INTERNATIONAL CONFERENCE ON SUSTAINABLE INFRASTRUCTURE 2021
Virtual Event | December 6–10, 2021

Leveraging Sustainable Infrastructure for Resilient Communities

ICSI 2021 Abstracts

December 6 – 10, 2021

This document contains the abstracts for the technical content of the ASCE International Conference on Sustainable Infrastructure 2021, held virtually December 6 – 10, 2021. The program was designed by the Technical Program Committee of ICSI 2021, which consisted of:

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Thank you to the many submitters, reviewers, and other contributors that made this conference possible.

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Plenaries at ICSI 2021

December 6, 2021

Remarks: Loic Fauchon, President, World Water Council

Remarks: His Serene Highness Prince Albert II of Monaco

Strengthening Climate Resilience in Water-stressed Communities

Moderator: K.N. Gunalan
Speaker: Shamila Nair-Bedouelle, Assistant Director-General for Natural Sciences at the United Nations Environment Programme (UNEP), UNESCO

How Do We Scale Sustainable and Climate Resilient Infrastructure to Achieve the UN SDGs by 2030?

Moderator: Elise N. Zoli, Partner Jones Day/Stimson Center/ACRE
Speakers:
- Joyce Coffee, President, Climate Resilience Consulting
- Frank Nutter, President Reinsurance Association of America
- Peter Hall, Vice President/Wood Engineering/ACRE Ambassador COP26
- Andrew Wishnia, Deputy Assistant Secretary for Climate Policy, US DOT

This plenary will speak about how we scale sustainable and climate resilient infrastructure to achieve the UN SDGs by 2030. Our goal is to provide insight on what to expect in a solutions-oriented manner, recognizing that infrastructure investment is estimated at $100T by 2030 by the World Economic Forum.

December 7, 2021

Post-Black Swan Infrastructure: Lessons Learned and Plans for the Future

John Williams, Nick Russo, Minelly De Coo, Mark Pestrella, David Miller, Hardeep Anand

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ABSTRACT
This moderated panel pauses to ask the question, "what did we learn from recent Black Swan (major unpredictable) events and recession that now influences infrastructure planning decisions?" It has never been clearer that much of the infrastructure that we rely on to move us around, support our economy, and keep us safe as well as healthy needs significant rethinking given the implications of the last year.

This panel includes leaders from four major jurisdiction in two countries. Each had their own unique, regionally specific challenges. Each took different approaches to setting the stage for recovery and enhanced resilience. Each is assuming that federal funding will catalyze a transition to infrastructure that is up to the challenges of the 21st century. There will be strings attached to that funding in the form of new expectations in response to climate change, the ongoing threat of pandemic, systematic racism, as well as public security and questions of fairness and equity. Infrastructure projects are shaped by the engineering community.

Mayor Miller and his panelists will describe how they are collaborating with and shaping the direction engineers move in as they respond to new demands. He will also probe ways in which each city and county are preparing to make the case for sustainability given extreme economic pressures.

The audience can expect to hear about flood control, mobility, communications, water supply, and global supply chain initiatives. They will also hear about plans for innovation in procurement, economic analysis, and steps being taken to leverage infrastructure investments lift the vulnerable class.

Engaging to Serve: Fighting Systemic Oppression through Systematic Community Engagement

Frederick Paige*[1], Yvette Pearson[2] and Joseph James[3]

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Keywords: ABCD, Citizenship, Community, Engagement, Equity, Ethics, Partnerships, Universal Design, User-Centered Design

ABSTRACT

By definition, and in alignment with the ASCE Code of Ethics, civil engineers are expected to serve society. "How" civil engineers protect the health, safety, and welfare of the public is dependent on "why" civil engineers engage communities. In this session, presenters will discuss how and why civil engineers should partner with the communities they serve. Appropriate engagement leads to an improved quality of life for all and better design. Inappropriate engagement leads to inequitable infrastructure systems and decreased productivity. Inequitable infrastructure systems are inefficient systems that underserve some and overserve others. A design that results in an imbalance will prematurely require a redesign and creates other issues such as mistrust.

 Civil engineers design, develop, and construct socio-technical infrastructure systems and further guidance is needed to better serve communities that have been oppressed. While ethics are critical to consider, even a well-intentioned civil engineer can design infrastructure systems that reduce the human experience to a life plagued by environmental racism, economic instability, miseducation, famine, contaminated water, limited accessibility and other inequities. Civil engineers benefit from gaining competence in engagement practices and socio-technical theories to complement their technical expertise. Presenters in this session will share examples of effective engagement strategies using social innovation frameworks (e.g., active citizen continuum, asset based community development [ABCD], innovation spiral, and engagement quadrants). By presenting social innovation frameworks in the context of infrastructure project case studies, participants will be provided guidance on how to appraise their current engagement protocols, reflect on previous engagements, and devise future engagements.

December 8, 2021

Community Equity Agreements (CEAs): Engaging with Frontline Communities to Identify and Incorporate Enforceable Commitments During the Design and Review of Major Infrastructure Projects

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ABSTRACT

This moderated panel is aimed at addressing a dilemma experienced by frontline communities, where people live adjacent to or nearby major infrastructure initiatives. Those communities are at risk for being "crushed" because of projects being granted some form of pre-approved status aimed at accelerating the environmental review process. While cases can be made in exceptional times for finding ways to reduce the overall time required to progress from early-stage planning through environmental review, permitting and the beginning of construction, projects that are viewed as essential can also be seen as having a guaranteed path to approvals. That perception or even reality can place local people at odds with ultimate outcomes. When this happens, those people and their communities can experience a disadvantage that leaves them vulnerable to an unfair project development.

Members of this panel are community advocates, experts in project delivery and permitting, and an international project developer. They will share perspectives on ways in which local people are vulnerable to the impacts of project development. They will define the term, Community Equity Agreement (CEA), offer examples of how such an agreement might be used during a typical or accelerated environmental review process. They will describe elements of a CEA that are emphasized within the emerging ASCE Sustainable Infrastructure Standard. They will focus on ways in which the local community can leverage CEAs and the SIS to assure that they receive a fair and equitable deal as being part of an infrastructure development plan. Just as important, they will clarify equity expectations associated with federal funding (particularly Merit Based Grants) resulting from stimulus spending.

The audience will be introduced to a case example in the form of development plans for 21st century air cargo facilities to be located at three or more major U.S. airports. The projects, among the first to commit to piloting both the CEA and the ASCE Sustainable Infrastructure Standard, will illustrate how multi-billion-dollar infrastructure projects can

lift vulnerable communities and provide multi-generational benefits that change worker lives as well as the future of their families and host communities for decades to come.

World-Class Sustainability Leadership through a Diverse Workforce: Panel Discussion for the International Conference on Sustainable Infrastructure (ICSI) 2021

Keywords: Diversity, Inclusion, Leadership, Sustainable Infrastructure, Women's Leadership

ABSTRACT

World-class talent in the sustainability industry begins with supporting a diverse scientific community that is made up of unique experiences and various points of view. This Women's Leadership panel discussion will address the importance of diversity and inclusion in the Sustainability profession by a panel of highly accomplished women leaders. These leaders will share their professional journeys, advice, and their contributions to the profession. This session is intended to evoke inspirational discussion and encourage all of us to embrace diversity as part of achieving excellence in sustainability.

Roles and Panelists (order of speaking)**:**

Christine Harada, VP of Government Affairs for Heliogen and Former US Federal Chief Sustainability Officer, Panelist

Catherine Flowers, founding director of the Center for Rural Enterprise and Environmental Justice, Vice Chair of the Biden Administration's inaugural White House Environmental Justice Advisory Council

Gretchen C. Daily, Ph.D. , Co-founder and Faculty Director of the Stanford Natural Capital Project, Bing Professor of Environmental Science; Senior Fellow in the Woods Institute; and Director of the Center for Conservation Biology at Stanford University

Tera Haramoto PE, Civil Engineer, Los Angeles County Public Works, Moderator

Engagement and Advocacy for Investment in Sustainable and Resilient Infrastructure

Donald Anderson[1], Jimmy Kemp[2], and Tyron Picard[3]

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This panel of lobbying and community engagement experts will discuss the importance of private and public collaboration in creating successful partnerships and compelling narratives to support infrastructure investment to develop resilient communities.

Speakers:
- **Tyron Picard,** Founder of The Picard Group**,** a full-service governmental affairs consulting firm with offices in Louisiana and Washington DC. The Picard Group assists clients with the strategic planning and execution of communications and relationships to promote ideas and priorities with federal, state, and local government.

- **Jimmy Kemp**, Executive Director of the Empower America Project and President of the Jack Kemp Foundation. Both organizations seek to advance the American Idea, which is rooted in the vision that each human person is created with inalienable rights to life, liberty, and the pursuit of happiness.

Innovation for Sustainable and Resilient Infrastructure

Jerry Buckwalter[1] and Edgar Westerhof[2]

[1]Chief Innovation Officer, ASCE
[2]National Director for Flood Risk and Resiliency for North America, Arcadis

The International Coalition for Sustainable Infrastructure Innovation Action track has been working to highlight innovative sustainable and resilient projects and programs from around the world. This session will explore the work completed to date by highlighting key sustainability programs that move innovative thinking forward, our research into the most innovative sustainable and resilient projects from around the globe and recognize exemplar cities leading in sustainable and resilient innovations. The discussion will focus on the areas in which we have found important ongoing innovation, areas in which more innovative approaches are needed, and on case studies representing multi-faceted and systems-focused innovation.

Ensuring Infrastructure is Resilient and Sustainable - Advancing the Triple Bottom Line - Standard Requirements for Sustainable Infrastructure – An ASCE Standard

Jim Rispoli[1], Brad McCoy[2], Tom Bostick[3], Jennifer Cass[4], Katherine Gregory[5]

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[2]Chair, ASCE Committee on Sustainability, Sustainable Infrastructure Standards Committee
[3]Chair National Academy BICE, former Chief USACE
[4]Senior Vice President & Chief of Staff, Capital Program New York City Economic
[5]43rd Chief of the Naval Civil Engineer Corps and currently the COO for Fermilab

This panel will discuss the importance of applying a consistent approach, by owners and the engineers who serve them, to designing in sustainability. The panel will deliberate on a higher order notion that we need to do better and be more consistent in our approach to providing more sustainable infrastructure going forward.

Global Adoption of Sustainability Standards

Brian Finlay, President & CEO, The Stimson Center

Hot Topics at ICSI 2021

December 6 - 9, 2021

Doing the Right Projects on the United States-Mexico Border

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ABSTRACT

The border between the United States and Mexico extends 1,954 miles spanning communities, cities, rivers, and areas of environmental significance. People, goods, and services regularly cross this border facilitated by large systems of infrastructure. For both countries the economic impact of these infrastructure systems extends far beyond the border region itself. This panel will explore the importance of cross-border infrastructure as both countries work toward a sustainable and resilient future. Specifically, the panel will consider the sectors of energy, water, and transportation that are critical to the well-being and economies of communities on both sides of the border.

As an example of how market forces drive cross-border infrastructure development, in Baja California Mexico is currently developing renewable energy sources to help supply the growing demand for renewable energy in Southern California. Meanwhile, in northern Mexico natural gas imported from Texas is a significant source of energy. In February 2021 the arctic weather disaster in Texas led to cutoffs of natural gas to Mexico leaving almost 5 million people without power and halting manufacturing. This highlights the interdependence of communities on cross-border infrastructure.

If planned well cross-border infrastructure can increase sustainability and resilience. However, if not planned well, it can become a new source of risk and exacerbate the impacts of natural disasters on a national scale. The panel will assess the challenges and opportunities of cross-border infrastructure through the lenses of governance, development, and finance.

Come Hell and High Water:
Building Resilience for a Sustainable Houston

Sharon Citino*[1], Stephen Costello, P.E.*[2], Adam Eaton, P.E., ENV SP*[3], and Laura Patiño*[4]

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ABSTRACT

In August 2017, Hurricane Harvey ravaged the Houston area with one trillion gallons of rain over three days. No other large American city has endured such a natural disaster in modern times. In the five years since, Houston has recovered from six more federally declared flooding disasters, including Tropical Storm Imelda in September 2019, that tested the limits of the City's physical and fiscal infrastructure. These storms and the cumulative impacts and recovery effort were the catalyst that led to unprecedented momentum to address the challenges Houston faces. Not only is Houston especially susceptible to devastating flooding events, but it is also expected to endure temperatures above 100° F for fifty-five days per year by 2100, which will further threaten health, livelihoods, and infrastructure.

In the face of increasingly severe and potentially more frequent climatic changes, Houston adopted *Resilient Houston*, a progressive and ambitious framework aimed at strengthening the City's ability to address and recover from acute shocks and chronic stresses. The plan identifies the goals, targets, and actions necessary to ensure safety and equity, encourage innovation and adaptation, and live safely with water to better serve all Houstonians, present and future.

This presentation will include discussion of the *Resilient Houston* framework and a detailed look at how Harvey Recovery programs, large-scale hazard mitigation projects, and One Water and Stormwater Master Planning efforts are being utilized to support health, housing, and economic development to ensure equity for all Houstonians.

Incorporating Holistic Sustainability and Resilience into Civil Engineering Projects

Elaina J. Sutley*[1], Donovan Finn[2], Caroline Field[3], and Jarrod Loerzel[4]

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ABSTRACT

Investing in sustainability and resilience in the context of civil infrastructures systems delivers value by reducing disruption, speeding recovery, connecting our communities, supporting our way of life, delivering productivity gains and economic growth, reducing environmental impact, and providing enhanced protection. However, these types of investments are not codified, leaving stakeholders asking "how"? This session will ask panelists thought-provoking questions on what practices in design, planning, and operation of civil infrastructure projects can deliver social, economic, and environmental value to communities. Four panelists, from diverse backgrounds, will draw from their experiences with measuring and enhancing community capacities across the lifecycle of an infrastructure project. They will cover organizational functionality, environmental justice and social equity, local-level recovery planning, and measuring resilience value from a community housing project, each expanded herein. Questions and discussions from this session are transferrable to a range of actors beyond civil engineers, including urban planners, policy makers, or regional developers, preferably collectively in a collaborative manner across these groups. The session will designate 30 minutes to open discussion with the audience, and will conclude with a synthesis from the moderator.

Measuring community capitals. Inherent to all communities are six capitals, namely, built, social, human, political, natural, and financial. Community resilience and sustainability assessments should work across all six capitals in evaluation and planning. Civil infrastructure is a major part of the built capital whereby it plays an important role in supporting the other five capitals. To date, metrics associated with standardized civil engineering procedures and guidelines relate to physical properties and the function of the finished project. For example, engineers evaluate bridges on the number and width of lanes (i.e., capacity) and the loads that they can carry. Similarly, they evaluate buildings on compliance with applicable building codes, fire ratings, and zoning regulations. While these metrics are important, it is difficult for taxpayers or developers to see the linkage to life, safety, health, and welfare outcomes, particularly at the scale of a community. This failure to create linkages undermines a popular awareness of the important role that infrastructure plays in our daily lives. It is not enough for engineers to provide a design that functions, they must also contribute to sustainable development as stewards of the natural environment while also incorporating distributional equity and procedural justice considerations of the communities they serve and support.

