structures, buildings, etc. Using the BCG paradigm and making sure that civil engineering can cater to this is quite important.

In the new paradigms, there are several new ways to call our cities; green cities, sustainable cities, resilient cities, livable cities, smart cities, and future-proof cities. As civil engineers, we should not only be aware of these terms but make sure that when we design our infrastructure, be it the water supply systems, drainage systems, waste systems, or environmental systems that cater to these various city models, but also to the future city models that are going to be resilient, livable, sustainable, smart, and so on. Smart cities are the results of the convergence of planning, engineering, technology, policy, and management. It brings many disciplines together along with various aspects (information) associated with them. Once again civil engineering has an important role to play.

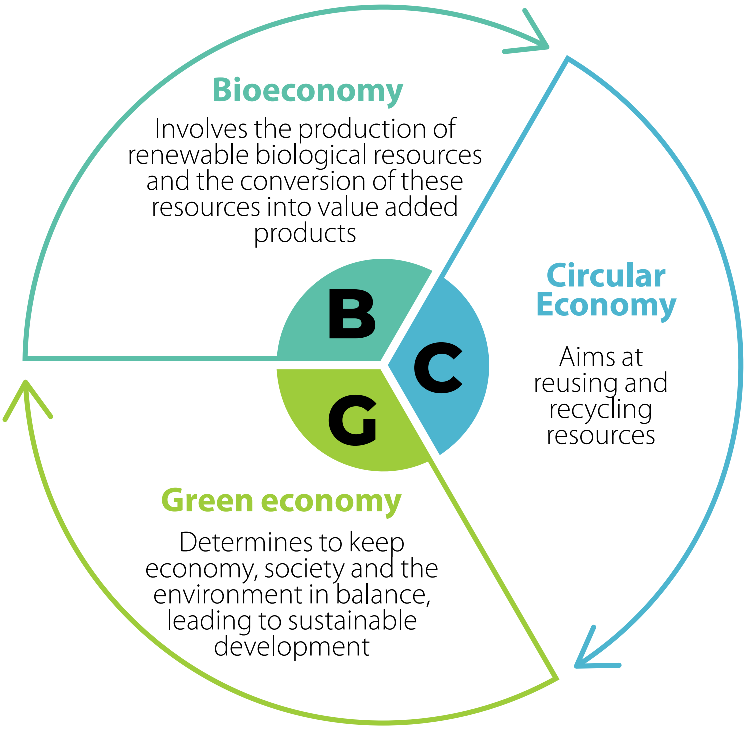

Figure 5: *BCG and its significance to civil engineering*

Building Information Modeling (BIM)

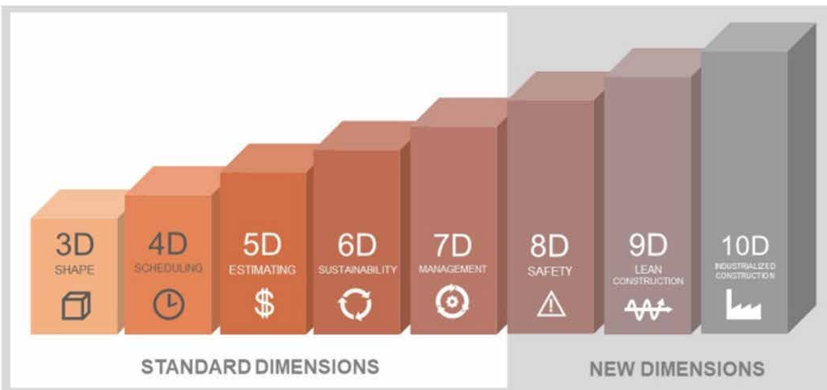

Figure 6: *Multiple dimensions of BIM to capture life cycle information (BibLus, 2022)*

BIM or Building Information Modeling says building, but it can be applied to many infrastructures including bridges and other developments. BIM is developing to manage the infrastructure in a numerous dimension catering to several life cycles and steps. These BIM dimensions are now becoming the platform on which we can design, build, and operate our systems.

For example, a life cycle application of BIM starts with the conceptual design to detailed design, analysis, documentation, fabrication, construction, all the dimensions of construction, operation, maintenance, renovation, retrofitting, and so on. All of that could be integrated into the multiple life cycles through proper development, maintenance, and integration of the building information into real or as they are called digital twin models.

Similarly, we have Radio Frequency Identification Reader (RFID Reader), a device used to gather information from an RFID tag that is used to scan the materials automatically and add to the system. Here BIM, GIS together with AI, and robotics are put together into a fully digital delivery system in the form of a product. So, the construction of the projects can go to that level once the technologies are fully integrated.

Furthermore, on a construction site, people could use wearable devices that ensure safety and provide information. Similarly, that can be integrated with other sensors and technologies which are managing the system from a distance. Once we have the wearables, they can communicate between themselves, between humans and finally help us in managing all the infrastructure that civil engineers are proud to design, build, and maintain. BIM on one hand, and IOT on the other hand when combined will have the advantage or power to build & manage our built infrastructure in a much more integrated manner which we can use for future decision-making along with its performance and monitoring.

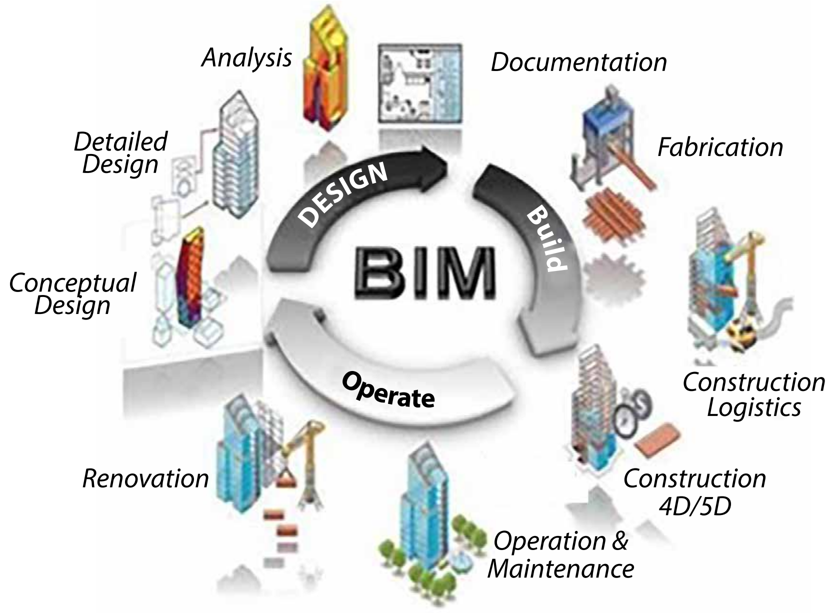

Figure 7: *BIM as the basis for managing project lifecycle information (Olugboyega, O. L. U. S. E. Y. E., & Aina, D.,2015)*

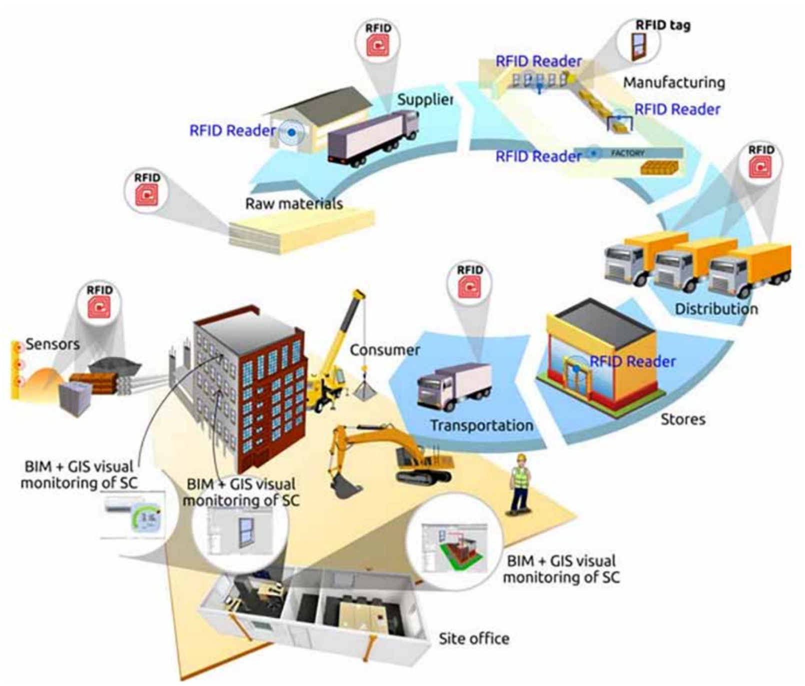

Figure 8: *Future construction procurement and project management (Edirisinghe, R.,2019)*

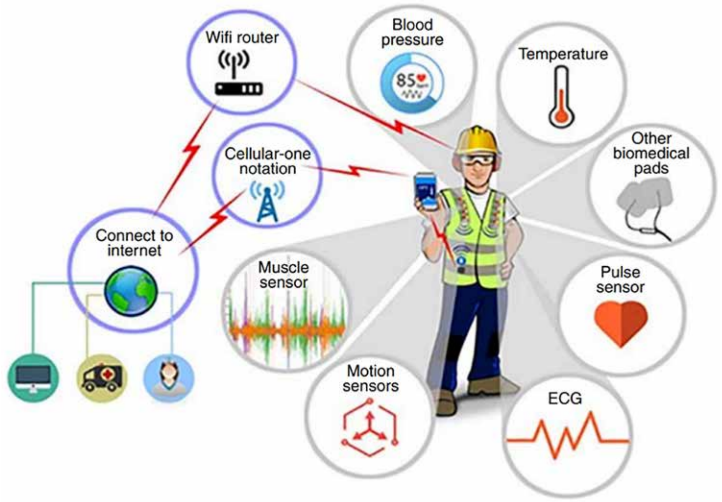

Figure 9: *The future construction worker (Edirisinghe, R.,2019)*

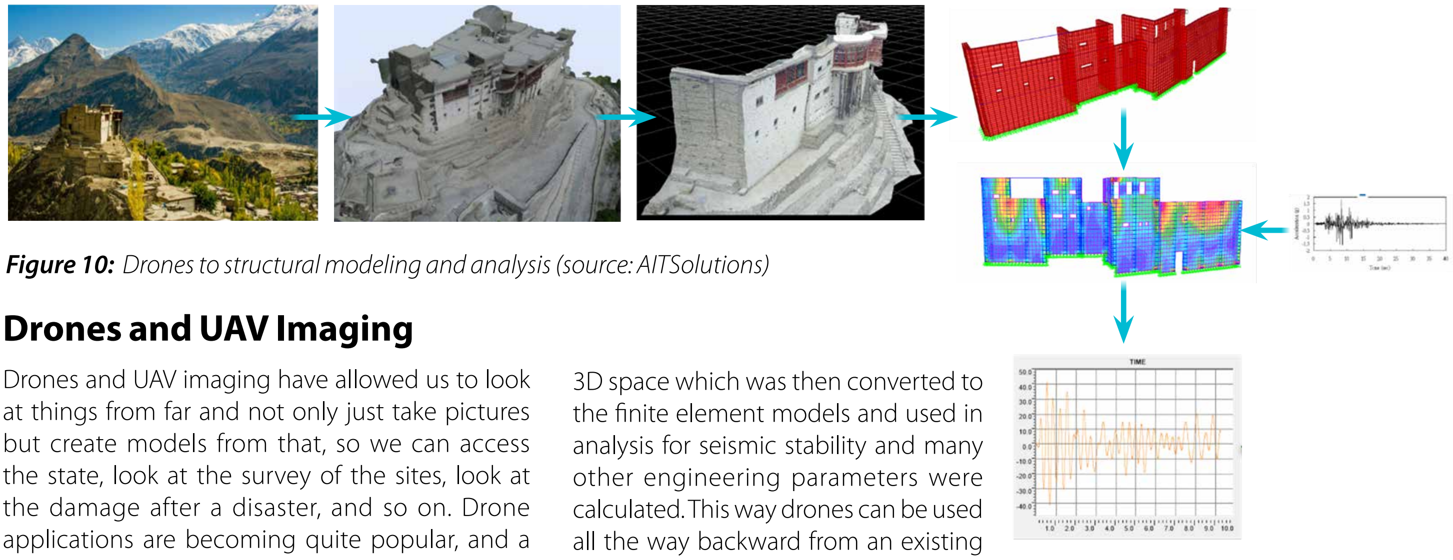

Figure 10: *Drones to structural modeling and analysis (source: AITSolutions)*

Drones and UAV Imaging

Drones and UAV imaging have allowed us to look at things from far and not only just take pictures but create models from that, so we can access the state, look at the survey of the sites, look at the damage after a disaster, and so on. Drone applications are becoming quite popular, and a drone is no longer just a video-making tool but rather it's a modeling and monitoring tool. Figure 10 is an illustration of one project conducted in Pakistan where a drone was used to create a model of this fort. The drone took images of the fort in a 3D space which was then converted to the finite element models and used in analysis for seismic stability and many other engineering parameters were calculated. This way drones can be used all the way backward from an existing one instead of construction after the analysis and design. Drones and BIM can also be used for construction site monitoring in a similar way as shown in Figure 11.

Figure 11: *Smart monitoring of construction projects using UAVs (source: AITSolutions)*

When we have a BIM model and drone images, we can put them together to monitor the construction and its progress. Also, the measurements can be taken because both can be converted into 3D space. When we move them and place one on top of the other then we can find the difference and progress between them.

Sensing and making sense of sensing: Extremely Important!

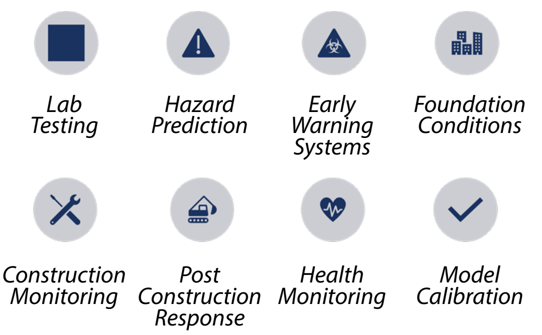

Figure 12: *Smart sensor technologies towards future smart construction sites*

We can install different kinds of sensors in our buildings and structures that can provide us with valuable information at all stages during construction and post-construction. After that, we can integrate them for hazard prediction, early warning systems, foundation conditions, stability, health monitoring, construction monitoring, model calibration, and the like. These sensors are a great way to convert our real structures with real behavior into full scale labs because we can bring that measurement back and can use them to understand and make decisions as well as update our knowledge.

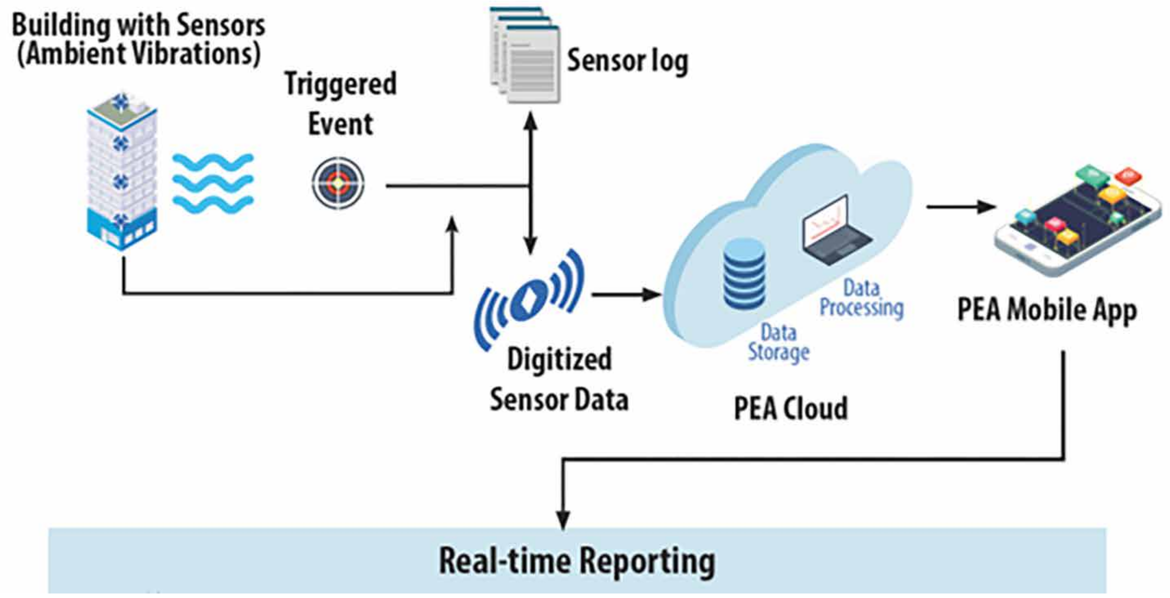

Figure 13: *Smart system for post-earthquake assessment of structures (source: AITSolutions)*

The sensors can record the acceleration data from the buildings and send it to digitize which is then sent to the cloud where the data processing takes place that updates the models based on the received data. Since the structural models are already available and we have the real data from the sensors, we can calibrate the model. Those calibrated models can then be used for further analysis for safety and performance.

Can we learn and apply all of them?

Now that we have explained so many technologies and so many things happening around us, it is quite overwhelming as it seems no single person can keep track of everything. It is thus important to keep updating the knowledge and always stay in the mode of innovation. Organizing seminars, webinars, regular conferences, inviting different experts to our organization, attending international events, etc. might be the way to keep ourselves updated with the required knowledge and to keep us motivated in developing and applying technologies to our field. That means for each discipline, engineers should consider which task can be performed better by using which technologies. This is something that we can do in a continuous manner such that we can analyze or audit whether we are using the best technologies and what new processes can be developed that leverage the technologies.

We need to encourage our engineers and professionals to develop the key skills to understand and establish relationships to simulate and visualize, to create and communicate. These are the things that are the hallmarks of future education, which are beneficial, not just reading or passing exams but understanding things more deeply and being able to simulate and visualize which is more like learning by doing and learning by practicing.

Acknowledgement

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NEWS In Brief

April - June 2022

JUNE 2022

AIT, Microsoft, SCB, and depa Join Alliance to Develop AI Talents and Pioneer Thailand's Economy

Asian Institute of Technology (AIT), Siam Commercial Bank (SCB), Microsoft Thailand, and Digital Economy Promotion Agency (depa) signed a Memorandum of Understanding (MoU) to collaborate on the "Digital Manpower Development" program on June 23rd, 2022. This collaboration aims to develop and prepare future talents in Artificial Intelligence (AI) to meet the demand of the job market and support the new S-Curve businesses and industries to enhance Thailand's digital economy.

The program developed under this MoU is specifically targeted to tackling five fundamental skills in AI, particularly Fundamentals of AI and Cloud Computing in Practice; Machine Learning; Computer Vision; Natural Language Procession (NLP); and Conversation AI. The courses will allow the soon-to-graduate bachelor seniors and recent graduates to maximize their chances of employability by giving them an opportunity to earn "AI on Cloud" certificate through this Public Private Academic Partnership.

AIT and Christiani & Nielsen Energy Solutions Co., Ltd. sign MOU on Agrivoltaic project

The Asian Institute of Technology (AIT) and Christiani & Nielsen Energy Solutions Co., Ltd. (CNES) signed a Memorandum of Understanding (MOU) focusing on Research & Development and Electrical Energy Generation in Agrivoltaic Solar Farming. The MOU was signed on 10 June 2022 between AIT President Dr. Eden Y. Woon and Mr. Bhargab Mohan Das, CNES Managing Director & CEO, and AIT alumnus who did his Masters in Structural Engineering in 2005.

CNES is a developer and turnkey solution provider of Sustainable Solutions having C&I Solar PV Projects as a predominant business venture together with assorted supporting services pertaining to the Energy Storage, Sustainable Agriculture, Automated Operations and Building Energy Efficiency Enhancement being the other facets of its services.