The application of measuring broader social and economic outcomes is gaining traction, particularly on large projects that provide both positive and negative impacts on communities. The American Society of Civil Engineers Infrastructure Resilience Division Committee on Social Science, Policy, Economics, Education, and Decision (SPEED) focuses on integrating social science and economics into the planning, design, and management decisions surrounding physical infrastructure projects. With two representatives from the SPEED committee, this session will present one timely SPEED project that focused on identifying metrics that allow for quantification of socially driven outcomes into civil engineering projects within the discourse of resilience. The project reemphasizes that investing in resilience in the context of infrastructure systems delivers value by reducing disruption and speeding recovery; connecting communities; supporting our way of life; delivering productivity gains and economic growth; reducing environmental impact; and providing enhanced protection. Such metrics spanning the community capitals can be employed in various project phases, including planning, design, and operations, for individual projects. The metrics can also be used for a community-wide assessment across infrastructure projects to evaluate sustainability and resilience capacity, and measure how these capitals are disrupted after a disaster event.

Social equity and environmental justice. Social equity and environmental justice are getting national attention with President Biden's issuance of Executive Orders 13985 and 14008. Numerous federal agencies are gathering data and interacting with civic leaders, policy makers and the general public to support the goals articulated in each Executive Order. The information and data will provide an opportunity to examine social equity and environmental justice in a community's ability to bounce back from disasters.

In the U.S., disaster recovery is stricken with inequities. This is observed through the ever-present intersection of physical and social vulnerability that exists before disaster strikes, which leads to those with the least resources to recover being hit harder and more often by disaster, and results in exacerbated inequalities. An example of such disparities is the City of Lumberton, NC, a diverse community with median income far below the U.S. average. Lumberton suffered extensive flooding following Hurricane Matthew in 2016 and again following Hurricane Florence in 2018. On-going research by two panelists shows that household dislocation is as much of a function of flood damage as of race and ethnicity. Applying a spatial lens to explore social equity and environmental justice issues as they relate to flooding, the spatial intersection of the racial distribution within Lumberton and flood prone areas is evident. More poor, black, and American Indian residents live in the floodplains, compared to wealthier, white residents living North of the Lumber river at higher elevations.

These relationships are common in the U.S. To assist communities in being better prepared for disasters, NIST is developing tools to address social equity and environmental justice. Use of these tools with infrastructure projects requires an inclusive process that engages stakeholders that understand and represent the diverse community values, culture, and needs, and may include: representatives from the local government, such as community development, public works, and building departments; public and private developers; owners and operators of buildings and infrastructure systems; local business and industry representatives; representatives of community organizations, non-government organizations, health and educational institutions; and other stakeholders or interested community groups, such as residents of public housing.

Hurricane Sandy. The recovery process after Superstorm Sandy was unique in that the most heavily affected region (the greater New York Metro area) is rich in financial resources and political capital as compared to many other parts of the country. As such, the region approached long-term recovery and resilience in a number of unique ways. The federal government, the states of New York and New Jersey, New York City, and even some of the smaller municipalities in the region have access to significant expertise related to resilience planning and engaged in a number of innovative programs designed to help communities recover from Sandy, while at the same time injecting future resilience into all of these efforts. This resilience mandate originated in part from the federal government, best embodied in the Hurricane Sandy Rebuilding Strategy developed by the Hurricane Sandy Rebuilding Task Force, and found its way into on-the-ground efforts ranging from HUD's Sandy Recovery Infrastructure Resilience Coordination Group as well as the agency's National Disaster Resilience Competition, the New York Rising Community Reconstruction Program, and New York City's Special Initiative for Rebuilding and Resiliency.

In all of these efforts the recovery process was in large part an opportunity to rebuild infrastructure and to radically rethink infrastructure planning and design for a new era of increased risk by prioritizing innovative design solutions, cross-jurisdictional collaboration, community participation, and holistic solutions emphasizing economic, social and environmental co-benefits. Some important drivers of this approach include planning and engineering expertise available in the region and a combination of top-down and bottom-up factors including a federal emphasis on resiliency, a long history and culture of local planning, experience with previous disasters, and a strong civil society sector intent on promoting a just and equitable recovery, among other factors. At the same time, these successes have been limited by the enormous costs inherent in some of the necessary resilience strategies, the region's complex political fragmentation, congressional restrictions, and other factors that must continue to be addressed.

Community housing project. The "We Can Make" Community Housing Project was born as a 'bottom-up' response to community demands and concerns about housing need in Knowle West, one of the most deprived areas of Bristol, UK. We Can Make uses an asset-based approach to re-imagine "how to do housing" differently in Knowle West. It starts with the know-how and resources the community already has, and uses a process of co-design to work with people to develop the tools to do housing on their terms. They call this approach "urban acupuncture" – where people with particular needs opt in to using a small piece of land to meet their housing needs.

We Can Make is about much more than just delivering housing "units". It is important that the process of building new homes contributes to the wider economic regeneration of the neighborhood, including creating new jobs and skills for local people. We Can Make uses Modern Methods of Construction (MMC) and they have developed a community fabrication space, KWMC: The Factory, as a neighborhood housing factory. They provide training for local residents and tradespeople to learn new digital construction skills. Architects and residents have worked together to create the designs for the first two We Can Make homes. Many resilience and sustainability metrics were utilized to capture individual, community and broader project benefits including social, economic, and environmental value. This will be presented and discussed, articulating the value delivered by this community-led approach to housing.

Current Sustainability Practices of U.S. Transit Agencies: Panel Discussion for the International Conference on Sustainable Infrastructure (ICSI) 2021

Antoinette Quagliata, ENV SP, LEED AP*[1], Cris Liban, DEnv, PE, ENV SP*[2], Amy Shatzkin*[3], and Rachel Healy*[4]

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ABSTRACT

This panel will offer attendees an overview of current U.S. transit agencies sustainability practices, along with specific examples of these practices in use. The panelists will offer takeaways on lessons learned through the process of incorporating sustainability into current practices, along with insight as to the role that transit agencies play in making communities sustainable – and areas of focus in order to do so effectively.

This panel features speakers from several of the country's largest transit systems, discussing current sustainability practices across the U.S. transportation industry.

Antoinette Quagliata, ENV SP, LEED AP, will provide an overview of transit sustainability initiatives across the U.S., including federal updates. She will offer a broad view of resiliency practices and tools in use by major transit agencies, such as Envision®, the LEED® green building program, agency policies, funding strategies, and APTA sustainability commitment. Panelists from Los Angeles County Metropolitan Transportation Authority, Sound Transit, and Washington Metropolitan Area Transit Authority will each describe sustainability practices within their respective agencies, share success stories, and offer lessons learned in developing their programs.

These brief presentations will be accompanied by a moderated discussion on the future of sustainability within transit agencies, and how to measure success.

Climate Migration and the Importance of Host-Recovery Cities in Disaster Recovery

Jordanna Rubin

Vice President, Resilience and Disaster Recovery, AECOM
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ABSTRACT

While advances in technology and climate modeling have continued to improve forecasting of natural disasters with increasing precision, little is known about the impacts and consequences of human migration or "climate refugees". Even less is known about the impacts to the cities that work to absorb the dispersed communities. Because the United States doesn't have a comprehensive way to track evacuees, little is known about these populations that end up in shelters or move to other cities. This has prevented the adoption of policies, interventions and funding for the "Host Recovery Cities" to help evacuees rebuild their lives.

These Host Recovery Cities, at many times, are not located in a federally declared disaster area and as a result, are not eligible for federal recovery dollars. However, it is the Host Recovery City that must absorb and support the dispersed communities. These cities must quickly pivot to ensure that infrastructure can support an increase in demand, identify ways to cover the cost of short- and long-term changes, and ensure that safety and social services can support the city's population.

Gordie Howe International Bridge: Connecting Communities Beyond Four Wheels Panel Discussion for the International Conference on Sustainable Infrastructure (ICSI) 2021

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ABSTRACT

The Gordie Howe International Bridge project includes construction of a 2.5 kilometre bridge, two state-of-the-art ports of entry and a Michigan Interchange connection. It is one of the largest international infrastructure projects underway along the Canada-US border. Valued at $5.7 billion (CAD), it will deliver much-needed transportation improvements for travelers between Windsor, Ontario and Detroit, Michigan, and broader regional socioeconomic opportunities.

While the 0.5-mile bridge river crossing will be the most visible portion of the project, the broader scope of this bi-national, complex P3 megaproject is unique for its focus on community and attention to sustainability and human experience. Commitments to enhancing public space, connectivity, and mobility for all roadway users and skillful integration of large-scale infrastructure components within the local streetscape network differentiate it from similar transportation projects.

This session will address:
- Community-driven and collaborative approaches taken to deliver this major infrastructure project between two nations, six levels of government, and two economically and socially diverse communities
- Project team, community and government partnerships to create meaningful, sustainable benefits for adjacent neighbourhoods and lessen the burden of construction
- Best practices and engagement principles implemented throughout the project life cycle.

The following case studies will show a 360-view of how the owner, constructor and communities worked together to identify and achieve shared ownership of outcomes:

- **Incorporation of an International Multi-use Path:** During the procurement phase, the Owner amended the bridge's design scope to include a cross-border multi-use path following a groundswell of community requests. The project and local governments are now investing in complementary initiatives to develop and connect regional active transportation networks.
- **Community Benefits Plan Development:** A three-year consultation and engagement process occurred over the procurement and design phases to incorporate local community priorities into the project's robust Community Benefits Plan. This provides tailored workforce opportunities and neighbourhood infrastructure benefits for the region, above and beyond the project's physical infrastructure.
- **Local Road Improvements:** In recognition of the host communities' new role as a gateway community and in response to public consultation, accessibility enhancements were incorporated into the project scope through local road improvements to be undertaken in Canada and the US adjacent to the project footprint. These include road reconstruction, intersection improvements, cycling facilities, and several pedestrian bridge crossings over Interstate-75.

In addition to proactive and responsive stakeholder and community relations, the integration of access and mobility enhancements and overall community benefits initiatives were leveraged within project plans and design outcomes to further advance the project's overall target Envision award level.

Visit www.gordiehoweinternationalbridge.com to learn more about this once-in-a-generation project.

Kowis Street Improvements: The First Harris County Area Project to Pursue Envision Verification

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Moderated By: Niki Foster, P.E., ENV SP, KCI (E-mail: niki.foster@kci.com)

This session provides the "real deal" information about cost concerns, cost estimating issues, the need for alternative bid items, the uncertainty about the level of verification that will be achieved, challenges with obtaining sufficient contractor interest, concerns about number of construction proposals to be received, and other real issues.

Topics of Discussion will include:

1. Existing Infrastructure, Social, Economic, Cultural, and Equity Conditions
2. Stakeholder Engagement During Covid-19 Pandemic
3. Stakeholder Input
4. Alternatives Developed and Presented
5. Policy Commitments (Safety, Skills, Procurement, Resilience, Traffic)
6. Project Cost Estimates, Value Engineering, and Pending Choices
7. Construction Procurement Method (RFP)
8. Current Status

Justice, Equity, Diversity, and Inclusion (JEDI): Improving Our Profession, Improving Our World

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ABSTRACT

The terms justice, diversity, equity, and inclusion (JEDI) are often treated as buzzwords that amount to little more than counting people and perhaps a mandatory annual training. The reality is that JEDI (or the absence of JEDI) impacts every facet of the organization. When JEDI is a priority, the benefits are vast; it results in improvements in the quality and innovation of engineering design and problem solving, organizational culture and climate, and the fiscal bottom line. While there isn't a one-size-fits-all JEDI rule book for organizations, there are best practices that can be adopted or adapted to improve outcomes for all stakeholders, including society as a whole. The American Society of Civil Engineers (ASCE), through its board-level body MOSAIC (Members of Society Advancing an Inclusive Culture), has curated a set of resources called the Best Practices Resource Guide (BPRG). This session will highlight actionable strategies from the BPRG on areas such as communications, partnerships, assessment, accountability, leadership, and events.

At the end of this session, participants will be able to: define justice, equity, diversity, and inclusion (JEDI); recognize the impacts of JEDI (or the lack thereof) on organizational and societal outcomes; and create and implement action plans toward engaging diverse teams in just, equitable, and inclusive engineering education and practice.

A New Day for Green and Multi-Benefit Infrastructure/Programs in LA County: The Safe Clean Water Program

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ABSTRACT

In 2018, voters in Los Angeles County, California passed Measure W to establish the Safe Clean Water Program (Program). This one-of-a-kind Program has empowered the County to step up its leadership in multi-benefit and green infrastructure, fostering a paradigm shift across the entire region that is sustained by ongoing resources, collaborative and diverse governance, and robust equity and stewardship provisions to establish a lasting and meaningful trajectory. The lofty goals of the program are centered in three primary objectives – improving water quality, increasing water supply, and enhancing communities and public health – and have already led to significant multi-benefit investments across the region. The adaptive Program implementation and management process, in tandem with focused engagement with (and participation by) others, continues to create a space to explore and implement green infrastructure now and in the future.

The County's own stormwater project development efforts have been a model of success during early implementation phases, demonstrating the principles of the Program in numerous ways and bringing together multiple entities to advance the Program goals in efficient and innovative ways. Many years of partnership and planning within the region had laid the groundwork for this exciting new era, but the paradigm shift is finally here – and we invite all to learn more about the Program itself and the related efforts by the County to maximize this opportunity and lead by example.

The Resiliency Cycle

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Keywords: resilience, climate change, coastal, natural disasters, recovery

ABSTRACT

In the face of changing climate and growing costs of natural disasters, resilience of built and natural systems and communities is vital. Resilience is most often defined as the ability to bounce back or recover from a shock or disaster. The speed and cost of this recovery is not fully based on a single event, but is based on the planning, design, and preparation completed in advance of the disaster, the ability to resist/absorb the disaster, and then the post-disaster response and adaptation efforts. After a shock or disaster there is a reevaluation period and modifications are made to the plans, designs, and response methodology to decrease the time and cost of recovery from subsequent disasters – RESILIENCE.

This presentation/panel discusses how true resilience is a cycle that transitions from planning through disaster recovery and back to planning. Aspects of the resilience cycle will be discussed from assessing risk and vulnerability, planning and prioritizing, designing and implementing solutions, responding to natural disasters, recovering, adapting, and then back through the cycle by sharing details from federal, state, and engineering viewpoints. This will include Federal (FEMA) and State (Louisiana Coastal Protection and Restoration Authority) perspectives, together with engineers and disaster response and recovery professionals discussing the interconnectivity and interaction of the elements of the Resiliency Cycle.

Special Sessions at ICSI 2021

December 6 & 7, 2021

Solving Infrastructure Disaster Recovery Problems in Consideration of UN Sustainable Development Goals

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ABSTRACT

The United Nations Sustainable Development Goals (SDG) were agreed in September 2015 and came into effect on 1 January 2016. Since that time there have been many disasters, and a similar number of efforts to recover.

Ricciardelli et al. (2018) indicates that the SDGs are "universal, ambitious, and comprehensive," before commenting that implementation of the SDGs is not "an easy endeavor… as increasing disaster risks represent an immense challenge to the success of the outcome of SDGs and its target actions."

Peng et al. (2013) has noted that sustainable development requires "balancing reconstruction with economic, environmental, and social considerations," while Tuhkanen et al. (2018) points out that the SDGs require "identification and negotiation of trade-offs and competing interests," which are not insignificant issues.

One target of the SDGs is the building of resilient cities. Takeuchi & Tanaka (2016) identify that "In order to build resilient cities, the strategy of building back better, a new focus priority in the Sendai Framework for Disaster Risk Reduction, plays a key role." The opportunity for building back better is most obvious after a disaster requires extensive repair or replacement, and if implemented, can lead to significant, strategic improvement.

Collective lessons learned and potential responses to a variety of different life-like disaster recovery scenarios, crafted to align with different SDGs, were gathered from the experience and knowledge of small virtual groups. Common problems, successful strategies, and other lessons were compiled as recommendations to solve a variety of disaster recovery problems.