Mobile App Developed by AIT Alumna Eyes to Boost Livelihood of Bamboo Farmers

Bamboost, an online marketplace app developed by Ms. Analiza Cruzat Diaz, MS Climate Change and Sustainable Development graduate from the School of Environment, Resources, and Development-Asian Institute of Technology during her thesis study eyed to help bamboo farmers in marketing their products.

The Bamboost App is one of the outputs from a project titled "Mainstreaming of Bamboost App as an Online Marketing Platform of Bamboo Farmers in Select Science & Technology Community-Based Farm (STCBF) Sites jointly led by Ms Diaz and Prof. Love Jhoye M. Raboy of the University of Science and Technology of Southern Philippines. It is funded and supported by the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (DOST PCAARRD). This also forms part of the collaboration program between DOST-PCAARRD and AIT.

Soft launching and user testing of the Bamboost App was held on May 24, 2022, at the iDEYA: Center for Technopreneurship Innovation, Mindanao State University-Iligan Institute of Technology (MSU-IIT) which was meant to introduce the app to bamboo farmers, processors, and entrepreneurs who will eventually be the target clients once it is already up and running. It was attended by the key players in the bamboo value chain in Northern Mindanao, Philippines. Apart from Iligan City, Bukidnon and Iloilo provinces are the other "initial target sites of the Bamboost project where the app is to be adopted.

APRIL 2022

Targeted Businesses to Enjoy Privileges from New BOI Designated Zone for AIT

The Thailand Board of Investment (BOI) announced early this year that it granted the status of Science and Technology Park to the Asian Institute of Technology (AIT). This will promote active collaboration between the industry and educational/research institutions and provide an opportunity for entrepreneurs to strengthen their capabilities in research and development.

UNDP and AIT join hands to Promote Research on Sustainable Development Goals

The United Nations Development Programme (UNDP) and the Asian Institute of Technology (AIT) signed a memorandum of understanding (MoU) to raise awareness and enhance knowledge on the SDGs and their status in Thailand among the Thai public through research studies, publications, and seminars.

The MoU will encourage the two bodies to cooperate not only on exchanging knowledge and expertise on sustainable development and the implementation of the SDGs, but also on jointly identifying innovative solutions to address development challenges and engaging in programmatic interventions to contribute to the achievement of the SDGs and other national development goals.

Will Model Updating Improve the Reliability of Engineering Assessment of Buildings?

Kishor Timsina and Chaitanya Krishna

Earthquakes are threatening forces of nature which, when guided by poor built environments, can lead to severe risk. The resulting damage can be massive if our buildings cannot withstand the forces caused due to the earthquakes. This leads to the question, who will tell us the condition of the building? Well of course, the engineers should be able to convey the condition; which then begs the eternal question: how is the structural condition assessment of buildings done and what are its facets? Now, let's talk about this.

Will Model Updating Improve the Reliability of Engineering Assessment of Buildings?

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Many existing buildings are exposed to high risk of seismic hazards in the real world due to poor construction practice and non-uniform materials. These buildings are often subjected to numerous temporal changes after their construction, and past earthquakes have inflicted immense damage in such structures resulting in major human casualties and economic loss. So, it is imperative to understand the structural condition of existing buildings in order to mitigate the seismic risk before the disaster. Similarly, it is also necessary to study the damages that have occurred in the structures after the disaster for their repair and reconstruction process.

Figure 1(a): *Large number of building stock in urban sprawl*

Figure 1(b): *Damage due to earthquakes*

It is challenging, however, to model and analyze real-world engineering problems as it is. So, generally, these structures are equivalently transformed theoretically to easily replicate the behavior as that of the real-world problems. In their theoretical representation, these problems are defined in terms of geometric properties, material properties, and structural capacities. These different parameters of the real-world structures are needed to be replicated to an analytical numerical model accurately to understand the correct behaviour of the structure for a real disaster.

It is essential to bridge the gap between the real-world and the theoretical-world with an accurate and applicable numerical model, and to do so, one of the most important parameters is the accurate identification of the material properties. There are different non-destructive tests, such as ultra-sonic pulse velocity (UPV), Schmidt Hammer test etc., to identify the material properties. Even then, it is still quite difficult to obtain a high accuracy using these methods as the existing buildings we are dealing with are primarily non-engineered with non-uniform material distribution throughout the structure. Additionally, the accuracy of the instruments used, and their calibration also plays a significant role in the accuracy of the data. Other methods to identify material properties include vibration-based methods. However, as we are dealing with existing structures and we do not know the input loading, we can only perform operational modal analysis. Furthermore, as the structures are also low rise and relatively stiffer, it is very challenging to get the higher modes and modal properties of the structure. As a result, it is tough to obtain the accurate material properties without data of the higher modes.

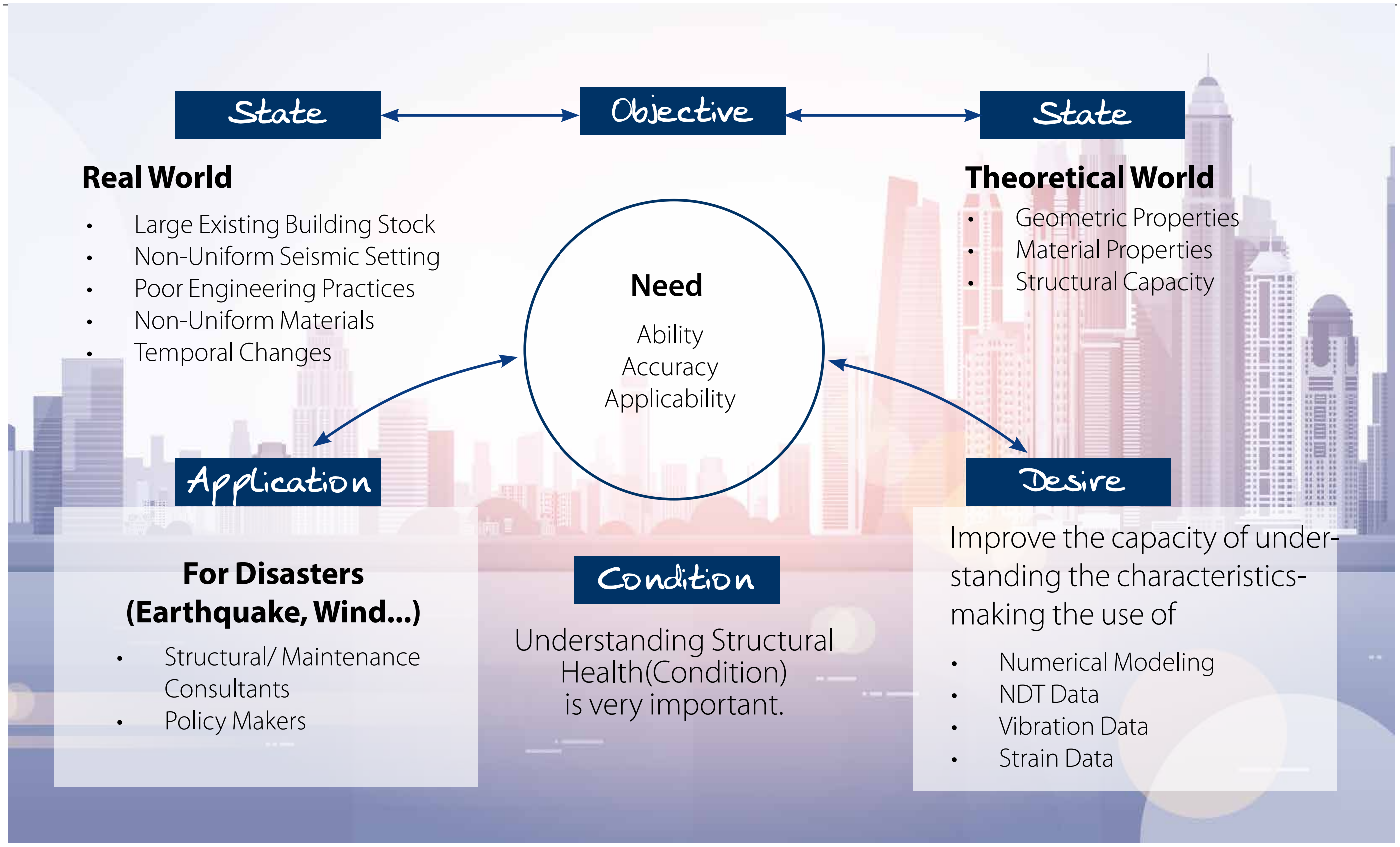


Figure 2: *State of numerical modeling of buildings in engineering*

Various model updating methods are being used to update the identified properties from the modal properties. The model updating is the modification of an analytical-numerical model of a structural system such that the response of the modified analytical-numerical model becomes consistent with the experimental (real-world) results. Also, it is one of the most common approaches for structural performance assessment. The difference between the analytical predictions and the experimental observations is caused by modelling errors, inaccurate modelling of material constitutive behaviour, inaccurate modelling of the boundary conditions and measurement errors.

Generally, model-updating are of two types: a) direct methods; b) iterative and indirect methods. In direct methods, it is assumed that a mathematical model fully describes the physics of the problem, but it is not easy to do so. Also, this does not account for the factor of "noise" that exists in measurements. It does not account for variation of the measured response of identical nominal structures even under the same loading/ condition due to manufacturing and material variability, and the point estimates also may not represent the entire sets of possible solution. The common iterative and indirect methods for model updating are sensitivity-based method and Bayesian-based method, and these methods can somehow overcome the above mentioned issues of direct methods in the following way:

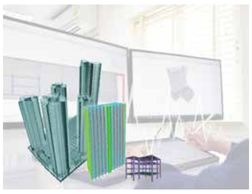
1. Sensitivity based model updating involves estimation of the changes in the model parameters depending on how sensitive the modal characteristics are to these model parameters. This method is based upon linearization of the generally non-linear relationship between measurable output. This method can identify the changes in model parameters which affect the monitored response qualities most strongly, while preserving the basic character of the structural property matrices: symmetry, positive definiteness, and sparseness. The sensitivity method with data driven regularization scheme before the linearization of modal parameter vector as a function of updating parameters to penalize the total update can give a stable optimization result.

2. The Bayesian model updating approach for probabilistic assessment of structural performance has been used in recent years to account for the uncertainties introduced by measurement noise, identification errors, and most importantly, modelling errors. The first proposed Bayesian updating methods included the incorporation of prior information into the model updating problem. In the Bayesian model updating method, the posterior probability distribution of updating structural parameters is estimated based on the initial knowledge (i.e., prior distribution) and the acquired data (i.e., likelihood function).

Despite having different model updating methods, there are very limited studies for model updating using Bayesian approach for the low-rise RC buildings, which is the common building type in this world with limited modes and with non-uniform, complex materials used in construction. The studies show that the probabilistic method using the Bayesian approach has better results compared to the sensitivity method for the limited modal data. However, these methods still have certain critical parameters which dictate the accuracy of the method. Initialization and regularization in sensitivity method and prior distribution, and tuning parameters for proposal distribution in Bayesian method needs to be defined appropriately. If we can estimate these parameters with the help of existing database for similar problems, these methods can yield higher accuracy for the system with limited modal parameters and model updating can be realized at a more local scale of numerical modelling level such as strain.

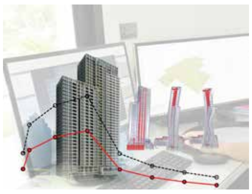
The existence of a large building stock means higher exposure with increased seismic risk, but on the other hand, it can also be considered as a resource called data. As already mentioned, whether it is the regularization in sensitivity methods or tuning in Bayesian methods, the data driven numerical model updating can further bridge the gap between the real-world and the theoretical-world. The data, in this context, refers to the development of NDT test results database, vibration based modal properties database and numerical analysis based modal properties database. The use of machine learning utilizing these databases can improve the accuracy and applicability of the model updating for non-engineered structures.

Performance-based Seismic Design



With its in-house team, AITS has conducted structural performance-based design of over 120 tall buildings located in high seismic zone. For our partners & clients in these projects, AITS conducts highly detailed earthquake simulations to check and improve the structural performance as well as cost-effectiveness. The scope that AITS carries out to evaluate the primary lateral load resisting system for specified performance objectives under different levels of earthquakes.

Structural System Development and Code-based Design Review

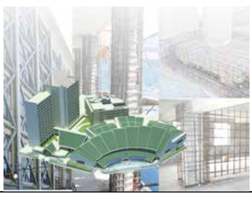


AITS team conducts the structural system development and code-based design review to check the structural design in terms of strength and serviceability requirements as well as conformance to the building codes. Firstly, AITS develops the structural system and provides it to the main structural consultant for detailed design. After substantial completion of structural detailed design by main structural consultant, structural design review is carried out using the information from the structural drawings and documents provided by the main architect and structural consultant.

Computational Modeling and Analysis of Complex Structural Systems

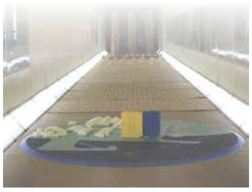
AITS team carries out the computational modeling and simulation of various types of structures with complex geometry and behavior under normal and extreme loading conditions.

Structural Failure Investigations and Retrofit Design



AITS team conducts site investigation as well as structural design review as part of the structural failure investigations.

Wind Tunnel Testing



AITS in-house team works closely with project engineers and developers to enhance the reliability and cost effectiveness of the structural design thereby ensuring occupant comfort, façade design optimization, and improving pedestrian comfort. The wind tunnel test is carried out in the atmospheric boundary layer wind tunnel, in which the working section is 2.5 m wide and 2.5 m high with 23 m long.

Structural Health Monitoring

This advanced analysis technique, researched and developed by AITS in-house team, monitors the structural health of instrumented buildings/ structures. This analysis can be relayed to building managers, developers, engineers, and occupants to assess the safety and reliability of the structure as well as enabling damage detection, especially in a post-earthquake scenario.

Building Information Modeling (BIM)

The Computers and Structures, Inc. (CSi), the pioneering leader in software tools for structural and earthquake engineering, partnered with AIT Solutions to establish CSi BIM Lab at AIT for the advancement of the application of BIM in various aspects of building design, construction, management and operation. BIM Lab team carries out the research and development of platform and tools to read and check the different data format of BIM models as well as development of BIM models from scanned data.

Software Development & IT

AITS in-house team has collaborated with several leading industry partners to research and develop software solutions in the field of structural engineering, mobile computing, knowledge products, construction monitoring & management, travel & leisure, and smart living. AITS develops customized desktop, web, mobile and cloud-based applications to fulfill the needs of partners and clients.

Comprehending Urban Complexity for better Resilience Planning

Yasmin Bhattacharya

With the inevitable progression of climate change, disasters such as floods and hurricanes have become more commonplace in our society; and even non-climate related disasters, such as earthquakes and tsunamis, cause more fatalities today than ever before due to the high vulnerability and exposure rate of our communities. The underlying reason for this are the existing interdependencies of complex urban systems and our inability to comprehend them within the context of rapid urbanization fueled by rural-urban migration trends and economic pressure.

Comprehending Urban Complexity for better Resilience Planning

Ancient cities were never planned; rather they evolved organically. Their evolutionary process included several self-regulatory mechanisms (such as the emergence of streets and neighborhoods) that were based on the day-to-day activities of the people and enabled to systematically sustain the population that inhabited the space. However, the field of modern urban planning which emerged as a means to eradicate diseases, fortify against military attacks, and beautify existing perspectives, has been based on defining a set of planning rules to achieve each of the respective goals. This notion of urban planning as a set of guidelines to design and regulate the urban environment is still very much prevalent today. There is however currently a disconnect between the planning guidelines developed for the urban environment (essentially a top-down process) and our understanding of complex urban systems which actually drive the function of the urban space (which includes bottom-up processes and their interactions).

The management of urban complexity is dependent on comprehending the city as a complex system with interdependencies between demographic, climatic, infrastructural, economic, ecological, cultural, legal, and social aspects (Gurr and Walloth 2014). Only after understanding these and further identifying the implications of planning intervention in such a complex system can urban planning contribute effectively. Research in this field is essential to rectify the current failures of urban planning on several fronts including: the inability to accommodate for uncertainties; lack of flexibility to adapt and formulate policies; and the inability to plant effective 'nudges' in bottom-up processes to direct organic planning processes. In this regard, urban modeling, especially approaches that model 'organized complexity' (Weaver 1948) such as agent-based modeling (ABM) and system dynamics (SD), can be a highly useful.

Tackling uncertainties

The act of planning, especially in consideration to hazards, is almost always scenario-based. This means that there are several underlying assumptions acting as constraints based on which a solution is formulated. Therefore, both the input and the output are limited by our assumptions. In effect this renders us defenseless against un-encountered scenarios. For example, an earthquake hazard input may assume the highest recorded earthquake in the region to date for its scenario, but planning according to the past does not necessarily equip us for an un-encountered scenario. This was the case in Kobe, where with no prior experience of earthquakes, disaster mitigation activities had been aimed at resolving vulnerabilities against the more frequent typhoons, leaving the region completely unequipped to handle earthquake disasters (Shaw and Goda 2004). Similarly, although the Tohoku region of Japan had previously experienced tsunamis, the scale at which the 2011 Great East Japan Earthquake and Tsunami struck surpassed all that the municipalities had been prepared for (Kato, et al. 2013). This calls for the need to envision and consider scenarios previously unheard of which can only be achieved through the simulation capabilities of modeling tools.

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Understanding interdependencies

Hazards in the urban planning context are often seen as a spatial problem. While it is true that urban planning solutions are essentially spatially-based, our comprehension of the problem should be system-based. This is because, in the words of Turner et al. (2003) "vulnerability rests in a multifaceted coupled system with connections operating at different spatio-temporal scales and commonly involving stochastic and non-linear processes." This means that any disruptions (caused by disaster) in a densely interconnected system will almost always lead to a cascading effect of secondary and tertiary damages over the network. For example, a robust road network with many connections may be highly beneficial for mitigating everyday traffic problems by providing alternative routes; however, this same robustness can become a vulnerability in disaster situations as damage in such a network will affect all the connections as well. Hence, interdependencies within the complex urban system must not be neglected.

Furthermore, to increase the resilience of both physical and social systems, urban planning policies should be designed for dynamic rather than the static systems we consider today (Atun 2014). For example, the capacity of storm water management infrastructures of urban areas is designed on the basis of empirical data of past precipitation levels. However, in addition to increased frequencies of heavy precipitation due to climate change, the increase in impervious surfaces due to urbanization has caused the water run-off levels to surge manifold. These dynamically changing environmental circumstances and systems need to be considered in the policy and planning processes, and approaches which are flexible and adaptive to these long-term dynamics need to be further developed. Estimating such dynamics are easier through modeling approaches.

Utilizing feedback mechanisms

Feedbacks are an emergent characteristic of dynamic systems. Some feedbacks are positive (those that amplify changes and cause the system to move away from its equilibrium) while some are negative (those that dampen changes and stabilize the system). Knowing what feedback mechanisms exist in our urban systems is mandatory to be able to correctly position 'nudges' which could drive the system naturally towards a desired equilibrium. Nudges as described here refer to the non-coercive soft measures taken to change behavior (whether it be of a system, a collective, or an individual) as proposed by the Nobel prize winner behavioral economist Richard Thaler (2008).