Table 1 provides an overview of the virtual break-out group discussion topics, and how these align with the UN SDGs.

Table 1. Virtual break-out groups (8)

Situation for Discussion	UN SDG Themes
A. The recovery is not addressing the humanitarian needs of the affected community. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	1. No Poverty
	2. Zero Hunger
	3. Good Health and Wellbeing
B. Existing social or governance structures are preventing equal opportunity which disadvantages segments of society during recovery. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	4. Quality Education
	5. Gender Equality
	10. Reduced Inequalities
C. The restoration of water / sanitation services does not consider opportunities to improve the sustainability of water supply, water treatment, water storage, water distribution, wastewater collection, wastewater treatment, or wastewater disposal. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	6. Clean Water and Sanitation
D. Restoration of power does not consider opportunities to improve the sustainability of generation, transmission, distribution, or demand. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	7. Affordable and Clean Energy
E. The recovery efforts do not incorporate recognized innovations and/or economic requirements of industry. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	8. Decent Work and Economic Growth
	9. Industry, Innovation and Infrastructure
F. The recovery is all about replacement of things that were broken, and is not implementing improvements. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	11. Sustainable Cities and Communities
	12. Responsible Consumption and Production
G. There is inadequate consideration of environmental factors by the government organizations leading recovery. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	13. Climate Action
	14. Life Below Water
	15. Life on Land
H. There are different objectives by different recovery organizations, with different levels of influence or power. *(Share positive examples of responding to a situation like this, and what lessons were learned)*	16. Peace, Justice and Strong Institutions
	17. Partnerships for the Goals

Notes: These topics are indicative

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Understanding Life Cycle Impacts for More Sustainable, Resilient, and Inclusive Infrastructure – Life Cycle Assessment (LCA), Cost Benefit Analysis, and Envision LD 3.3 Economic Analysis

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ABSTRACT

With climate change exacerbating natural disasters, pandemic-driven fiscal deficits, and social unrest becoming widespread, more than ever infrastructure is needed to create job opportunities, mitigate and adapt against hazards, and create social cohesion amongst diverse sociodemographic groups. Prudent planning plays an important role in establishing the development of only the most effective projects - those with the greatest social, environmental and community benefits, with a lens to the highest value for money. Empirical, evidence-based data in the form of science and economic analytics can support planners, policy makers, engineers, and stakeholders in making more informed, comprehensive project designs and funding decisions that maximize public value and create benefits across multiple dimensions. Analytical tools such as Life cycle assessment (LCA) – understanding the cradle-to-grave embodied carbon outcomes; life cycle cost analysis (LCCA) – understanding full project costs over their life cycle; and cost benefit analysis (CBA) – quantifying and monetizing social and environmental co-benefits – are all important tools that can help to inform better project design, greater funding, and quicker buy-in. The Envision rating system – a holistic sustainability and resilience planning framework for civil infrastructure – includes such considerations, and specifically within credit LD 3.3 'Life Cycle Economic Evaluation' supports this comprehensive life cycle economic analysis approach. With billions of dollars expected in the form of fiscal stimulus, more than ever this approach to planning is needed to ensure the desired outcomes from infrastructure projects are maximized for every dollar spent.

Technical Track Abstracts - Monday, December 6, 2021

Track 1: Coastal Resiliency

Moderated by Liv Haselbach, P.E., Ph.D., F.ASCE

A Resilient Texas Coastline – Aligning Our Natural and Built Infrastructure for the Future

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ABSTRACT

Texas is taking steps to proactively plan for climate-related challenges along its coast, both in the immediate future and the long-term. The Texas General Land Office (GLO) has led the charge to assemble the Texas Coastal Resiliency Master Plan to confront the challenge our coast is facing. Taking a collaborative approach to planning, the GLO has embraced the perspectives of local coastal communities, scientists, planners, industry, and academia to enhance resiliency, mitigate risks, and protect coastal environments and communities along the coast. Understanding the latest science and continued dynamism of the coastal zone, including impending changes to weather patterns and sea levels, is paramount to the planning effort. Another critical development in the planning process has been to build consensus among stakeholders with dramatically different priorities by promoting collaborative solutions and helping Texans rally support behind key proposed projects. Growing collective understanding in what community infrastructure looks like in an evolving landscape is critical to identifying actionable and resilient projects that integrate both nature-based and traditional infrastructure working together. Ultimately, the Master Plan is one step in an effort to stand together along the Texas coast, championing a healthy coast for generations to come.

This presentation will provide perspectives of community resilience through the lenses of coastal managers representing multiple entities along the Texas coast, including agencies, consulting, and academia. Under this lens, we will discuss the ability to develop resilient communities while also preserving the coast's natural systems.

Galveston Bay Park Plan SSPEED Center (Severe Storm Prediction, Education, & Evacuation from Disasters)

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ABSTRACT

In 2008 Hurricane Ike made a direct hit on Galveston Bay with a flood surge not experienced in the area since the early 1900's. This event spurred the concept of the Ike Dike, a coastal barrier along Galveston Island and Bolivar Peninsula to protect the bay and Galveston from future storms, and a companion project, Galveston Bay Park.

GALVESTON

The risk of a major storm surge hitting Galveston Bay is a national and international concern. The Port of Houston is currently the largest port in terms of tonnage in the United States. The widening of the Panama Canal and the increase in goods coming into and going out of the US has played a large role in the growth of the Port of Houston. Over 25% of all petrochemical activity in the US takes place within this area, including over 30% of the nation's aviation fuel and 13% of the national refining capacity. Impact to this area would have a significant impact to the national and global economy.

The area has an overall population of over 5,000,000 people with more than 800,000 people located in areas of direct impact risk from storm surge in Galveston Bay. Galveston Bay is one of the most productive estuaries in the nation providing oysters, shrimp, sport fishing, birding, boating and many other recreational activities. The bay is part of the migratory route for a number of bird species and is a favorite spot for birders during the migratory season. Even a relatively small spill as a result of storm surge could have an immeasurable impact on the bay, potentially creating impacts that would last decades.

The threat is real. While every storm has its unique characteristics, the fact is that gulf storms are getting larger, stronger, and less predictable. Category 3 to 5 storms are more prevalent. The chance of a storm hitting the southeast coast in a location that would send a huge surge up the Houston Ship Channel into Galveston Bay has increased. To not prepare for such an event is unthinkable.

Hurricane Ike did get attention. Bill Merrill at Texas A&M Galveston started looking at the

possibility of developing a coastal barrier, taking a page out of the book from The Netherlands to envision a barrier that would run from High Island to Freeport. His effort led to a state-funded effort that was eventually turned into a project for the US Army Corps of Engineers in Galveston. The project became known as the Ike Dike due to its similarities to the Dutch system.

The Ike Dike was studied by the US Army Corps of Engineers (USACE) and is being presented as the locally preferred plan. However, during Dr. Merrill's TAMU Study and the USACE study, the Severe Storm Prediction, Education, & Evacuation from Disasters (SSPEED) Center, funded by the Houston Endowment, was studying similar protection alternatives that would protect against in-bay surge that the Ike Dike would not completely address. The SSPEED Center project was announced to be a compatible project to the Ike Dike to add the additional protection that would replace a portion of the USACE solution for the west side of Galveston Bay.

The solution was Galveston Bay Park, a resilient project proposed to provide year round recreational and commercial benefits, aid in widening and maintaining the Houston Ship Channel, provide environmental measures to help clean the waters within Galveston Bay, and provide greater protection to the area from Texas City to Baytown, including the Port of Houston and the surrounding industrial complex as well as the homes of many of the residents that provide the labor needed to operate those facilities. The project is a more inclusive and more complete solution to the trending large magnitude storms.

The Galveston Bay Park is a continuation of the legacy of those that came before. After the 1900 storm that wiped out Galveston, Jesse Jones, a leader in the region at the time, started to develop the idea to move the port from Galveston to Houston. The result was a 40-mile channel starting 20 miles out into the Gulf of Mexico and running up the swampy river known as Buffalo Bayou. The timing was everything. At the time the Houston Ship Channel was being constructed, another major shipping marvel was underway, the Panama Canal. Shortly thereafter, Spindletop, the start of the Texas Oil Boom, was drilled. The result is the major port that Houston and Galveston Bay has become. The leadership and vision of Jesse Jones is the legacy that Galveston Bay Park is taking to take another bold step to create a world class multipurpose facility that will help protect the region from the growing threat of coastal surge while providing everyday use for recreation, as a long term cost effective use of ship channel maintenance dredging spoils, as a way to help fund and optimize widening the Houston Ship Channel to make it safer and capable of larger vessels, all while providing some environmental enhancements and protecting the west side of Galveston Bay from CAT 5 storms.

It is important to note that the Coastal Spine, while a major portion of the coastal protection, is limited in what can be done due to the limitations on the barrier and the size of the bay behind it. The large size of Galveston Bay makes it susceptible to residual surge, which occurs when surge caused by the wind and pressure from a storm causes surge of water just within the Bay. And due to the limited height of the coastal spine, a CAT 4 or 5 storm would overtop it and add to the water contributing to the in-bay surge damages along the shores and up the tributaries draining into Galveston Bay. The current plan in the USACE Coastal Spine solution puts gates in Clear Creek at Clear Lake and in Dickenson Bayou, but leaves the homes and industries along the shoreline and the Houston Ship Channel exposed to the residual surge. This is where the Galveston Bay Park plan comes in, providing that additional protection to the most vulnerable and critical areas. This second line of defense is the same approach used in The

Netherlands to protect the Zuider Zee and Amsterdam.

Galveston Bay Park provides a 25' high surge barrier island in the middle of Galveston Bay. The barrier is to be constructed with dredged material from widening the Houston Ship Channel beyond the currently approved plan to expand the width from 530' to 700' by an additional 200'. The 900' width was one of the options included in the Environmental Impact Statement for the currently approved plan. The current channel is unsafe and typically has to be used as a one-way system. The additional 200' beyond the currently approved plan will add to the safety of the channel and allow larger vessels to enter Galveston Bay and access the Port of Houston and other port facilities within the Bay. Using the dredged material for the barrier puts the material to beneficial use and reduces the cost of the dredging operations since the deposits will be immediately adjacent to the channel. It is also this adjacency that provides ongoing benefit for the continuous maintenance dredging that is ongoing to keep the channel from silting in.

Galveston Bay is typically a shallow estuary with normal depths ranging from 4' to 12'. There are channels cut throughout the bay for deeper-keeled craft. The Galveston Bay Park barrier will cross three of these channels plus the Houston Ship Channel where gates are planned to serve navigation in the bay. In addition, there are two additional locations where small craft gates are planned to improve access within the bay and to improve water circulation. The small gates are planned to roughly match the current channel width or as needed to improve navigation and water circulation. The large Houston Ship Channel gate will be in the same class as the large navigation storm gates across the world such as the Maeslant Barrier outside of Rotterdam in the Netherlands, the Thames River Barrier in London, and the St. Petersburg Dam in Russia. The smaller gates will include bridges that will provide access to the barrier for recreation and maintenance.

The Galveston Bay Park barrier is unique in that the barrier has a beneficial use even when not providing protection from storms. Galveston Bay currently has a very limited public beach access. Private ownership extends to the bay with only a few parks providing direct public access. The barrier, when fully built out, will create over 22 miles of beach and marsh lands for public access, providing fishing, birding, camping, and other outdoor recreation opportunities. It is anticipated that the barrier will allow franchise development of public amenities such as marinas, fish camps, horseback rentals, performance venues, etc. which will provide ongoing income to help pay for the maintenance of the barrier.

The project is currently in a study phase to firm up cost, determine the best sources of financing, address potential environmental concerns, and advance the design of the barrier. The intent is to move forward with the environmental permits once the study is completed. Depending on the permitting process and the success in finding a funding mechanism, the project could move forward into final design in a couple of years, pushing for approvals and moving into construction before the end of the decade.

Findings from Two Flood Disaster Response Exercises for Southeast Texas

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ABSTRACT

Disaster preparedness needs regular updates to identify strengths and weaknesses of available resources and increase resilience. This study overview activities to increase collaboration between infrastructure professionals, emergency personnel and decision makers. Two virtual Homeland Security Exercise and Evaluation Program tabletop exercises were held. They focused on Southeast Texas but are applicable to other disaster-prone areas. The SETx Flood Exercise identified major strengths for disaster resilience of the various parties and recommended some areas for enhancement. The Sabine River Authority Exercise focused on a river gauge website which was found to be very useful, but for added ease of use, upgrades might include enhanced map symbology and comparative and predictive data. Obtaining familiarity with running virtual tabletop exercises can aid in preparation for, response to and recovery from disasters that affect our infrastructure especially under multi-disaster conditions and virtual exercises may be more accessible and inclusive for the varied parties involved.

Coastal Resilience and Sustainable Infrastructure Management System

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ABSTRACT

Over 90% of urban centres worldwide are in coastal areas, and cities face increasing risks from destructive hurricanes, floods, and other natural hazards that are becoming more frequent, intense, and severe due to climate change and its effects.

A critical issue confronting the coastal cities and island states in the Americas is the vulnerability of its population and economy to the effects of climate change and natural disasters, which has seriously impacted the environment, communities, and the productive sectors. Development pressures and systemic deficiencies have resulted in substantial damage to critical infrastructure, housing, and livelihoods during disasters.

The goal of this project is to develop a Coastal Resilience and Sustainable Infrastructure Management System to optimize the resilience and sustainability of infrastructure in coastal regions in North America, South America and the Caribbean by 2030, in tandem with the United Nations Sustainable Development Goals (SDGs).

The project activities are to (1) Identify existing work on actual and potential future climate change-related effects and sustainable development, ongoing activities, and good practice examples; and (2) Develop a coastal resilience and sustainability digital road map towards the year 2030, based on stakeholder engagement, the SDGs, the Sendai framework and applicable international sustainability rating systems such as Envision.

The Coastal Resilience and Sustainable Infrastructure Management System has the potential to positively impact the infrastructure, environment, economy and livelihoods of coastal nations in the Americas and would serve as a foundation for the development of similar projects to help shape the future of digital sustainable development engineering.

Track 2: Green Infrastructure

Moderated by Cliff Davidson

Engaging Owners in Low Impact Development (LID): Lessons Learned from Implementing Sustainable Design with Public and Private Institutions

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ABSTRACT

The environmental benefits of LID are well understood, so why can it be difficult to generate buy-in from owners and see green infrastructure designs come to fruition?

Private developments generally focus on the Return on Investment (ROI) of a property/project, which can make adoption of sustainability practices that don't have short or measurable ROI less appealing. For the designers and engineers who work for these clients, the general rule has been: if it doesn't pay back, they are not interested. So how do you describe the ROI in a way that continues the conversation and better represents the benefits of sustainable practices such as LID?

Institutions have different drivers and, while ROI is still a big part of the equation, their decision-making tends to have more variables including educational benefits and long-term ownership. How is green infrastructure both facilitated and hindered by municipal regulations through the lens of these client types?

This study focuses on lessons learned from engaging different types of owners in sustainable design, featuring cases studies from both institutional and private clients that found ROI in implementing LID.

Use of Green Stormwater Infrastructure to Sustainably Address Changing Storms

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ABSTRACT

Changing storm characteristics present challenges for developed areas, where criteria used to size existing stormwater infrastructure may no longer be reflective of the current climate. Conventional approaches to overburdened stormwater infrastructure often involve adding or replacing pipe infrastructure; however, these efforts can be disruptive and expensive with limitations on scalability. Additionally, with substantial removal, disposal, and new material installation, these efforts can lack many characteristics of a sustainable infrastructure project.