To explain the idea, we may consider a post-disaster situation: as presented in Fig. 1, there may be three possible equilibrium scenarios achievable as the recovery outcome (A, B and C), but only one which is desirable by the stakeholders (A or C). Without any understanding of the existing feedback mechanisms, it is up to chance how the implemented policies would play out and where the recovery would land. For example, the same individual-oriented compensation policy may cause the individuals of a community to move out to a more attractive city (leading to population decline of the affected region), or it may also drive them to rebuild in-situ (ensuring a sustainable recovery) depending on the pre-existing feedback mechanisms (e.g. community or place attachment) present in the community. Thus, with the knowledge of feedbacks it is possible to utilize the negative or positive feedback loops effectively and plant nudges in the processes to direct the recovery towards a certain desired direction (e.g. in Fig. 1: outcomes A and C are attained through policy 1 and 2, respectively). The identification of such feedbacks and their effects can be revealed by modelling approaches. This would also allow to reform the age-old practice of implementing the same 'best practice' models of urban planning in every scenario by acknowledging that different systems respond differently to similar interventions, and modeling each system separately in order to find the effective intervention for each case (Bhattacharya and Kato 2021).

These dynamically changing environmental circumstances and systems need to be considered in the policy and planning processes, and approaches which are flexible and adaptive to these long-term dynamics need to be further developed. Estimating such dynamics are easier through modeling approaches.

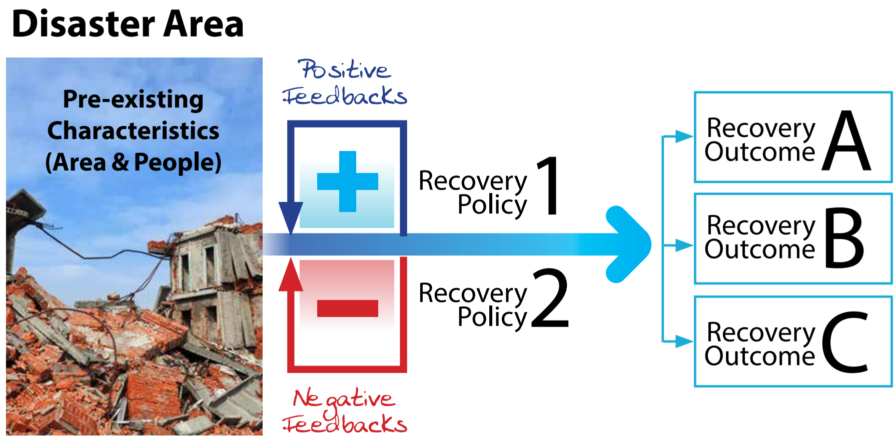

Figure 1: *Post-disaster situation*

Modeling methods for systemic comprehension

We have spoken at length about the necessity of modelling approaches for better resilience planning. It is also important to then comment on which approaches are better suited for our purpose. Though not the only approaches out there, two commonly used methods to model uncertainties, interdependencies and feedbacks are Agent-based Models (ABM) and System Dynamics (SD) models. The advantages of both approaches lie in their ability to understand rapidly changing environments by describing and simulating complex systems. The methods by which they achieve this however are a little different: ABMs focus on modeling individual decision-making entities and their interactions while dynamically linking social and environmental processes; while SDs are more focused on processes and use causal loops and stock and flow diagrams to model feedbacks. One method can be more advantageous over the other depending on the modeler's goal. For example, modeling emergent spatial phenomena is only possible in ABM, while a simpler representation of a complex system can be attained through SD. In addition, multimethod modelling approaches which combine the strengths of each method are also gaining popularity (Gebetsroither-Geringer 2014). It is hoped that with further advances in this nascent field of research and deeper understanding of complex urban systems, we can address urban problems through a more dynamic lens and propose planning solutions that are resilient to uncertainties and dependencies while utilizing urban feedback mechanisms effectively.

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Healthy Rivers and Urban Resilience: Role of Bioremediation as a Green Infrastructural Solution

Jyoti Verma and Uday Bhonde

Healthy rivers are excellent avenues to help mitigate the impacts of floods, droughts, water-related pandemics, and loss of biodiversity. Many urban rivers across the world, especially in developing countries, are in a deteriorated state, mostly because of drains that carry untreated wastewater and empty out into rivers. Bioremediation is one of the green solutions that can be applied to treat domestic wastewater and to minimize industrial pollution by using naturally occurring harmless bacteria, fungi, or plants to degrade substances hazardous to human health and environment.

Healthy Rivers and Urban Resilience: Role of Bioremediation as a Green Infrastructural Solution

It is becoming increasingly evident that healthy urban rivers have a vital role to play in the long-term resilience strategies of cities. For example, rivers with well-defined and well-maintained riparian buffers can reduce the threat of fluvial flooding significantly. However, many urban rivers across the world, especially in developing countries, are in a deteriorated state. This is mostly because of drains that carry untreated wastewater and empty out into rivers. The conventional approach to revive such drains has relied solely on typical engineering and infrastructural solutions. There is growing evidence in literature that non-engineering approaches, such as green infrastructure, are equally effective in addressing such challenges, and additionally provide a range of co-benefits. This article elaborates on the role of green infrastructure, particularly bioremediation techniques, to complement grey infrastructural solutions for wastewater management in drains.

Introduction

It is now well established that water is the primary medium through which effects of climate change are manifested. Already cities across the globe are facing increasing instances of floods, droughts, water-related pandemics, loss of biodiversity, and other detrimental impacts. Healthy rivers are excellent avenues to help mitigate these impacts. For example, rivers with well-defined and well-maintained riparian buffers can reduce the threat of fluvial flooding significantly. Likewise, effective floodplain management can augment depleting groundwater levels, and subsequently enhance the overall water security in the city. The range of ecosystem services that a river provides—i.e. provisioning, regulating, supporting, and cultural—are unparallel. However, many of these ecosystem services are likely to be compromised in light of climate change. Effective and sustainable management of healthy rivers is, therefore, a vital cog in the wheel of any strategy for urban resilience.

Despite their manifold benefits, urban rivers and associated ecosystems are facing increasing threats because of development pressures. One of the main key threats is untreated wastewater, which enters the rivers through drains passing through cities. Cities often rely on costly grey infrastructure to treat wastewater, but they are constantly on the lookout for innovative, cost-effective, and easy-to-manage alternatives. Nature-based solutions (NbS) that make use of natural ecosystems as opposed to engineering structures provide a range of possibilities for treating municipal waste and is gaining traction among governments (WWAP, 2018). Bioremediation is one such NbS option that is widely considered as a safe, effective, low-cost, and environmentally acceptable long-term solution for controlling aquatic pollution (Aktaş, 2013). As the name suggests, bioremediation employs the use of living organisms, like microbes, bacteria and plants, for removing contaminants from water and other environments. The purpose of this article is to succinctly discuss the key features of bioremediation, and its implementation in a real world situation.

De-mystifying Bioremediation

Bioremediation has been practiced to treat domestic wastewater since the mid-nineteenth century. It was originally used to minimize industrial pollution and can be aerobic (with oxygen) or anaerobic (without oxygen). The process uses naturally occurring harmless bacteria, fungi, or plants to degrade substances hazardous to human health or environment. Microbes are deliberately introduced at target sites (e.g., drains emptying into rivers) to reduce pollutant load, rehabilitate polluted areas and increase self-cleansing capacity of the water body, as depicted in Figure 2. The microbes/plants consume contaminants like organic matter like food waste, oil, and convert them to expel carbon dioxide and water (EPA,2012). The procedure aids in the decrease of wastewater's Biochemical Oxygen Demand (BOD) as well as the foul odor.

Figure 1: *A drain carrying polluted water in Delhi*

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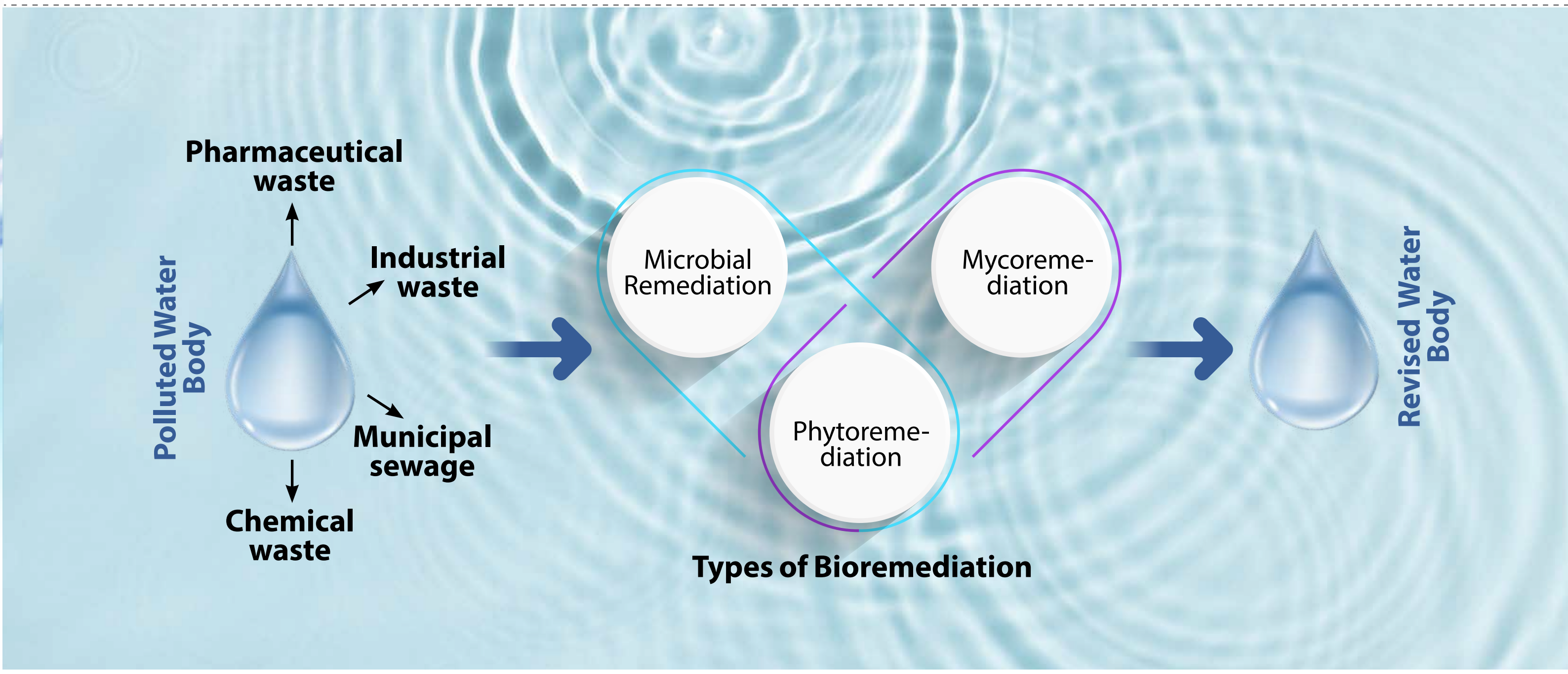

Figure 2: *Impact pathways of bioremediation application for reviving polluted waterbody*

There are two main categories of bioremediation, ***"in situ"***, which is carried out at the site of the contamination itself, and ***"ex situ,"*** that involves excavating the contaminants from the contaminated site and transporting them to a designated treatment site. In situ techniques are relatively less expensive and simpler to adopt because there is no need for excavation (that is typically required for ex situ). Contrarily, ex situ techniques are easier to control, faster, and able to treat a wider range of contaminants and soil types than in situ techniques.

As seen in Figure 2, there are three main types of bioremediation techniques:

Microbial bioremediation: employs bacteria to neutralize and remove the contaminants. The bacteria use the contaminants as a food source and break them down into harmless substances.

Phytoremediation: uses plants to bind extract, and remove contaminants, such as hydrocarbons, pesticides, and heavy metals.

Mycoremediation: uses fungi to break down contaminants, such as pesticides and hydrocarbons, into harmless substances.

Application of Bioremediation

India's National Environmental Engineering Research Institute has developed an in-situ drain treatment technology known as "RENEU - Restoration of Nallah with Ecological Units" (CSIR, 2019) that treats the sewage flowing in drains using nature-based physical and biological operations (Figure 3).

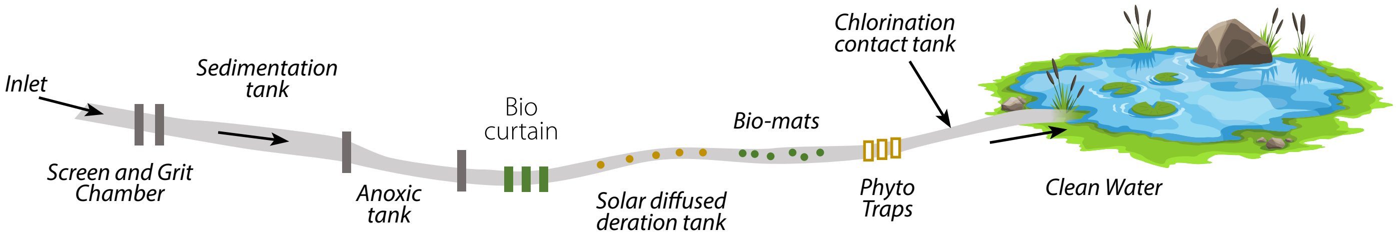

Figure 3: *Schematic diagram showing the RENEU Process*

Before

After

Figure 4: *Application of RENEU Technology in a drain in India*

As a first step, a water-proof base made of brick and mortar is constructed in a selected portion of the drain to prevent the percolation of the wastewater into the soil. Then, provisions are made for placing RENEU's ecological units in different parts of the drain. The first segment of the unit is a physical segment that has filtration gates, which act as sieves to filter the floating matter. From here, the sewage water enters the sedimentation zone, where grit and other suspended solids are allowed to settle down. After this, the water enters the biological segment, which begins with the anoxic zone that has low oxygen. Here, heterotrophic bacteria are introduced to break down some of the organic matter in the water. The water then passes through bio-curtains and bio-mats, where different microbes degrade more organic content present in the sewage. Water then enters the last zone of the biological segment, called fLororaft treatment unit, which contains floating plants. The floating plants not only beautify the drain but also breakdown more organic and inorganic chemicals. The effluent is now in its final leg in the chemical segment. Here, the water is treated with chemicals to kill any disease-causing microbes. From here, water can be used for irrigation, horticulture, or can be safely discharged into water bodies. The technology has been successfully employed in several drains across the country (Figure 4).

Limitations and Recommendations

While there is a growing demand for bioremediation, it has limitations which should be considered carefully before taking it up for river or drain rejuvenation projects. First, it is slower than its mechanical counterparts as all substances are not easily degradable in a short time. Second, the availability of metabolically competent microbial populations, environmental growth conditions and optimum quantities of nutrients, pollutants are vital for its success. Third, the bioremediation process requires relatively stagnant water, which limits it application where there is a constant ingress of raw wastewater.

Despite these limitations, bioremediation is still a good option going forward, especially in this present age where the emphasis is on decentralized management of wastewater, which makes the case for bioremediation stronger.

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Earthquake Risk Perception of Vulnerable Communities in South Asia: Why some residents are willing to take precautionary measures while others do not?

Fawad Ahmed Najam

A significant part of existing building stock in South and Southeast Asia is seismically vulnerable. The challenges of growing population, unplanned urbanization, and low seismic preparedness are also contributing to the seriousness of this situation.

Earthquake Risk Perception of Vulnerable Communities in South Asia: Why some residents are willing to take precautionary measures while others do not?

In the last few decades, earthquakes and associated hazards have resulted in substantial social and economic losses in many countries around the globe. According to the United Nations Office for Disaster Risk Reduction (UNDRR), a total of 552 major earthquakes occurred worldwide between the years 2000 and 2019, which resulted in an economic loss of US $450 billion [1]. These include many large-magnitude earthquakes (M_w 8+) e.g., the 2004 Indonesia earthquake, 2005 Kashmir Earthquake, 2008 Sichuan earthquake, and 2010 Haiti earthquake. These earthquakes resulted in severe physical and economic losses and caused psychological problems e.g. anxiety, fear, and mental distress [2] among those who experienced them.

The Issue of Earthquake Risk in Asian Context

In South and Southeast Asia, the issue of earthquake risk and its implications are serious. Several countries in this region lie in seismically active zones and have already experienced huge social and economic losses in last few decades. Besides the high level of seismic hazard, a primary reason for these losses is poor quality construction and the high vulnerability of existing building stock in these countries. A significant part of existing building stock in many South Asian countries is constructed using weak and seismically vulnerable materials. Take, for example, the case of Pakistan. It has been estimated that around 93% of the existing building stock of the country comprises unreinforced masonry (mostly made of burnt clay bricks). Due to very low lateral strength in out-of-plane direction and high unit weight, this type of construction is highly vulnerable to earthquake ground motions. In many rural and peri-urban areas, the construction of dwellings with irregular shapes or plan irregularities is also common (Figures 1, a). When combined with vertical irregularities, partial flat slabs, and overhangs, such buildings may exhibit poor performance during strong earthquakes due to torsional effects. Many typical two- to three-story dwellings use hollow pre-cast architectural columns for load-bearing purposes (Figures 1, b, and c). These columns may reduce construction cost and time; however, their compressive strength is generally lower than those constructed using structural grade concrete and steel. Therefore, their use in seismically active areas results in an increased physical vulnerability.

Similarly, in rural areas, the construction of houses with unreinforced earthen roofs and stone masonry walls is also common. The stone masonry walls are laid using mud mortar (Figure 2, d), while the wooden frame (or a combination of frames and walls) supports the roof, mostly made of earth and wood. In some cases, the thickness of roof material can be as high as one foot. Such buildings with heavy mass at the top and a lack of integration between their members may fail even under a moderate-intensity earthquake. Another typical feature of residential construction is the use of reinforced concrete frames that are partially filled with burnt clay brick masonry. These walls provide a partial bracing (along the height) to the columns in the lateral direction, resulting in the short column effect (Figure 1, e). Under severe ground shakings, these columns may experience a stress concentration at their mid-heights resulting in shear failure. It is also common for some buildings to have unplanned horizontal or vertical attachments, alterations, extensions, and unanchored appendages (Figure 1, f). Such buildings having horizontal and vertical irregularities are highly vulnerable to earthquake shakings.