Green stormwater infrastructure (GSI) can provide multiple benefits and support sustainability efforts; however, these controls are often intended to manage small, frequent storm events. An analysis of observed recent storm characteristics in relation to NOAA Atlas 14 demonstrates that many locations in the United States are realizing an above average frequency of storm events associated with nuisance flooding issues and an incremental increase in storm depths and intensities. A hydrologic analysis of multiple bioretention design configurations reveals that while basic GSI controls have limited impact on the storms used to design stormwater conveyance infrastructure, basic design modifications can mitigate the incremental increases in storm size associated with climate change and provide broader peak flow reduction benefits. Results suggest GSI can play a valuable role in conjunction with existing grey infrastructure to mitigate the incremental increases in storm depths and intensities associated with climate change while supporting other sustainability objectives. This presentation will discuss the analyses described herein and provide examples of where green stormwater infrastructure is and is not a reasonable option to assist in providing climate resiliency.

Green Infrastructure for the Anthropocene: An Early Career Perspective

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ABSTRACT

Climate-related disruptions expose the obduracy of existing urban systems built to deal with conditions of the past without the needed flexibility to address the challenges of the Anthropocene. Green infrastructure (GI) is a promising tool of resilience with the potential to address these disruptions. While GI's benefits span social, ecological, and technological dimensions, the commonly accepted definition—the direct use or mimicry of ecological systems (e.g. vegetated land) to perform infrastructural services (e.g. stormwater management)—oftentimes reduces GI to the technological dimension, which is maladaptive toward coordinated social and ecological transformations (Matsler et al. 2021). To better position GI for resiliency, we examine GI through robust interdisciplinarity and propose the social-ecological-technological systems (SETS) lens as a guiding framework. We present perspectives from a group of early career researchers and practitioners with diverse disciplinary backgrounds who participated in a 4-day symposia series. Throughout the symposia, participants led a collaborative autoethnographic study to generate holistic principles for GI design, implementation, and maintenance. The emergent principles emphasize process transparency, stakeholder and community engagement, simultaneous consideration of SETS objectives, and adaptive management to 1) address previously dismissed needs and emergent issues and 2) clarify responsibilities for increased accountability. These principles challenge existing procedures surrounding GI and present a research agenda to move toward more holistic implementation.

Reference:
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Measurement and Modeling of Hydrologic Flows and Energy Flows on a Large, Extensive Green Roof in Syracuse, New York

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Keywords: CHAMPS-BES, Energy Flow, Green Roof, HYDRUS, Stormwater, SWMM

ABSTRACT

Increasing numbers of cities in recent years have turned to green infrastructure for stormwater management, and this trend is likely to continue as decision makers study the benefits of green over traditional gray infrastructure (Flynn and Davidson, 2016). For example, the Save the Rain program in Onondaga County, New York has implemented more than 200 green infrastructure projects through public-private partnerships in the past decade. One of the largest of these projects is the 5,550 m^2 green roof planted with sedum on the Onondaga County Convention Center (OnCenter) constructed in 2011 in downtown Syracuse. To study the performance of the roof, temperature sensors have been installed to obtain a multi-point profile through the roof layers at five locations on the roof, an electromagnetic flow meter is positioned to measure the stormwater runoff flowing down the roof drains, several soil moisture sensors have been buried in the engineered soil to determine volumetric water content in the growth medium, and a weather station has been set up on the roof. In addition, samples of rain and leaf washoff are collected for chemical species analysis to determine atmospheric wet and dry deposition.

In this extended abstract, we discuss research findings in three categories. First, we address the hydrology of the roof, examining retention of stormwater to reduce combined sewer overflows (CSOs) and flooding. Second, we report on modeling the hydrology of the roof using two well-known computer models, SWMM and HYDRUS. Third, we consider energy flow through the roof, monitoring the temperatures in the various roof layers as well as modeling heat flow through the roof. Although not discussed in this extended abstract, studies on the green roof and the SU campus are examining the transfer of chemical pollutants from the atmosphere to the surface by wet and dry deposition.

Measured Retention of Stormwater. The roof contains a 3-inch depth of engineered soil and is planted with six species of sedum, designed to effectively capture a 1-inch storm. There have been several measurement campaigns; the first campaign ran from October 2014 to July 2016, a total of 21 months (Squier-Babcock and Davidson, 2020). The overall retention rate was 56%

for this time period, and the reduction of peak runoff relative to peak rainfall averaged 65% for all events with runoff.

The amount of stormwater retained by the roof was a function of several factors, especially the moisture content of the engineered soil at the start of the rain and the total depth of rainfall in a particular storm. The storms fell into one of four categories: very small (< 2 mm), small (2-10 mm), medium (10-20 mm), and large (> 20 mm). Removing data when snow was present and when there was instrument malfunction, a total of 165 rainstorms could be analyzed with a total depth of 1062 mm. Roughly half of these were very small, having a total of only 5% of the measured rainfall throughout the 21 months. Only one of these very small events had runoff, indicating that the roof captured essentially all the rain in very small events. In contrast, there were only 11 large events, which accounted for 38% of the total rainfall. Just 24% of the total measured retention occurred during these large events, suggesting the roof is more effective at capturing small and medium events.

The effectiveness of the roof in capturing stormwater has not been constant over time, according to Yang and Davidson (2021). Comparing retention data for the year 2015 with retention data for the year 2017 suggests that the roof has gotten slightly more effective with age in capturing rainwater. The maximum water holding capacity of the engineered soil increased from 39% in 2011 to 46% in 2018; consistent with this measurement, the fraction of soil particles with diameter smaller than 0.05 micrometers increased from 5.9% in 2011 to 8.4% in 2018.

Modeling hydrologic flows on the roof using SWMM and HYDRUS. The EPA model SWMM was first applied to the OnCenter green roof using physically representative parameter values. Results showed poor agreement between simulated and measured runoff for a number of storms, indicating the need for a manual calibration of the model parameters. Using data from a 9 cm storm on October 28, 2017, the parameters were adjusted to optimize agreement between modeled and measured runoff throughout the storm. Applying the calibrated model to several additional storms demonstrated good results for predicting runoff. However, the calibrated model could not replicate the observed soil moisture time series between storm events.

SWMM was also used to investigate the sensitivity of the various model parameters in influencing the simulated outputs, using one-at-a-time analysis by holding all parameters except one constant; the target parameter was then varied to determine the sensitivity of this parameter. Sensitivity varied among the 14 parameters, and the sensitivity depended on whether the original physically-based parameters or the calibrated parameter values were used. The insensitivity of some parameters is a partial explanation of the occurrence of equifinality, when a simulated output can be obtained by many different combinations of parameter values. Equifinality in SWMM complicates the interpretation of agreement between measured and simulated results.

HYDRUS-1D has been used to simulate runoff, infiltration, evaporation and soil moisture for a number of rain events on the OnCenter green roof. Statistical tests were conducted to compare the measured and modeled time series for drainage from the roof, which showed that green roof performance could be simulated successfully for rainstorms of sufficient size. The statistical criteria were satisfied for 8 out of the 10 large storms examined but were satisfied for only 4 out of 18 medium storms and 0 out of 7 small storms. HYDRUS was also used to model

three key parameters related to roof performance: percent retention by the roof, reduction of peak runoff relative to peak rainfall, and lag time between peak runoff and peak rainfall. Statistical tests are underway to determine the success of HYDRUS in predicting these three parameters.

Energy flow through the green roof. The flow of energy through the roof has been estimated using data from temperature sensors in the layers of the green roof (Yang et al., 2021). Temperatures within the growth medium and below the roof membrane can exceed the air temperature during the summer, especially on cloudless days when direct sunlight can reach the roof surface. During the winter, temperatures at these locations can also exceed the air temperature due to direct sunlight and heat rising from the interior of the building. The presence of plants and growth medium nevertheless reduce the temperature variations of the roof membrane in both summer and winter. The CHAMPS BES model can successfully predict heat flow through different layers of the roof and can be used to estimate heat loss from the building in winter and heat gain to the building in summer.

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Stormwater Capture/Infiltration/Reuse Case Studies: Improving Regional Sustainability and Watershed Resiliency

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ABSTRACT

Would you like to make a difference in the sustainability and resiliency of water supplies and flood control? Watearth has investigated a range of case studies involving environmental quality projects as well as master plans and design. Across dozens of projects, we have learned how best to incorporate sustainable and resilient water strategies. Multi-benefit projects like those that Watearth develops range from watershed-level stormwater capture projects to site-specific 100% stormwater infiltration projects to solve structural flooding, improve water quality, and increase groundwater supplies.

On one regional stormwater capture project, Watearth identified the most efficient intersection of combined on-site and offsite treatment to manage a complex system of flood control channel, storage, and sewer diversions that improve both regional water quality and the availability of irrigation water. Elsewhere, Watearth designed an implementation of permeable pavement to reduce localized ponding and flooding, restoring safe parking access to a community building. Watearth assessed a positive cost-benefit.

Watearth staff are Envision-certified and work on watershed-level projects, site-specific projects, campus-wide projects, and system-wide projects to provide diverse benefits at a range of project scales and levels of complexity. As engineers, scientists, and communicators, we strive to provide clear analyses of take-away planning and design concepts for implementation into future projects. On many projects, particularly at the environmental documentation level (such as OCTA Systemwide Rail Resilience, studying green solutions to improving rider/commuter safety) and at the planning level (such as the City of Austin Drainage Criteria Manual, studying updated rainfall data), Watearth practices the reader-friendly document format, ensuring that recommendations pertaining to sustainability and resilience do not "sit on the shelf."

Track 3: Vulnerable Communities

Moderated by Eric Bill

Hurricane Dorian's Impact on The Bahamas:
Making the Case for a Risk Management Based Approach to Infrastructure in a Small Island Developing State

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ABSTRACT

The Bahamas, like many Small Island Developing States (SIDS) in the Caribbean, is especially vulnerable to the impacts of climate change. Characteristically low-lying land coupled with a high ground-water table contribute to an acute sensitivity to the effects of sea level rise (SLR) and storm surge during hurricanes. These physical vulnerabilities are exacerbated by limited availability of funds and a culture of dependency on foreign investment and external post-disaster assistance.

The relatively small land mass of most of the Bahamian islands places the majority of the population within one to two miles of the coastline. The archipelagic nature of The Bahamas presents significant challenges to effectively implementing meaningful hazard mitigation policies and effecting responses during and immediately following a crisis event. Moving persons from one island to another is logistically challenging, forcing most to adopt a "shelter in place" approach to hurricane preparation.

Hurricane Dorian hit the Bahamas in September of 2019. The devastation caused by Dorian resulted in significant human, social, and financial impacts that will have lingering effects for years to come. Dorian exposed the vulnerability of The Bahamas to natural disasters and underscored the need to implement policies based on proactive and adaptive risk management.

In the aftermath of Dorian (and similar storms before it) lives were lost, buildings and infrastructure were destroyed, business were crippled and entire communities were decimated. While it is impossible to accurately calculate the toll on the social and psychological health of disaster victims or to put a value on human lives, it is vital that means of mitigating the impacts on a community are explored from a risk management perspective in order to minimize the long-term effects.

Two years after Hurricane Dorian struck The Bahamas a considerable amount of work remains to be done in some of the communities most impacted by the storm. Many of the buildings damaged have not been reconstructed and electricity has not been fully restored. There is no clearly articulated plan for recovery of the once thriving community of Marsh

Harbour Abaco, which was perhaps the most significantly impacted of the affected areas. This scenario prevents persons who were displaced from the community from returning home and resuming their lives.

Climate change has introduced a new range of uncertainties and potential risk to small island communities. While the protection of life is clearly paramount, it is also clear that attention must be paid to increasing the resilience of a community in the face of natural disasters. SIDS must seek new and sustainable means of increasing resilience in the face of hazard events such as hurricanes and the chronic threat of sea level rise. Historically building codes and by extension building regulatory departments have focused on the preservation of life, guided by the assumption of stationarity of climate conditions. The inability of The Bahamas to recover in the aftermath of Hurricane Dorian has made it obvious that from both an economic and social perspective, a reactive approach to disaster management is not sustainable. A risk-management based approach to handling infrastructure decisions will involve identification of potential risk, examination of impact vulnerability, and incorporation of a cost benefit analysis to drive implementation of avoidance, mitigation, recovery and adaptive measures.

A risk-management based approach which also recognizes the concept of non-stationarity and incorporates an element of adaptive design will increase a community's resilience to hazard impact and will promote a greater ability to quickly recover after a natural disaster. Adoption of a framework for adaptative designs and risk management such as that described in ASCE MOP 140 would provide a standardized basis for assessing risks and methodically examining the means, implications, and costs for mitigating them.

Humanitarian Crisis Engineering at a Refugee Camp

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ABSTRACT

From January 2019 through March 2021, a refugee camp was formed in Matamoros, Mexico, immediately across the US border and within the floodplain of the Rio Grande River. The over-3000 Central American refugees living in the camp relied on relatively small, local humanitarian aid organizations for food, shelter, water, sanitation, healthcare, and more.

Solidarity Engineering was created when three women engineers met at the Matamoros refugee camp after they individually heard about the conditions there, and decided to uproot their lives, move to the border, and volunteer there full time. Between March 2020 and March 2021, this engineering team – which was unassociated with any established non-governmental organization (NGO) at the beginning of their time there, and only formalized as Solidarity Engineering after 6 months working together – tackled many of the camp's needs pertaining to water filtration, stormwater management, emergency hurricane response, COVID-19 response, and site infrastructure including building a shower block, school, playground, and soccer field. Each project required the team to partner with other local NGOs, as well as the refugee community itself, to identify and implement projects. More information on each project is on the Solidarity Engineering website, www.solidarityengineering.org.

A less-than-perfect emergency response at the camp to Hurricane Hanna by the NGO collaborative in July 2020 prompted the team to officially establish themselves as Solidarity Engineering, and adopt a model that included holding community meetings before, during, and after a project to ensure that community input is incorporated into each design. The team also committed to hiring local refugee community members to help with the construction, as well as the operation and maintenance, of all infrastructure.

Each project included fundraising through GoFundMe, designing, community feedback, redesigning, sourcing materials, construction, and modifications. Some design restrictions were enforced by the local Mexican authority (Instituto Nacional de Migración), such as all work being "temporary", using local Mexican vendors for building materials, and maintaining as much of the natural park landscape and protective flood levee as possible. Additionally, limited funding played a major role in what could and could not be accomplished. These constraints led to creative designs, utilizing and incorporating the existing aspects of the park in which the camp was located, which resulted in more sustainable projects with less environmental impact.

Green-Gray Infrastructure for Coastal Climate Resilience

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ABSTRACT

Globally, coastal regions make up 9% of our land area, house 28% of our population (1.9 billion people) and produce 42% of our GDP. Every year $1.8 trillion is invested in coastal infrastructure, like roads, seaports, water, and wastewater treatment. At the same time, an estimated 150 million people and US$9.1 trillion in coastal assets are vulnerable to climate change impacts including rising sea levels, storm impacts, erosion, and coastal flooding. Coastal ecosystems like wetlands, coral reefs, and mangroves provide natural protection for coastal communities. However, this 'green infrastructure' alone is often inadequate to fully safeguard people and physical assets from the increasing threats associated with climate change. Conventional 'gray' infrastructure (e.g., seawalls, breakwaters, etc.) alternatively offers immediate protection, but is often prohibitively expensive to build, maintain, and replace, and can create unintended negative impacts. Blending "green" conservation and restoration with "gray" engineering techniques capitalizes on the best of both and has the potential to create a new generation of climate resilient coastal infrastructure. However, these approaches are not yet commonly used by engineers and practitioners globally.

The Global Green-Gray Infrastructure Community of Practice, led by Conservation International, is a forum for collaboration across the conservation, engineering, finance, and construction sectors to generate and scale green-gray climate adaptation solutions. The Community has grown to over 100 member organizations, including AECOM, Bechtel, Deltares, Arup, Caterpillar, World Resources Institute, IUCN, TNC, RARE, and many academic partners. This multidisciplinary community has identified key barriers to implementing green-gray projects:

1. Engineers, developers, industry, and governments lack experience, familiarity and, consequently, confidence in the reliability and application of green-gray approaches;
2. Technical knowledge and data needed to standardize reliable green-gray solutions is not broadly or equitably available;
3. Most infrastructure policies and regulations do not currently incentivize green-gray solutions; and
4. Real and perceived risks constrain investments in developing economies despite significant opportunities for achieving social, economic, and climate mitigation and adaptation objectives at a competitive cost.

The community has identified strategic and collaborative initiatives to address these barriers.

Comprehensive Stakeholder Engagement in an Emergency Management and Debris Project

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Keywords: Emergency Management, Hurricane, Stakeholder Engagement, Social Surveys

ABSTRACT

This study addresses the need for comprehensive stakeholder engagement, taking as an example a disaster recovery emergency management project at a landfill (dump). Phillispburg, Sint Maarten received uncontrolled debris from the clean-up after hurricanes Maria and Irma devasted the island in 2017. The landfill now contains burnable and non-burnable waste, and the periodic, toxic dump fires at the landfill that had occurred sporadically in the decades before Irma became almost a constant as the post-hurricane debris mounted. Prior to starting the engineering works required to suppress the fires (oxygen starvation, water, foam) and close the landfill, a disadvantaged community that resides in closed proximity/adjacent to the landfill needs to be relocated. To provide the client with the tools and information necessary to develop a resettlement plan that earned the community's trust and buy-in, we developed a comprehensive stakeholder engagement plan and detailed census survey of the affected persons. The study addresses the methodology employed to conduct the census survey and the engagement with the affected community.

Track 4: Sustainable Infrastructure: The Big Picture

Moderated by Krishna Reddy

From Results-Oriented to Process-Oriented: Leveraging Disruptive Practices to Face Complex and Uncertain Futures

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ABSTRACT

Infrastructure projects are defined by unique challenges and opportunities, including diverse funding streams, contrasting stakeholder priorities, and a variety of triple-bottom line impacts. The way the engineering industry has traditionally approached infrastructure projects has been through a step-by-step process with very little engagement and collaboration. These approaches can result in unproductive silos and segmentation – leading to unnecessary rework, change orders, and an inherent disconnect from the true desired outcomes of the project. To address increasing complexities, interconnection, and interdependence, a disruptive shift in how we approach infrastructure must occur.

Taking a process-based versus a results-based approach to infrastructure problems fundamentally changes the way we approach project delivery. It also produces outcomes that are well-suited to address the root-problems communities face in this time of growing uncertainty and complexity.

The Envision framework, Integrated Design Process (IDP), and alternative project delivery are tools and methods that project teams can use to apply process-oriented solutions to create more resilient and sustainable infrastructure. They facilitate early involvement from specialists, contractors, and stakeholders to leverage opportunities, address challenges, and mitigate risks. Process-based approaches to sustainability and resilience can help project teams break the cycle of reactive project design and construction and contribute to a more effective project. Examples of this can be found across sectors and regions, including port and airport development, campus infrastructure renewal, flood management and resilience, and public transit.

Defining a Sustainability Path to Meet Short and Long-Term Goals

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ABSTRACT

Sustainability and resiliency are a journey, rather than a destination. The practice is organic, evolving and changing. For organizations that have been incorporating sustainability for a long time, it can be challenging to update processes and for organizations that want to be more sustainable it can be intimidating to know where to start and how to implement a broad sustainability program across an organization.
Whether creating or enhancing processes, it is helpful for an organization to examine how a broad range of sustainability and resiliency factors are taken into consideration for projects and operational processes to determine where resources can best improve sustainability within the organization.

This presentation will provide examples of how we worked with two organizations to assess their sustainability approach, reveal gaps and opportunities, and define a path forward to meet their short and long-term sustainability and resiliency goals.
The goals of the presentation will be to describe a scalable processes for evaluating sustainability in projects and programs, illustrate how sustainability rating systems can be employed as a tool in programmatic sustainability evaluations, convey case studies that demonstrate analysis used to compile sustainability "best practices" that can be applied across an organization's projects and practices, and explain resulting actions used to integrate sustainability into organizational processes.

Tiered Quantitative Assessment of Life Cycle Sustainability and Resilience (TQUALICSR): Framework for Sustainable Design Assessment

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ABSTRACT

Considerable efforts have been made recently to incorporate sustainable practices into the design of engineering projects (e.g., civil infrastructure) with an aim to minimize the net negative environmental, economic, and social impacts of the project. There have been several tools developed to assess and compare the sustainability of potential design alternatives; however, most of the developed tools focus on assessing the environmental impacts, with minimal regards to the broader social and economic dimensions. Moreover, the increased occurrence of climate change-related events and impacts have challenged the function of engineered systems and their ability to achieve sustainable development, forcing policy makers and stakeholders to consider resilience in engineering designs and projects. Resilience and sustainability are inseparable, as an engineering system cannot be sustainable if it is not resilient. Nevertheless, few tools and frameworks integrate resilience and sustainability. In this study, a tiered quantitative assessment of life cycle sustainability and resilience (TQUALICSR) is proposed with the following key features: (1) a flexible, tier-based selection of tools to assess the environmental, economic, and social impacts of a project and its resilience; (2) integration of resilience and sustainability into an unified assessment framework ; (3) integration of interdependencies among the technical, environmental, social, economic, and resilience dimensions; and (4) applicability to various stages of an engineering project, from planning to decommissioning. The different steps involved in the framework, useful triple bottom line quantification tools, and application challenges are highlighted.

Incorporating Sustainability in an
Undergraduate Environmental Engineering Curriculum

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ABSTRACT

In the past decade, sustainability has become a core element in civil engineering projects. This need has urged the civil and environmental engineering programs to introduce or increase sustainability components in their curricula. This study presents the effort of an environmental engineering program to incorporate sustainability in its curriculum. The Accreditation Board for Engineering and Technology (ABET) requires sustainability components to be addressed in the senior capstone design in an environmental engineering program.

This particular environmental program has been developed from a water resources management program by including non-water courses such as Solid and Hazardous Waste Management and Air Quality Engineering. The concept of sustainability is introduced in the course, Introduction to Environmental Engineering with the concepts of vertical and horizontal sustainability and SDG 17, and the introduction of ENVISION and LEED certifications. The core courses, Air Quality Engineering and Solid and Hazardous Waste Management, include sections that address sustainability and introduce them in modeling and practice. The course, Senior Capstone Project I, dedicates lectures on SDG 17 and ENVISION. The students are expected to analyze an environmental engineering project case study with their acquired knowledge on ENVISION.

In addition, the students are also encouraged to become members of ISI. Senior Capstone Project II mandates to include the brief ENVISION-based analysis of the students' senior design in their final report and project presentation.

Creating More Gender-Responsive Infrastructure: Major Opportunities Ahead

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ABSTRACT

Delivering sustainable infrastructure requires a holistic involvement of the stakeholders that will potentially benefit or be impacted by the projects. However, despite the growing interest in gender-inclusive infrastructure, historically this field has been biased towards men as women have been disproportionately left out of planning, design, and execution of infrastructure projects. Inevitably, women's gender-specific needs are unmet and an economic opportunity is seen as 3.2% of the world´s development GDP is unrealized. Actionable guidance is needed in this field as most of the existing literature on this topic focuses on recommendations for policymakers.

This study is aimed to address key questions such as: Why is infrastructure not gender-neutral? What are the main considerations to incorporate gender-responsive strategies through the project lifecycle? and What are the key tools to implement to quantify progress? This study incorporates specific information regarding the business case for gender-inclusive infrastructure. Selected case studies highlight good practices used in different parts of the world to scale up solutions in this area.

Track 5: Energy Resilience & Reliability

Moderated by Anthony Kane

Design of Interconnected Infrastructure Systems for Resilient and Sustainable Communities

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ABSTRACT

Resilient and sustainable infrastructures, including buildings, bridges, and lifeline systems, play a central role in the socio-economic development of our communities. Regardless of size and population number, communities rely on critical infrastructures to serve their basic needs during normal circumstances and in the aftermath of a natural disaster (e.g., earthquake, hurricane, tornado, flooding, fire). This work investigates the interconnection between infrastructures and their relation to community resilience. Case studies of critical interconnected infrastructures are first introduced. Then, the effects of the failure of a single infrastructure system on the whole infrastructure network and the community are discussed. Finally, design recommendations on how to holistically enhance the resiliency and sustainability of critical infrastructures are presented. Figure 1 shows a schematic representation of the topics covered in this work.

Figure 1. Representation of interconnected infrastructures, their relation to community recovery, and possible solutions to enhance the resilience of infrastructures and community as a whole

Civil infrastructure lifeline systems, such as power transmission, water pipes, natural gas lines, communication, and public transportation networks, *are traditionally designed as independent systems*. However, the failure of one of the infrastructure systems might generate service disruption in other infrastructures, impacting post-disaster management operations and interrupting daily activities in the whole community. For instance, natural gas pipelines can

fracture during earthquakes due to fault ruptures, lateral spreading, and land sliding. The failure of natural gas pipelines could negatively impact power generation and the gas released from the pipelines can lead to post-earthquake fires. To extinguish fires, communities need water, a fire station facility, and enough electricity and power to pump the water. If an earthquake causes a failure in one of these infrastructures, it may affect managing the disaster at a community level. For example, the failure of power transmission lines may cause malfunction of water pumps necessary to extinguish fires and perform rescue operations. If the water pumping station provides potable water to a nearby hospital, water service would also be disrupted in the hospital. While the failure of the power transmission line is not directly disruptive to the fire station and hospital operations, the consequent loss of water service would be. It follows that to reduce recovery time of communities, *interconnections between various infrastructures should be considered in the design phase*, thus enhancing the community's resilience.

Community resilience can be defined as "the ability to prepare and plan for, absorb, recover from, and successfully adapt to adverse events" (National Research Council 2012). Because of the interconnections between infrastructures, the resilience of a community is related not only to the resilience of a single infrastructure but to the resilience of the whole system of critical infrastructures. It follows that a resilient community's design must be guided by understanding the interconnections and correlations among infrastructure systems. The current design and operation of infrastructure systems are compartmentalized, and the community tends to overlook such interdependencies, which in turn might create vulnerable infrastructure links, negatively affecting daily and post-disaster response operations. For example, during Hurricane Matthew (2016), water pumping stations in Lumberton, North Carolina, were flooded. Although the hospital in Lumberton was equipped with an emergency power generator, the operations in the hospital were disrupted by the unavailability of potable water. During Hurricane Sandy (2012), damage to the transportation infrastructure resulted in tanker trucks not being able to supply gasoline and diesel fuels to service stations. Although the service stations were not physically damaged by the hurricane, their service to the community was interrupted in the aftermath of the disaster by a breakdown in the transportation network. Another example of the interconnection between infrastructures is emergency management during seismic hazard events. Most utility companies in California use ShakeMap to determine the area of concern in order to perform detailed post-earthquake inspections. To use ShakeMap applications, employees of utility companies need access to the internet and electricity. Any damage to the internet and electricity infrastructures would cause delays in access to ShakeMap, and therefore hinder the initiation of proper seismic emergency operations, affecting the recovery time of a community.

These examples show how the performance of the social infrastructure (e.g., health care, gas stations, post-disaster management) is connected to the performance of critical civil infrastructure systems (e.g., power transmission lines, transportation networks, gas lines), and how the failure of one or more components of the infrastructure system can provoke undesired cascading effects on community recovery. It is therefore paramount to consider interdependencies between different infrastructure systems, including civil and social infrastructures. Such interconnections need to be accounted for in the planning and design phase by adding redundancies or enhanced performance with critical components, thus making the whole infrastructure system more robust to prevent possible cascading failures.

Redundancies can be valuable during an extreme natural hazard event. For example, during Hurricane Harvey, a significant number of electrical transmission lines failed, and the Houston area experienced a large blackout. However, natural gas lines performed relatively well, with minor disruptions. Communities were, therefore, able to maintain minimal functionality in the aftermath of the hurricane. If the whole city were to have become more dependent on electricity in order to reduce its carbon footprint, the consequences of hurricane Harvey might have been more severe. This example shows the importance of having redundancy and having different sources of energy, as an advantage to communities vulnerable to natural disasters.

Another solution to achieve the goal of resilient infrastructure could be to add a *new risk category tailored for critical infrastructures, their functions, and the services they provide.* Typically, structural engineers use ASCE 7-16 (ASCE 2017) to determine the risk category and associated importance factors for buildings and other structures. Applying a higher risk category and importance factors to the design of the most critical infrastructures could reduce the damage to lifeline systems and their consequences on the interconnected networks. For example, a water facility or transmission line supporting a fire station could be designed as a Risk Category V and associated importance factor of 1.5.

A *Risk and Resilience Management Plan* (RRMP) that includes the linkages between critical infrastructure systems could be an essential tool for managing the risk on individual projects and systems. A standard RRMP identifies a list of hazards and threats to the function of the infrastructure system for its lifetime. This requires looking forward and accounting for the effects of climate change. The RRMP is a living document to be updated through the operational life of the system. Critical assets of the facility/system are identified and evaluated along with the full facility. An owner or operator may know some or all the hazards/threats to the facility. It is recommended that an authority/city/region considers minimum hazards/threats that shall be addressed during the preliminary design phase (e.g., hurricane, earthquake events). Then, the design team needs to develop a risk assessment of the critical assets of the facilities and identify the interdependency on other infrastructure systems, such as the electrical grid for power. The risk assessment needs to consider the functional and design lifespan of the critical linkages. The design team should also address management, mitigation, and avoidance of disruption of service. For example, some natural hazard events can be accounted for in the design load cases used for designing the facility. Other events will be managed during operation with mitigation strategies, such as deployable flood protection. Some events could be avoided by adding redundancy to the system, such as an electric generator for emergency backup power. All this information must be contained in the RRMP.

Advancing equity, social justice, and the development of disadvantaged communities are among the main goals of *sustainable design*. Community leaders should develop *resiliency management plans* to address all aspects of infrastructures, such as livability, social injustice, climate change, and natural hazard resiliency. The interconnections between critical infrastructures should be considered in such plans, with the goal of maintaining communities' basic needs during normal circumstances and in the aftermath of a natural disaster.

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Inspection Planning for Transmission Line Systems Exposed to Hurricanes using Reinforcement Learning

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ABSTRACT

Recent hurricanes and extreme weather conditions and their impacts on aging power transmission infrastructures, particularly transmission line systems (TLSs), have magnified the growing need for optimal risk management policies for the grid infrastructure. Decisions based on optimal policies improve the sustainability and resilience of electrical power systems against gradual deteriorations as well as hurricane events. In real-world infrastructure systems, these decisions are often made based on limited information or unreliable observations of systems' conditions. To enhance the quality of information in the decision-making process, operators need to perform inspection and obtain reliable information about the state of systems prior to deciding maintenance actions. However, the costs and resources associated with inspection and monitoring limit the number of these actions. In this study, to address the conundrum of planning optimal inspection and monitoring policies for TLSs under uncertainty, a reinforcement learning (RL) framework is developed. In this RL framework, the optimal inspection policy is achieved through minimizing the incurred costs due to operation, maintenance, and inspection. Furthermore, this framework accounts for the quality of information obtained through inspection actions. High-fidelity models of TLSs are used for performance evaluation of these systems against hurricanes. The performance of the RL framework in achieving an optimal inspection policy for a TLS exposed to hurricane events is illustrated and compared to the performance of expert-based policies in allocation of resources. The results of this analysis assist stakeholders in inspection planning and management of TLSs.