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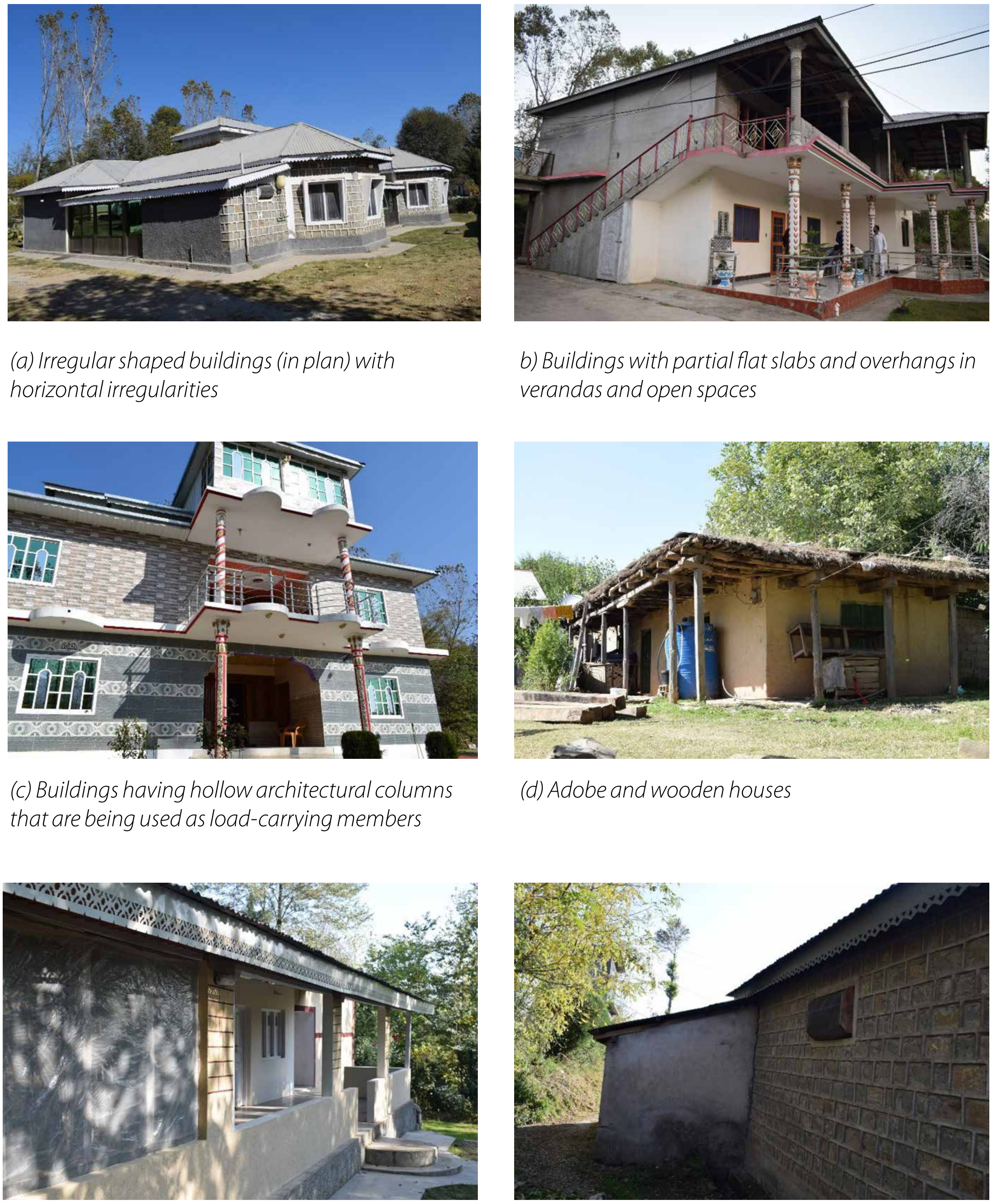

(a) Irregular shaped buildings (in plan) with horizontal irregularities

b) Buildings with partial flat slabs and overhangs in verandas and open spaces

(c) Buildings having hollow architectural columns that are being used as load-carrying members

(d) Adobe and wooden houses

(e) Buildings with short columns. The span between two columns is partially filled with burnt-brick masonry resulting in their partial bracing up to mid-height.

(f) Buildings with alterations, horizontal attachments, extensions, and appendages resulting in horizontal irregularities.

Figure 1: *Few construction features of typical low-rise residential buildings in south Asian countries.*

Besides having a significantly vulnerable building stock, several South- and Southeast Asian countries (e.g., Pakistan, Nepal, Myanmar) are also facing the challenges of increasing population, unplanned urbanization, and growing poverty. These factors have also significantly contributed to an increase in seismic vulnerability and risk in these countries. In fact, it has been estimated that around 37% of the disasters occurred in Asia are primarily due to an increase in urbanization and poverty [3]. Other challenges, e.g., the lack of public awareness about seismic risk, low preparedness level, poor construction practices, and passive role of disaster management institutions, have also contributed to the seriousness of the situation in these countries [4].

What is Earthquake Risk Perception?

Since it is not yet possible to precisely predict the occurrence and location of future damaging earthquakes, the effective risk reduction strategies are primarily based on prior preparedness and loss mitigation. In order to devise effective seismic risk reduction measures, the first step is to quantify the actual level of earthquake risk posed to the built environment. The site-specific probabilistic seismic hazard analysis is carried out for this purpose, which uses the historical and empirical data related to all seismo-tectonic features and sources to forecast the future hazard. However, in certain areas, the required information about the historical seismicity and seismic sources (e.g., slip rates and geometry of causative faults, the exact location of epicenters, magnitudes, and focal depths of past recorded earthquake events) is not available. In the absence of required data, the level of "perceived seismic risk" in a community can be quantified and used to determine the approximate risk. This perceived risk can then be used to propose seismic risk reduction measures.

Risk perception is a subjective judgment made by a person depending upon his/her attitude, mood, or opinion. It is an imaginative picture of the risk posed by a future disaster and involves collecting, selecting, and interpreting signals about uncertain impacts of events or activities [5]. In a certain community, the level of perceived risk may vary depending upon the nature of the disaster and socio-economic conditions of the people exposed to it. For many researchers, risk perception is a personal ruling made by a person about the severity of the risk. Generally, two approaches are used for understanding risk perception: the psychometric approach and the cultural theory approach. The psychometric approach addresses the psychological aspect of human reasoning, including observations, the process of drawing conclusions, and taking actions based upon those conclusions. The cultural theory focuses on cultural models that act as a base for an individual's construction of his cognitive categories and decision-making. In case of earthquake risk, depending upon the level of seismicity of a particular region and its demographic conditions, a significant part of the community may already have the hazard experience. This experience results in increased perceived risk and hazard intrusiveness in such communities that, in turn, may lead to a general acceptance and willingness to the adoption of risk reduction measures.

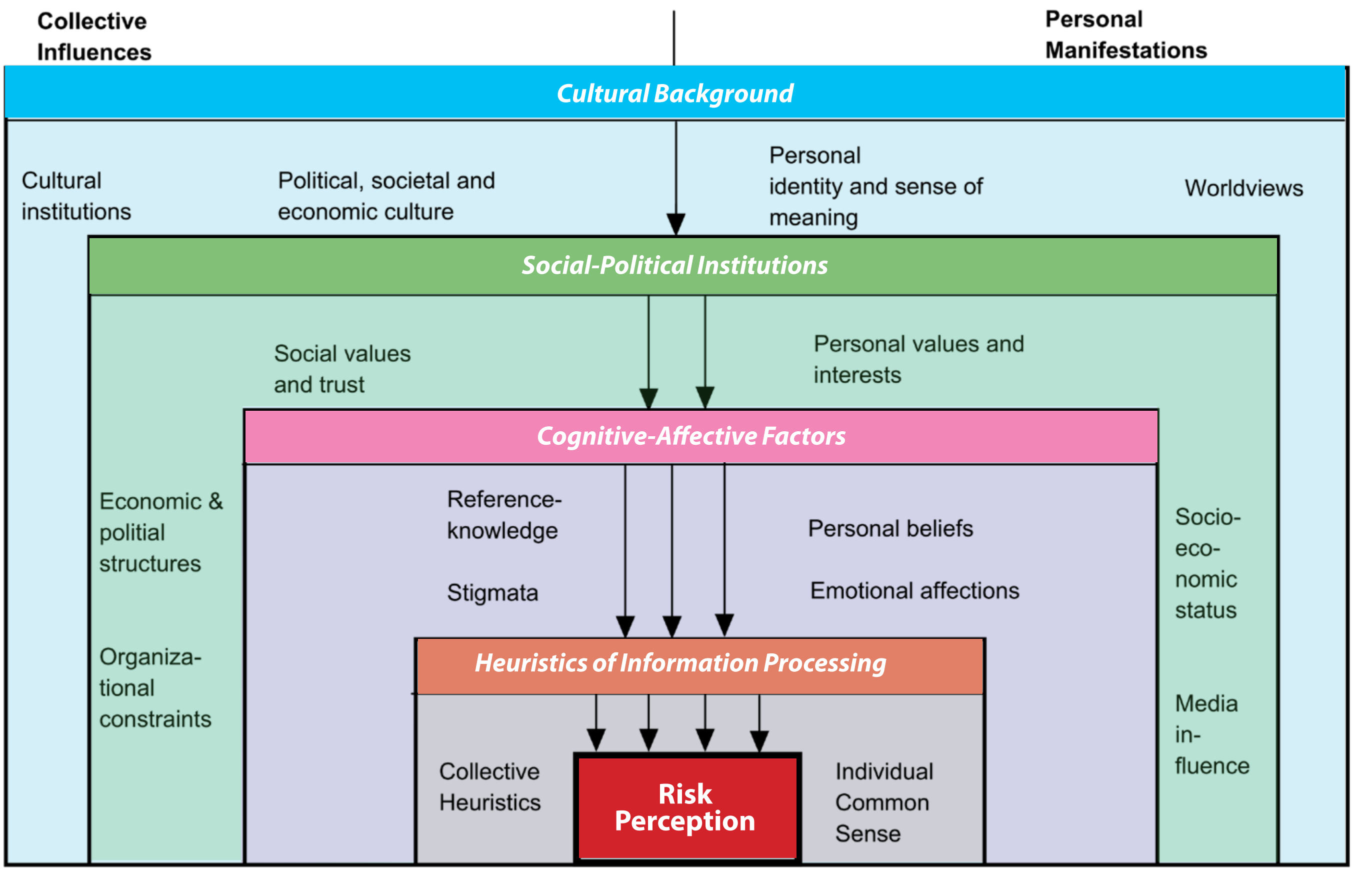

Figure 2: *Four context levels of risk perception [5]*

What Factors Affect Our Earthquake Risk Perception?

Several studies have identified the factors that affect the level of perceived risk in a particular community. For example, Khan et al. [6] have shown that an increase in the physical vulnerability of the houses and poor socio-economic profile results in increased seismic risk perception. Xu et al. [7] analyzed the disaster risk perception, sense of place, evacuation willingness, and relocation willingness among the residents of areas affected by the Wenchuan Earthquake and Lushan Earthquake in the Sichuan Province of China. It was concluded that residents, who already have experienced the earthquake event, have a strong willingness to evacuate and relocate. Xu et al. [8, 9] further showed that the perceived severity of the disaster is also significantly correlated with the evacuation willingness of rural households in China. Similarly, livelihood capital also has an important influence on residents' willingness to relocate [10]. Several studies showed that the past experience, age, gender, and the physical vulnerability of houses are the key factors influencing the earthquake knowledge and risk perception of respondents [6, 11, 12]. Some studies have concluded that religious and cultural beliefs influence the perceived risk more than the disaster experience [13, 14]. Sometimes, owing to their distrust in administrative authorities, people with higher risk perception may also show unwillingness to adopt and invest in protective measures [15]. Generally, people with prior disaster experience, poor socio-economic conditions, and those residing in highly vulnerable houses tend to rate the risk higher [16]. The demographic factors also have an impact on risk perception. Xu et al. [17] showed that the media exposure is negatively correlated with the perceived prospect ranks of the probability and severity of disasters. Xue et al. [18] concluded that trust is more closely related to the perceived level of disaster risks compared to social networks and different dimensions of trust have distinct effects on it. In the context of flood hazards, studies have also shown that the actual risk and perceived risk are positively correlated, and therefore, in the absence of actual risk data [19], the perceived risk can be approximately used to formulate the risk reduction measures.