Feasibility of Pumped Hydroelectric Storage Within Existing United States Army Corps of Engineers' Facilities: A Methodological Approach

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ABSTRACT

Variable, renewable energy (VRE) generation such as wind and solar power has seen a rapid increase in usage over the past decades. These power generation sources offer benefits due to their low marginal costs and reduced emissions. However, VRE assets are not dispatchable due to their variable nature, which can result in a mismatch of the supply and demand curves for electricity. Pumped-storage hydropower (PSH) seeks to solve this by pumping water uphill during times of excess energy production and releasing the water back downhill through turbines during energy shortages, thus serving as a rechargeable battery. Creating new PSH systems, however, requires a large amount of capital in addition to the challenge of finding suitable locations. The United States Army Corps of Engineers (USACE) is the largest producer of hydroelectric power within the United States, and as such, may have favorable sites for the addition of PSH. This study seeks to develop a method for evaluating these existing hydroelectric facilities using techno-economic methods to assess the potential for adding PSH. Each USACE facility was evaluated based on available head, flow rates, and reservoir size from previously unpublished data to estimate the power generation and energy storage potential. The temporal nature of local wholesale electricity prices was accounted for in the method to help estimate the financial feasibility of varying locations. Sensitivity analysis was performed on select installations to highlight how the method would identify the viability of facilities with different operational conditions. The methodologies detailed in this study will inform decision-making processes, toward enabling a sustainable electric grid.

Grid-Interactive Efficient Buildings: Leveraging the Federal Building Stock to Support the Future Grid – A Case Study from Central Islip, New York

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ABSTRACT

The General Services Administration (GSA) owns and maintains the largest portfolio of facilities in the United States. This infrastructure stock requires significant resources to operate, including ample, reliable access to electricity, natural gas, and water. The Department of Civil and Mechanical Engineering at the United States Military Academy has partnered with the GSA to study the opportunity to better integrate building assets with local energy infrastructure. The project is part of the GSA's Grid-Interactive Efficient Buildings (GEB) program and is focused on the Central Islip Federal Courthouse complex. Using a case-study approach, the project explores the capability for the courthouse to improve how energy is produced and consumed with the goals of reducing operating expenses, improving environmental impacts, and integrating more intelligently with the local grid. A technoeconomic model was built and a sensitivity analysis completed to consider the tradeoffs of conceptual design alternatives, including solar photovoltaics and energy storage. The solutions presented are placed in context with the broader literature on GEB, providing an overview of the most promising opportunities for buildings to become critical assets to support the future of energy infrastructure. The findings of the project show that a carport style photovoltaic array in an existing parking lot at the courthouse has an estimated payback period of 19 years, while the best ground mounted array has a payback of eight years, albeit a lower generation capacity compared with the larger carport array.

Thermal Energy Corporation: Real Life Benefits of Microgrids

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ABSTRACT

This study focuses on the planning, development, proven results and best practices garnered throughout the execution of Thermal Energy Corporation (TECO)'s Master Plan Implementation Project, an expansion rooted in the concepts of sustainability and resiliency.

The $377 million project was designed to meet the growing cooling and heating needs of the rapidly expanding Texas Medical Center, the world's largest medical city. The expansion made TECO's district cooling system the largest in the U.S., doubling its operating efficiency while reducing carbon dioxide (CO_2) emissions by 302,000 tons annually compared to previous operations. The CO_2 reduction is equivalent to taking 52,000 vehicles off the road or planting 72,000 acres of new trees.

Moreover, this project installed systems and equipment to better prepare TECO to be able to continuously provide thermal services for heating and cooling to the Texas Medical Center even through tropical storms and hurricanes that frequent the region. These upgrades proved effective during all of the various weather events that occurred after the project, including the most significant flood event on record in the United States, Hurricane Harvey and the recent winter storm, Uri.

When Hurricane Harvey hit Houston in 2017, the region faced record-setting rains and widespread flooding, severely impacting the community and putting those upgrades to the test. In spite of the 62+ inches of rain that inundated the city during the multi-day storm, TECO's steam and chilled water services remained uninterrupted, even as energy needs skyrocketed for those requiring medical care in a time of widespread community power outages and heavy flooding.

Technical Track Abstracts - Tuesday, December 7, 2021

Track 1: Healthy Communities and Their Role in Sustainable Infrastructure

Moderated by Theresa Harrison

The Joint Call to Action for Healthy Communities...Its Role in Planning, Designing, and Constructing Sustainable Communities: Panel Discussion for the International Conference on Sustainable Infrastructure (ICSI) 2021

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Keywords: Healthy Communities, Multi-disciplinary Teams for sustainable design

ABSTRACT

ASCE joined the American Public Health Association's Joint call to Action for Healthy Communities (APHA JCTA) in 2018. The APHA JCTA coalition is comprised of eight professional associations, working together to promote multidisciplinary cooperation to plan, design, construct, and implement facilities and programs which enable healthy, sustainable, and thriving communities. The eight signatory organizations of the coalition are (in alphabetical order): American Institute of Architects (AIA), American Planning Association (APA), American Public Health Association (APHA), American Society of Civil Engineers (ASCE), American Society of Landscape Architects (ASLA), National Recreation and Park Association (NRPA), US Green Building Council (USGBC), and the Urban Land Institute (ULI).

The United Nations Sustainable Development Goals (Figure 1) address 17 inextricably linked goals such as health, education, equity, social justice, and collaboration, many of which are paralleled by the APHA JCTA:

"Where we live, work, and play has a major role in shaping our health. Rates of chronic diseases attributable to the design of the built environment–including obesity, diabetes, heart disease, and asthma–are on the rise. The built environment also has direct and indirect impacts on mental health, including depression and anxiety. This is true for everyone, but is felt even more among vulnerable populations, who are less likely to have access to nutritious, affordable food and opportunities for physical activity and are more likely to be exposed to environmental pollutants and circumstances that increase stress.

Addressing growing health challenges and inequities requires new partnerships and collaboration between built environment and public health practitioners, and a health-focused approach to landscapes, buildings, and infrastructure. As signatory organizations to this Joint Call to Action, we encourage our combined 450,000 individual members to embrace collaboration across professions to promote healthier, more equitable communities. When professionals in the fields of the built environment and public health work together, we multiply our potential to improve health."

Figure 1. The 17 UN Sustainable Development Goals

The panel discussion will begin with an overview of ASCE's involvement in the APHA JCTA Coalition. The panelists will be members of the coalition discussing how cross-cutting, multi-disciplinary teams are needed to solve issues in our communities and also illustrating the inextricable connection between healthy communities and sustainability. It is the goal of this discussion to demonstrate how the civil engineering profession is a key player and stakeholder in planning, designing, constructing, operating, and maintaining sustainable infrastructure that will foster and support healthy communities.

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        <https://apha.org/topics-and-issues/environmental-health/healthy-community-design>

Track 2: Resilience (Part 1)

Moderated by Liv Haselbach

Integrated Framework for Design and Management of Sustainable and Resilient Infrastructure in a Changing Climate

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ABSTRACT

In a changing climate, there are a number of growing pressures on Canada's infrastructure such as increasing climatic loads and extreme weather events, aging/deterioration, increasing demand/population growth, greenhouse gas (GHG) reduction/carbon tax, demographic shifts, new technologies (e.g. driverless cars), and limited funding (Bush and Lemmen 2019). The design of current infrastructure and buildings mostly focused on life safety and was driven by low initial cost. There is a lack of integration of mitigation and adaptation actions to address effectively the challenges posed by climate change (Lounis and McAllister 2016). Also, there is a lack of integration of resilience and sustainability performance indicators in the design and management of infrastructure (Bocchini et al. 2014). There is a need for a transition from the standalone concepts of climate change mitigation and adaptation to a concept of integrated mitigation and adaptation in the construction sector. Also, there is a need to bridge the gap between the key performance metrics of resilience and sustainability of infrastructure to enable the move toward sustainable and resilient infrastructure and communities.

The decisions that are made in the design of new infrastructure and management of existing infrastructure are likely to contribute towards or detract from the long-term goals of sustainable and resilient infrastructure. There is a strong correlation between inadequate mitigation and the increasing demand for adaptation activities. Focusing on climate adaptation as a reactive approach, instead of focusing on climate change mitigation as a proactive approach, will lead to increased need for further adaptation in the future as illustrated in Figure 1. Environmental protection, economic effectiveness, and social development, as three pillars of sustainability, are referred to also as Triple Bottom Line (TBL), which should be accounted for in the sustainable design and management of infrastructure.

The adaptive capacity as the commonality of mitigation and adaptation is essential for meeting the goals of long-term sustainability. Figure 1 shows a possible approach presented in the current study to develop a comprehensive framework to consider the interactions between climate change mitigation and climate change adaptation as well as between sustainability and resilience of infrastructure.
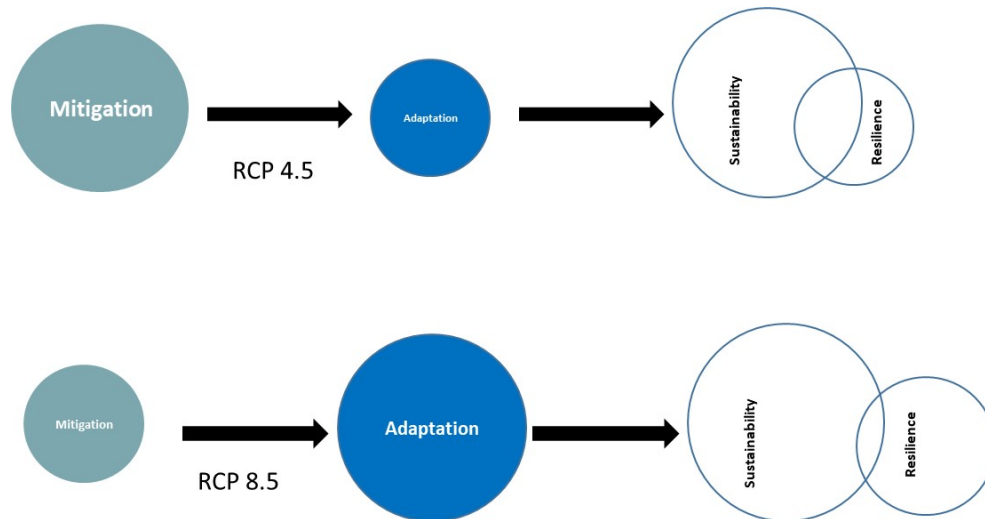
Figure 1. Overview of interactions between mitigation, adaptation, sustainability, and resilience

The integration of sustainability and resilience under a comprehensive framework structure could help to interpret the interactions between the climate change mitigation and adaptation approaches and the final comprehensive framework will support the decision makers to achieve more sustainable and resilient infrastructure. Ensuring both broadness (sustainability, resilience, and climate change impacts) and ease-of-use are the main attributes of the proposed framework to achieve an optimal decision support tool for sustainable and resilient infrastructure. The approach of system thinking has been considered in the proposed framework to address this gap. The proposed integrated framework requires: (i) collection of necessary data; (ii) computation of quantitative performance metrics for sustainability and resilience; (iii) taking into account the impacts of climate change; and (iv) consideration of the significant uncertainty associated with climate change, sustainability and resilience metrics. Applying the life cycle thinking (LCT) methods, such as life cycle performance assessment (LCP), life cycle assessment (LCA), life cycle cost analysis (LCCA), and social life cycle assessment (SLCA) can enable the selection of sustainable and resilient designs of new infrastructure as well as the selection of effective management options for existing infrastructure in a changing climate (Fauré et al. 2017).

In order to cover the mentioned aspects and consider the current needs, Figure 2 shows a simplified schematic representation of the proposed integrated framework for sustainable and resilient infrastructure that takes into account both climate change mitigation and climate change adaptation.

As can been seen, we will basically apply a climate scenario-based assessment to evaluate different possible levels of sustainability and resilience of new and existing infrastructure. It should be stated that improving the performance of new infrastructure can be relatively easy to achieve compared to the improvement of the performance of an existing infrastructure. The focus of the current framework is the relationship between three main blocks, namely: (i) Infrastructure sustainability; (ii) Climate scenarios or representative concentration pathways (RCPs) that predict the GHGs concentration trajectory under various socio-economic scenarios (van Vuuren et al. 2011) and (iii) Infrastructure resilience.   Additional sustainable community
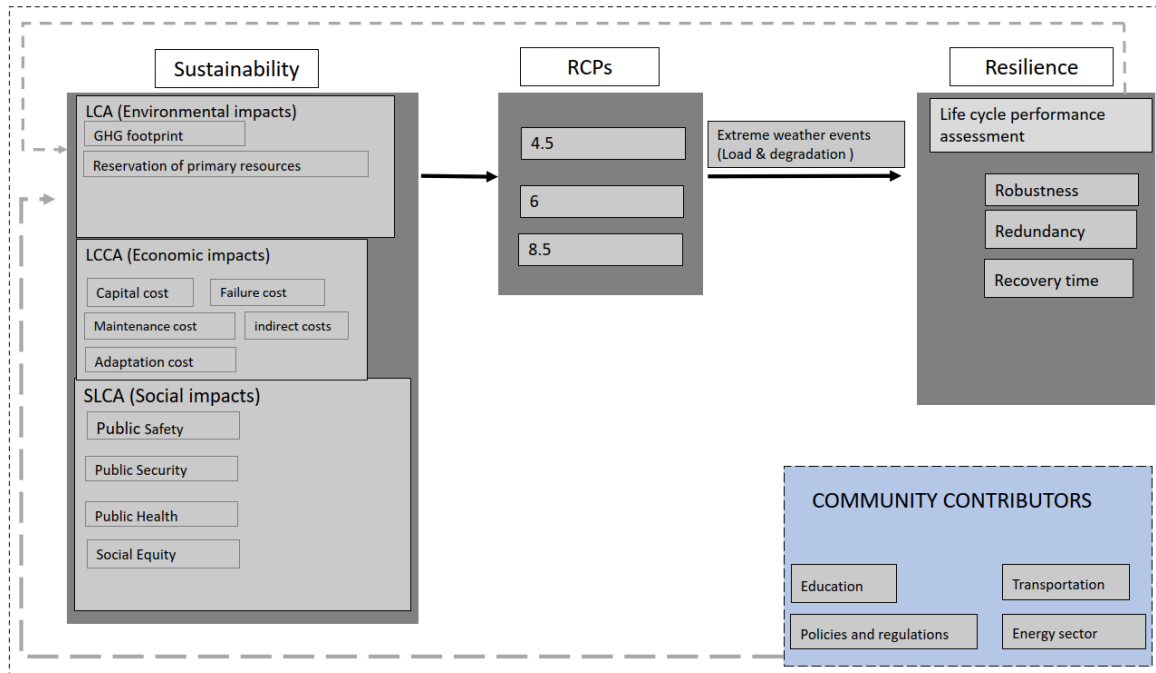
Figure 2. Simplified schematic of proposed scenario-based integrated framework for sustainability and resilience of infrastructure

indicators, such as policy and regulations, sustainable transportation, sustainable energy, education, etc. could be considered in the future.

This is the broader goal of the current integrated framework: to develop a decision support platform that will help achieve a sustainable community which consists of sustainable and resilient infrastructure, including sustainable and resilient bridges, roads, transit, potable water, stormwater and wastewater systems, and buildings, including critical facilities. The implementation of the proposed integrated framework will constitute a considerable piece of the puzzle of sustainable Canadian communities.

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Exploitative and Explorative Learning in Support of Infrastructure Resilience

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ABSTRACT

Infrastructure systems—a combination of physical, institutional, and educational components that help maintain a functioning society through their services—are operating in different conditions than which they were optimized for, but they are being designed and managed with the same rules, norms, and goals that have persisted for the past century. As infrastructure managers imagine opportunities to increase resilience competencies in physical infrastructure design, they must also examine the resilience capacities of their institutions, which relies on the institution's ability to navigate between stability and instability. We reviewed leadership and organizational change literature—with particular focus on Complex Leadership Theory, organizational structure, and ambidexterity—to learn from the field of business management, which often operates in a volatile and aggressive environment. Preliminary results indicate that institutions should 1) be able to navigate smoothly between operational tasks and innovative endeavors and 2) empower decision-makers across the organizational structure, from executives to operators. A flexible organizational structure should innately enable emerging (and similar styles of) leadership and interdisciplinarity (e.g., social-ecological-technological systems) within infrastructure systems because they share the same objective: to respond to complex and uncertain scenarios.

Resilience Dividends and Resilience Windfalls: Narratives that Tie Disaster Resilience Co-Benefits to Long-Term Sustainability

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ABSTRACT

The need for increased disaster resilience planning, especially at the community level, is clear, as is the need to address sustainability; these dual objectives have been deemed a US National Priority (e.g., Exec. Order No. 14008, p. 7619, 2021). The three major global climate agreements, the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015), the Paris Climate Agreement (UN, 2016), and the Sustainable Development Goals (UN, 2015), all emphasize the need to integrate disaster resilience and climate risks with continued sustainable development concerns. Thus, the ways we assess synergies and trade-offs across planning for disaster resilience and sustainability in investment projects that impact communities need to be reconsidered and new ways to express relative categories of co-benefits need to be developed. In recent years, categorizing some co-benefits as contributing to the resilience dividend has helped communication across fields and created bridges from research to practical on-the-ground planning. In parallel, growing focus on the need to recognize the role of narratives in driving decisions about how and where to invest (Shiller, 2017) elucidates the inherent value of archetypes that resonate across stakeholders and disciplines to describe investments that may meet multiple objectives. We introduce the concept of a resilience windfall, as an unexpected or sudden gain or advantage of resilience planning. The potential of resilience windfalls should be conceptualized alongside resilience dividends in community-level resilience planning and evaluation. We recount five narrative vignettes that demonstrate disaster resilience interventions and associated resilience dividends and windfalls. Through this exercise we highlight the utility of categorizing net co-benefits in a manner that evokes understanding from relevant communities. Additionally, this process highlights the need to readily consider the possibilities of resilience dividends and resilience windfalls during the planning, execution, and evaluation phases of disaster resilience projects.

Are Resilience, Climate Change Adaptation, and Sustainability Planning Approaches Compatible? Results of a Comprehensive Assessment Across Community-Focused Guidance Literature

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ABSTRACT

Communities in the United States have the primary responsibility for establishing plans and priorities for a range of objectives, including natural hazard preparedness, adapting to climate change, economic development, and environmental sustainability. Planning processes in resilience, climate-change adaptation, and sustainability are also informed by a variety of planning guidance documents that present differing methodological approaches and information requirements. While it is possible that these approaches may be complementary in many ways, they may also have important differences that need to be understood to advance potential integration of the topics in practice. We conducted a content analysis of community-scale resilience, adaptation, and sustainability guidance products to assess compatibility between their methodological approaches, data requirements, and outputs. By describing the ways in which these interdisciplinary approaches propose materially similar or distinct planning processes, we hope to contribute to efforts to inform and enhance community resilience, adaptation, and sustainability planning.

Balancing Trade-Offs Between Efficiency and Resilience in Pursuit of Sustainable and Adaptable Infrastructure Systems

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Keywords: Efficiency, Infrastructure, Resilience, Sustainability, Systems, Variability

ABSTRACT

Infrastructure systems are often faced with a critical tension between efficiency and resilience objectives. Efficiency relates to the optimal use of resources via efforts to minimize wasted time and resources. Conversely, resilience relates to avoiding, mitigating, and managing disruptive changes – often via features that are antithetical to efficiency such as increased redundancy and system diversity. Due to its applicability to "stable" conditions, the operation of many infrastructure systems tends to lean toward efficiency. However, under conditions of rapid change and widespread uncertainty (e.g., a global pandemic, climate change), continued emphasis and reliance on efficiency principles may be misguided. Instead, infrastructure systems would likely benefit from some level of "inefficiency" in the form of additional "slack" and redundancy in the system.

This project seeks to understand the efficiency-resilience tradeoff in the context of infrastructure resilience and sustainability objectives. Through literature review, synthesis, and conceptual framing, two primary questions are explored: 1) What is the state of knowledge regarding the tradeoff between efficiency and resilience in complex urban/infrastructure systems? 2) How does the efficiency-resilience tradeoff hinder (or enhance) broader sustainability/resilience goals? Insights and perspectives from engineering, ecology, and social sciences are examined. Ultimately, this work can help identify whether emphasizing efficiency over resilience (or vice versa) creates barriers to sustainable and resilient infrastructure transformations. It can also set the stage for research and practice aimed at quantifying and reducing these barriers.

Track 3: Climate and Society

Moderated by April Lander

Effects of Climate Migration on Town-to-City Transitions in the United States: Proactive Investments in Civil Infrastructure for Resilience and Sustainability

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Keywords: Climate Change, Infrastructure, Migration, Resilience, United States

ABSTRACT

Climate change is a risk amplifier for natural hazards (e.g. floods, droughts, wildfires) and contributes to changing precipitation and temperature patterns that alter an area's risk profile (Xu et al., 2020; Wilbanks and Fernandez, 2014). Existing infrastructure is not designed to handle climate change impacts and is often ill-equipped to absorb shocks associated with increased frequency and severity of these events (Zscheischler et al., 2020; Miller et al., 2018). As climate change progresses, climate change-induced migration is becoming more frequent and more likely, both within and across countries. People relocating to areas with actual or perceived lower risk is expected to add demand for built infrastructure systems and change governance needs as receiving communities grow. Anticipating demand growth can enable proactive rather than reactive investment. To date, although resilient infrastructure is necessary to overcome future climatic extremes and population growth, active measures to implement holistic resilience plans are rare and often limited in scope. Figure 1 presents a framework for considering both these dimensions for adaptive infrastructural investment under climate change—timing relative to disaster events, and location relative to populations. Here we analyze the impact of anticipated climate migration patterns on community growth in the United States (US), leveraging the US Environmental Protection Agency's (EPA) Integrated Climate and Land-Use Scenarios (ICLUS) dataset (https://www.epa.gov/gcx/iclus-downloads#tab-2) to infer possible US climate migration patterns with the goal of identifying opportunities for proactive infrastructural planning. This work expands migration estimates from ICLUS to specifically evaluate "tipping points" where climate migration is likely to contribute to infrastructurally relevant growth: specifically, when towns become cities. Projected 2020-2100 town-to-city rapid urbanization patterns are different from historical (1950-2010) patterns in the US, notably shifting from the Southwest (including California) to the Southern Plains (including Texas) (Figure 2). Climate change is expected to further shift this pattern northwards, contributing to land use change and new demand for civil infrastructure. Proactive investment in civil infrastructure in regions expected to attract climate migration can facilitate resilience and sustainability under climate change, emphasizing safe, sufficient, and equitable infrastructure.
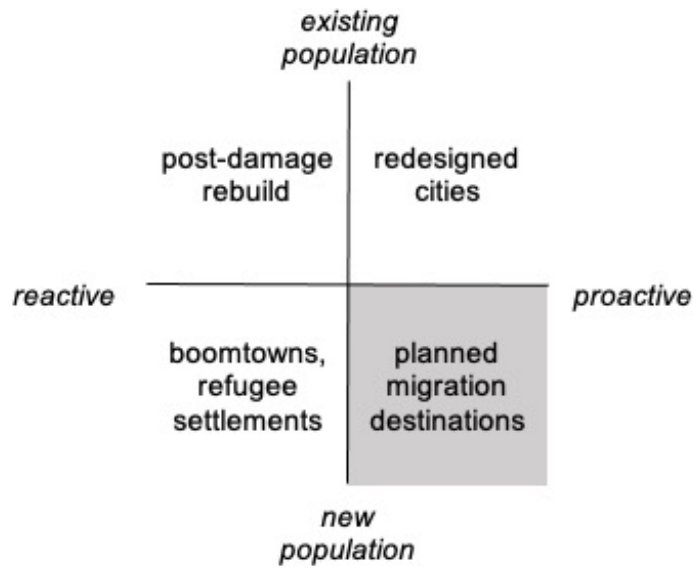
Figure 1. Matrix of infrastructural investment patterns for climate adaptation
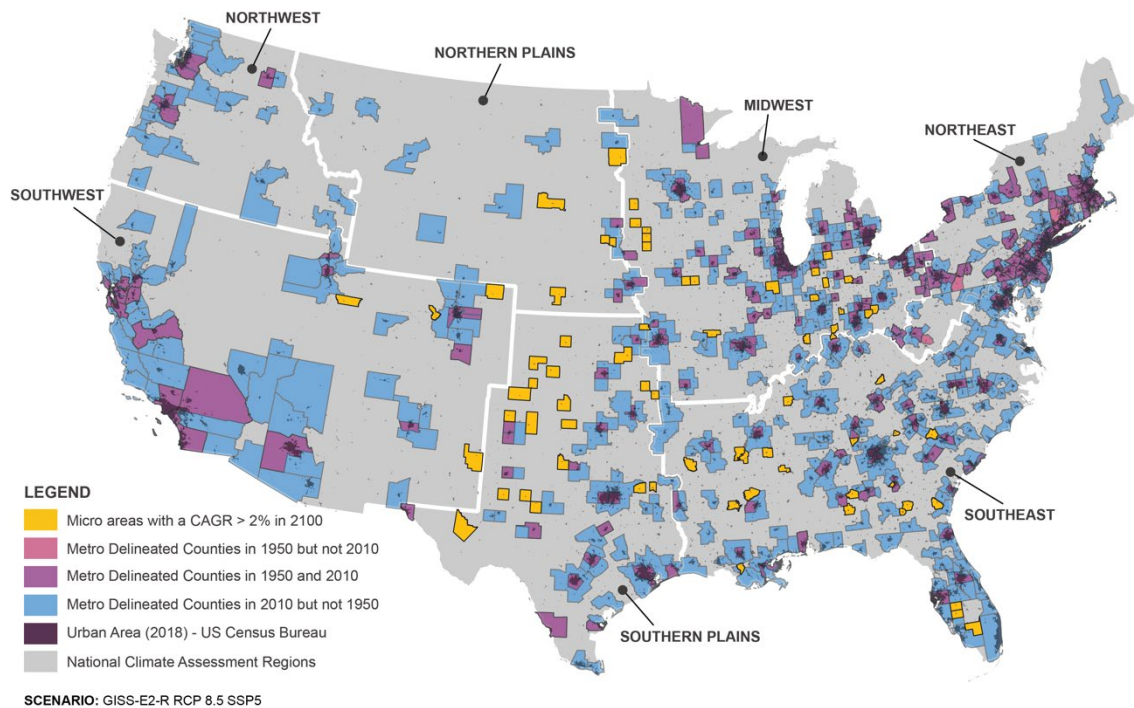
Figure 2. Micro areas with projected 2010-2100 Compound Annual Growth Rate (CAGR) over 2% for the scenario GISS-E2-R – RCP 8.5 – SSP5, where GISS-E2-R is the climate model; RCP: Representation Concentration Pathway and SSP: Shared Socioeconomic Pathway.

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Monitoring the Stability of a Moraine Dam by Differential Interferometry (DInSAR) to Prevent GLOFs Disasters from Arhuaycocha Lake

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ABSTRACT

The Cordillera Blanca in Peru is the most heavily glaciated tropical mountain range in the world (Emmer et al., 2020), where 800–850 km^2 total glacial area in 1930 decreased to 600 km^2 at the end of the 20th century (Kaser, 1999). The decline has resulted in the formation of moraine-dammed lakes from flow stagnation and recession of glacier tongues (Harrison et al., 2018) affecting 230 glacial lakes in the region, of which 119 were moraine-dammed (Emmer & Vilímek, 2013). The fast growth and formation of lakes caused a dramatic increase in glacial lake outburst flood (GLOF) occurrence from 1930 to 1970. A previous decline (Emmer, 2017) is associated with the Little Ice Age, while GLOF incidence throughout the 21st century as lakes and glaciation respond more dynamically is associated with anthropogenic climate warming (Anacona et al., 2015). Although the GLOF frequency has not fluctuated directly in response to global climate, it will increase as the global climate continues to warm, with hazardous impacts for downstream regions (Harrison et al., 2018). Most of the recorded GLOFs from moraine-dammed lakes in the Cordillera Blanca were caused by slope movements into lakes in which the displaced material was dominated by icefalls, snow avalanches, and rockfall (Emmer & Cochachin, 2013) producing displacement waves, which may overtop, deforming or displacing a lake's moraine dam (Jawaid, 2017). It is also clear that intense rainfall, the extreme variability of air temperature, or snowmelt will lead to a rise in the water level of the lake (Yamada & Sharma, 1993). This causes a deformation that can be identified through interstitial pressure measurements (Corsetti et al., 2018).

DInSAR techniques have been developed to measure the temporal behavior of the displacements or deformation (Toural Dapoza et al., 2019). With ascending and descending DInSAR measurements it is possible to calculate 3D deformation of glaciers at one instance of time (Samsonov, 2019). It is necessary to have two independent acquisition modes from the ascending and descending line of sight (LOS) motions and solve the geometry relationship (incidence angle and satellite tracking heading angle) which are inverted to retrieve the horizontal and vertical components of the displacement. This developed methodology is detailed in Fig. 1 and we call it multi-geometry data LOS fusion.