How Does the Perceived Risk Affect Our Earthquake Preparedness?

Another important aspect in reducing the social and economic losses caused by a future earthquake is the determination of preparedness level at the household level. The preparedness measures include predicting the disaster (where possible), preventing, and mitigating its impacts on vulnerable populations. These measures can help in the reduction of individual and community level vulnerability against seismic events and play an important role in achieving seismic safety. Several studies have identified that the level of perceived risk at household level also influences the preparedness measures adopted by a community. If a certain community has no or very low risk perception, it may cause an increase in their vulnerability (e.g., the inclination to construct unreinforced masonry buildings in earthquake-prone regions). On the other hand, increased risk perception often results in enhanced preparedness for reducing potential risks. Therefore, besides other components, seismic risk perception is also considered an important component of earthquake risk reduction.

Several studies have aimed to establish a relationship between the level of preparedness in a particular community and its risk perception [20]. For example, Uprety & Poudel [21] showed that the concern of a future earthquake and the experience of a past earthquake can significantly influence preparedness. Generally, the people with high seismic risk perception and a prior earthquake experience tend to have better preparedness. Qing et al. [22] evaluated the preparedness and quality of life of farmers in earthquake-prone areas of China and concluded that the adequately prepared farmers perceive a lower disaster risk compared to those who are not prepared. Rustemli & Karanci [20] have shown that preparedness can be predicted by educational background, perceived control, and risk perception. The study concluded that fear (a subset of risk perception) strongly affects the preparedness of a certain community. Gender and education level also have an impact on an individual's risk perception and preparedness level. Mohammed [23] assessed the seismic risk perception and preparedness of high school children and concluded that female students have a higher risk perception and preparedness. Morrissey & Reser [24] concluded that a higher level of psychological preparedness results in an increased level of physical preparedness. Similarly, Hoffmann & Muttarak [25] showed that a higher level of education is also linked with a higher level of disaster preparedness. The role of disaster management institutions is also emphasized in few studies. For example, Costas et al. [46] have shown that the mistrust of residents towards authorities negatively affects their preparedness and participation in disaster risk reduction (DRR) measures.

The study concluded that fear of disasters (a component of an individual's risk perception) strongly affects the willingness to take the preparedness measures in a vulnerable community. The socio-economic conditions and education of an individual also play an important role.

How to Quantify the Perceived Earthquake Risk?

Researchers have quantified the perceived risk and its different dimensions using the statistical analysis of data obtained through structured questionaries and surveys. Table 1 provides a comprehensive list of indicators (divided into four individual dimensions, including fear, awareness, trust, and attitude) to assess the perceived risk of a particular community. In this Table, the subjective weighting method is used to develop the response categories for each indicator and then assign the weights to each category. For this purpose, the Likert scale technique is used to rank people's opinions and judgments from low to high (or from poor to good) [27]. This scale assumes that the distance between each option/choice is equal. Therefore, the relative judgments were converted into numerical values or weights (with values between 0 and 1) by considering the type and response categories of indicators.

Table 1: The indicators used to measure the level of earthquake risk perception of respondents in a particular community.

Sr.	Indicators	Categories	Weights	Explanation
		Fear		
1	Level of the expected earthquake? What is the level of an expected earthquake?	High Moderate Low	1 0.66 0.33	Those who will expect high earthquakes will perceive the risk as greater.
2	Level of afraid: How much are you afraid of earthquakes?	High Moderate Low	1 0.66 0.33	Households afraid of earthquakes will perceive more risk.
3	Extend of damage in future: Do you believe that future earthquakes will cause loss of lives and assets?	High Moderate Low	1 0.66 0.33	Those who think that earthquakes will take lives will have more perceived risk.
4	Possibility of Supply chain breakdown: Do you think there will break down of supplies after an earthquake?	Yes No	1 0	Those who think the supply chain will break down will perceive high risk.
5	Thinking about the earthquake: How frequently do you think about seismic events?	Often Seldom Never	1 0.66 0.33	Those who think frequently will perceive more risk.
6	Pre earthquake 2005 structure? A structure constructed before the earthquake 2005?	Yes No	1 0	Those who have a pre-earthquake structure will feel more fear.
7	Faced earthquake in the past? Have you faced any earthquakes?	Yes No	1 0	Those having earthquake experience will perceive more fear.
		Awareness		
8	Seismicity of the region: Do you know you live in a high seismic region?	Yes No	1 0	Those who understand the true seismicity of the area will perceive high risk.
9	House capability to withstand earthquakes: Do you think your house has the ability to withstand future earthquakes?	No Yes	1 0	Those who think their building is unable to withstand will perceive high risk.
10	Knowledge about emergency plans: Do you know about emergency plans and protocols?	Yes No	1 0	Those who know about emergency plans and protocols may perceive high risk.
11	Precautionary measures: Do you have information about precautionary measures?	Yes No	1 0	Those who have knowledge of precautionary measures will perceive high risk.
12	First aid training: Do you have attended First aid training ever?	Yes No	1 0	Those who will have got trained will perceive high risk.

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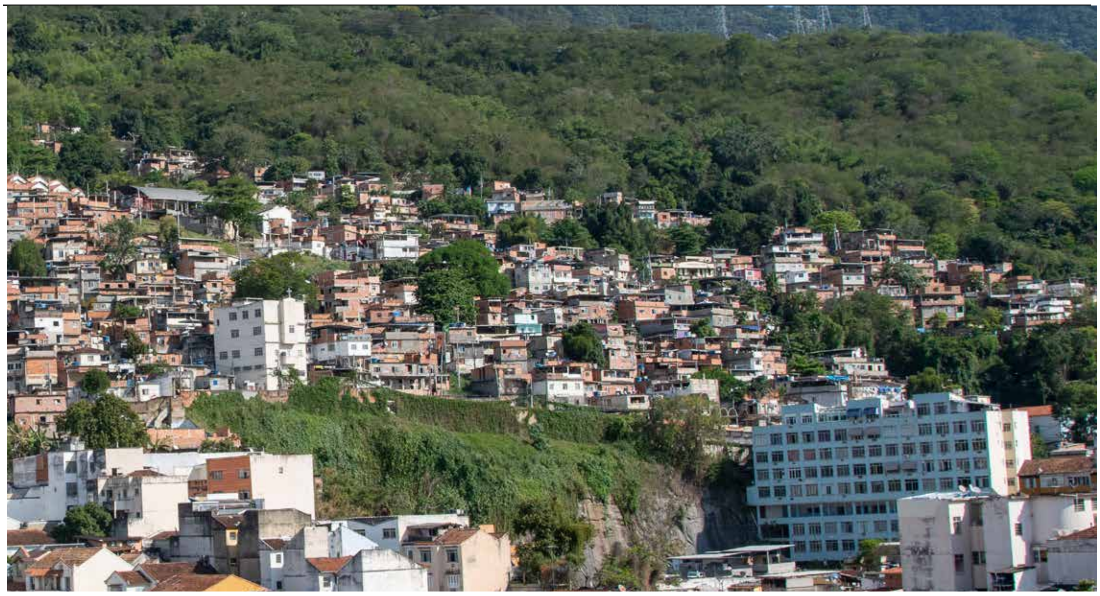
	Trust			
13	Trust in authorities: Do you have trust in disaster management authorities & their policies?	Yes No	1 0	Those who do not trust authorities will perceive lower risk.
14	Trust in media: Do you have trust in information sources like digital & print media?	Yes No	1 0	Those who will have no trust will be less informed and will perceive low risk.
15	Trust in strategies: Do you believe in emergency plans & strategies?	Yes No	1 0	Those who believe in emergency plans may perceive higher risk.
	Attitude / Behaviour			
16	Credibility of building code: Do you think that following building codes will help in reducing risk?	Yes No	1 0	Those who perceive risk will follow building codes to reduce risk.
17	Trend towards migration: In case of any threat, are you willing to follow evacuation/ migration orders by authorities?	Yes No	1 0	Households perceiving risk will follow such orders to save themselves.
18	Earthquake effects: Do you believe that earthquake effects can be minimized?	Yes No	1 0	Those who perceive risk understand that risk can be minimized.
19	Effect of natural hazards: Do you believe that natural hazards are fatalistic? Or can it be avoided?	Can be avoided Fatalistic	1 0	Low-risk perception is associated with fatalism.
20	Allow ability of conventional construction: Do you think conventional construction should be allowed in the high seismic risk zone?	No Yes	1 0	Those who perceive low risk will be willing for conventional construction in seismic regions.



Concluding Remarks

Several countries in South and Southeast Asia are facing challenges in terms of increasing population, mushroomed growth of cities, and lack of implementation of building codes and standards. This is resulting in an increase in the physical vulnerability of their existing building stock. Studies have concluded that the lack of coordination between government authorities, limitations in available resources, and poor infrastructure also contribute to the challenges faced during earthquake disaster preparedness. In this context, the studies focussing on seismic risk perception and its affecting factors can play an important role in policy formulation and improvement of risk reduction strategies in these countries. They can provide an insight into what decisions can affect the choices and priorities of different stakeholders involved in the risk reduction process. This insight can then be converted into effective strategies to convince all the stakeholders to adopt the required preparedness measures in context to their socio-economic conditions.

Continuation

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