The multi-geometry data fusion LOS methodology shows that the moraine dam of Arhuaycocha lake suffered subsidence of 17 cm (Fig. 2). The average subsidence zone was concentrated around the drainage channel (Fig. 2), and the zone of greatest subsidence was

recorded at the lateral base. The dam shows higher displacement in the greatest rainfall seasons (Fig. 3). We concluded that subsidence in the moraine dam tracked with continued precipitation in wet months, and the loss of storage in dry summer months triggered rebound.
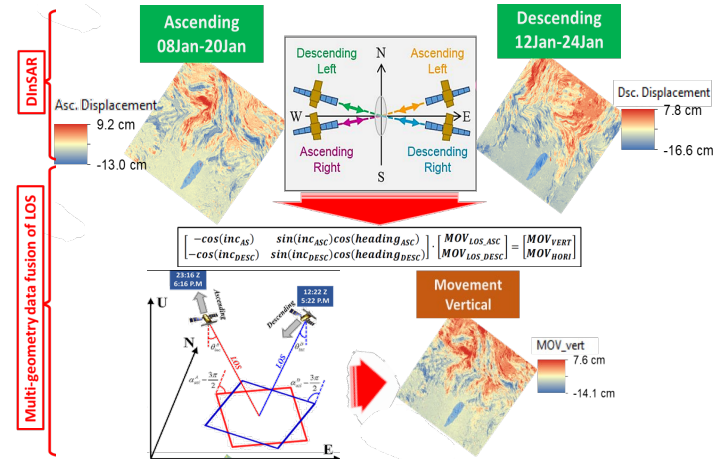
Figure 1. Methodology for multi-geometry fusion of LOS
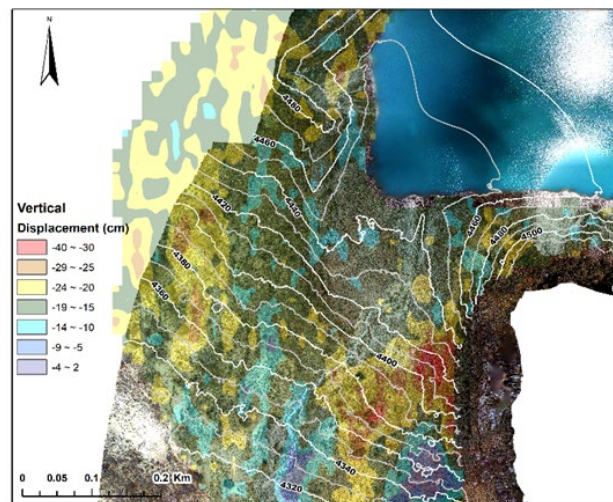
Figure 2. Accumulated vertical displacement for moraine dam Arhuaycocha
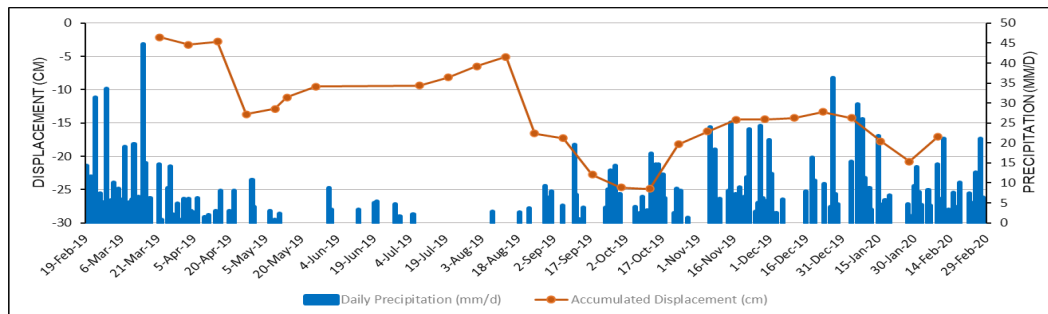
Figure 3. Daily precipitation and accumulated displacement of the moraine dam Arhuaycocha

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Empowering Communities through Climate Change Engagement and Capacity Building

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ABSTRACT

As the climate changes, communities are faced with a new reality of what it means to be resilient. Extreme events, storms, and flooding are increasing, forcing communities to address climate change impacts by building resilience, often without a clear understanding of what that means. By investing upfront in climate-change education, communities are empowered to play a more informed decision-making role in project planning and development, leading to stronger project outcomes and ultimately more resilient communities.

We share two community engagement and capacity building case studies from across America:

- In the San Francisco Bay Dumbarton Bridge project, a community-based organization developed a 3-week 'parent academy' through which the local community learnt about climate change and its projected impacts on their livelihoods. Through this process the community members were able to teach the project planners, scientists, and engineers about local components that would make for a more robust project design, and were empowered to make more informed decisions about their own long-term resiliency to climate change and teach each other what it means to live resiliently.
- Recognizing that children were heavily impacted by the 2017 hurricanes in Puerto Rico, and that many adults were occupied with meeting families' basic needs following the storms, an innovative outreach strategy engaged 360 schoolchildren in six school districts throughout the island. The students participated in educational modules on resilience and community-based participatory research through photography. Numerous student-proposed recovery actions are reflected in the $20 billion USD CDBG-DR action plan that is guiding the Island's Resilient Recovery.

Track 4: Flooding and Water Infrastructure

Moderated by Michael Bloom

Houston's Coordinated Approach to Sanitary Sewer Overflow Prevention

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ABSTRACT

Houston's wastewater collection system has evolved since its founding in 1836. Since its humble beginnings in 1837, Houston's wastewater system has grown exponentially to its current approximately 6,200 miles of sanitary lines, over 381 lift stations, and 39 treatment plants. Today this system serves Houston's 2+ million population, a number which continues to grow, ensuring that wastewater from these homes and businesses is effectively collected, conveyed, and treated to meet water quality standards prior to discharge to the bayous. In addition to rapid and often ad-hoc growth, Houston also claims many unique qualities such as one of the most diverse communities in the nation, a vibrant international restaurant scene, no formal zoning regulations, a relatively flat terrain, and aging infrastructure. These qualities combine to impact Houston's wastewater system, a system currently facing challenges such as sanitary sewer overflows (SSOs). Efforts to address these challenges began with the Greater Houston Wastewater Program. Completed in 1997 this program focused on capacity related to upgrades and improvements for the collection, conveyance and treatment system. In 2005 the Agreed Order with TCEQ accomplished the renewal and rehabilitation and cleaning of millions of feet of pipe and improved the City's management information system for SSO reporting and tracking. This Order ended in 2015 and resulted in the successful completion of the Supplemental Environmental Project and passage of the City's FOG ordinance for fats, oils, and grease.

Most recently, the City of Houston agreed to a Consent Decree (CD) with the Environmental Protection Agency. Effective April 1, 20201 the Decree commits the City to improving its wastewater infrastructure. Programs outlined in the CD include inspection of sewer mains, associated manholes, lift stations and force mains; cleaning of sewer mains to meet Consent Decree goals; and renewal, rehab, replacement or consolidation of lift stations, wastewater treatment plants, force mains and gravity sewer mains. The CD formalizes Houston's forward-thinking plan to improve its wastewater infrastructure and maintenance program, and upgrade assets and facilities to serve its residents while creating a more resilient system. In Houston, approximately 70% of SSOs are caused by clogged pipes from fats, oils and grease poured down residential sinks and wipes flushed down toilets. Through coordination efforts between data collection and analysis, infrastructure maintenance, community outreach, enforcement, and compliance HPW aims to reduce the frequency and volume of these SSOs.

To ensure that SSO prevention efforts are focusing on the appropriate solutions, locations, and problems, HPW conducts rigorous SSO data collection and analysis. When an SSO is reported to Houston's 311 Call Center, a Service Request is created and responded to by Wastewater Inspectors. These inspectors confirm the SSO and input field data into the Infor database. From there the City's Stoppage Crew responds, stopping the SSO and enters additional field data. The Regulatory Compliance Team then conducts QA/QC on this data for reporting, ensuring assets are completely and accurately represented in the City's GIS data clearinghouse. Data is further analyzed for patterns and trends using tools such as Power BI and ArcGIS. Mapping resources are continually improved and streamlined through collaborative partnerships between the field operations team and the IT/GIS team. HPW uses this data to inform its Preventative Maintenance (PM) Program for effective resource allocation. This program was established to lessen the likelihood of failure and to reduce preventable SSOs. It provides the City with an asset management framework to operate and maintain the collection system at an optimum level by identifying the locations, analyzing causes, frequencies, durations, and order of magnitude of SSOs. It assigns sewer lines routine cleaning cycles of 3, 6, 9, 12, and 18 months based on the amount of grease and debris identified on the pre-cleaning CCTV inspection data. The PM Program has evolved by taking advantage of available technology to quickly process large amounts of CCTV inspection data through a customized decision tree and GIS platforms that assign the appropriate cleaning cycle. While routine cleaning goes a long way towards reducing preventable SSOs, it is worth noting that reducing the amount of fat, oil and grease that enters the sanitary system can also reduce the amount of routine cleaning required. To reduce the "source" the City of Houston's GIS system also houses information on grease trap locations, inspection data, and data on the location of high-density housing. This information is analyzed for proximity to sewer lines in the Preventative Maintenance Program to create "Hot Spots" for the City to conduct targeted FOG outreach and enforcement. This allows HPW and the Houston Health Department (HHD) to focus outreach efforts where they are needed.

HHD's FOG Program protects the citizens and the environment from potential hazards that may result from unauthorized waste releases such as SSOs. The FOG Program tracks city regulated waste from cradle: where the waste is being generated and transported, to grave: where the waste is disposed of at a permitted disposal site. At the generation site, the FOG program ensures the waste manifest is obtained and properly filled out by the generator. The FOG program also permits and inspects FOG transporters. The transporter must be permitted by HHD and the vehicle must pass inspection prior operating in the City of Houston. Finally, the FOG Program inspects and audits the disposal site to ensure proper disposal. Each of these: The Generator, Transporter and Disposal Site fill out the waste manifest and submit it to the HHD. Additionally, the FOG Program educates and enforces Chapter 47 Article XI, Chapter 47 Article XII, Section 47-741 and Chapter 10 Section 10-451 of the City of Houston Code of Ordinances. There are approximately 16,000 special waste generators in the current data base system. Investigators are responsible for inspecting all special waste generators as often as needed but not less than once every 3 years. Special Waste Generators have interceptors designed to use differences in specific gravities to separate and retain FOG and settleable solids prior to the wastewater entering the sanitary sewer system. For example, grease trap interceptors are primarily installed in food establishments. The Health Department receives complaints daily from HPW, City Council, Mayors office, other departments, and the public. The FOG Program investigates complaints within 48 hrs. During the investigation Environmental Investigators gather all pertinent information and documentation, educate on

better management practices, and collect samples as needed. Public outreach is provided to multi-family residents with repeat sanitary sewer overflows. To ensure compliance the FOG Program issues enforcement that can result in fines up to $2,000 per day. The FOG Program also coordinates joint investigations with groups such as Code Enforcement, Neighborhood Protection, BARC, HPD-Hazmat team and other city departments to obtain assistance on one issue or address several issues at once. Depending on the severity of the case the FOG Program collaborates with HPD Major Offenders Division that may result in Water Pollution Felony Charges. HHD works closely with HPW's Stoppage and Regulatory Compliance teams to respond to SSOs and ensure data accuracy.

HPW also addresses SSOs through outreach and education. SSOs caused by clogged pipes from fats, oils and grease poured down residential sinks and wipes flushed down toilets are preventable if residents just engage in a few simple behaviors. Outreach and Education on this campaign is spearheaded by HPW's "Protect Our Pipes" campaign which asks the community to pour fats, oils and grease in the trash and only flush the 3 P's: Pee, Poo and (toilet) paper. Launched in fall 2020, "Protect Our Pipes" focuses on two primary methods of outreach: citywide brand-recognition and awareness and targeted community engagement. Citywide outreach occurs through strategies such as: social media; tv and radio ads, partnerships with local influencers, publications, and organizations; water bill inserts; and through outreach and presentations at community events and festivals. Through its campaign launch during winter 2020, the campaign achieved over 14.8 million views. HPW's Outreach Team also uses SSO data to conduct targeted outreach around recent SSOs and to identify SSO hotspots for community-specific outreach and engagement. These efforts focus on historically marginalized or underrepresented communities and includes collaborating with community partners to create local community advocates, provide school programming, deliver presentations to HOA and Civic Club meetings, and engage in additional community-driven outreach and education efforts.

As Houston's population continues to grow, increased pressure is being placed on its aging infrastructure system, necessitating a further need for collaborative and innovative infrastructure management practices. In addition to collaboration on SSO prevention specifically, these programs and initiatives include partnerships with Houston's resiliency initiatives, such as the Resilient Houston Plan which focuses on building resilience at every scale, and Houston's Complete Communities initiatives which focuses on revitalizing historically underrepresented or marginalized communities. Considering the size and scope of the City of Houston, collaboration amongst so many groups requires intentionality and consistency. Regular meetings between each organization have helped to improve these partnerships, remove silos, and reduce barriers. As Houston continues to address infrastructure and resiliency challenges, this level of coordination will be more and more essential. Our hope is that these current efforts will serve as a framework and starting point for future efforts, creating a strong foundation for Houston to thrive.

Turning Existing Grey Infrastructure Green, a Real Life Cinderella Infrastructure Story

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ABSTRACT

Today, sustainability is a buzz word in the civil engineering industry. But it can be more than that. In basic terms, sustainable or green infrastructure can be defined as infrastructure that serves its general civil engineering purpose, but is also designed to benefit the community, environment, and economy – the triple bottom line. The Conrad Sauer Basin Revitalization and Mathewson Lane Expansion project in Houston is a great example of this kind of infrastructure.

The Conrad Sauer Basin, located in west Houston, was built in 2000 as a large concrete detention pond to serve as mitigation for a subdivision to the north that was converting its drainage from a ditch system to curb and gutter.

In 2014, a public-private partnership with the City of Houston was formed to extend an adjacent road over the basin and enlarge the basin itself. The basin would also be transformed from the existing concrete surface to lush greenery with walkways throughout. Detention within the new and existing street would be increased and pervious (non-concrete) cover was added to the existing street's fully impervious area. Even the vegetation chosen for this project was designed to be sustainable and resilient, especially considering some of the fluctuating conditions within the basin.

This project provided numerous benefits to all three sectors of the triple bottom line. It truly transformed and redeveloped existing impervious property to a dual-purpose and beautiful asset for the community.

Hydraulic Modelling for Flood Risk Management of Underground Infrastructure Systems

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ABSTRACT

Climate change and sea level rise are poised to significantly increase flood risks to underground infrastructure systems in heavily urbanized coastal cities. While infrastructure managers are cognizant of the increasing flood risks associated with climate change, the existing literature and state of practice lack methods for understanding and conveying these increased risks and the associated impacts to networked underground infrastructure. Addressing this gap, we construct a flood risk assessment framework for a regional rail rapid transit system considering the expected increased frequency and severity of flooding resulting from climate change. Relying on as-built drawings, track charts, and a set of lowest critical locations, we construct a hydraulic model of the interconnected portions of a regional rail rapid transit system and simulate the impacts of a suite of coastal flood events under several sea level rise conditions, demonstrating the propagation of flooding through the rail tunnel network. We further simulate the benefits of a set of flood protection measures, underscoring the importance of a unified and cohesive flood risk management strategy for maximizing system resilience to climate change.

Track 5: Decarbonization and Electrification

Moderated by Anthony Kane

Smart Columbus: Electrifying America's Smart City

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ABSTRACT
The three-year Smart Columbus Electrification Program, funded by a grant from the Paul G. Allen Family Foundation and many public and private contributions, was designed to accelerate the transition to a low-carbon future. The City of Columbus, Ohio, and its partners initiated an electrification program with goals of increasing renewable energy sources by almost 1 GW, increasing electric vehicle (EV) adoption by almost 500% and deploying 925 public, workplace, fleet and residential chargers in the seven-county region. The program effectively increased the EV adoption rate from 0.42% in 2016 to 2.34% in 2019 of new passenger vehicle registrations, surpassing the overall program goal of 1.8%. Columbus has among the highest share of EV registrations of any American city with no zero-emission vehicle (ZEV) regulation or direct incentives to customers from the government.

Overall Program Impact
In three years, the Columbus region has increased EV adoption by over 500%, almost quadrupled the number of charging ports installed and emerged as one of the fastest-growing EV markets in the Midwest through Smart Columbus education and programs that will impact innovation and sustainability in the city for years to come.

Greenhouse gas savings, shown in Figure 1, have come from the:
- AEP Energy Efficiency Programs, including the installation of over 500,000 AMI smart meters
- Sale of Green Power by the City of Columbus Division of Power (DOP)
- Other efforts such as DOP LED streetlights, solar deployments and new AEP distributed energy customers
- Use of electric vehicles instead of internal combustion ones
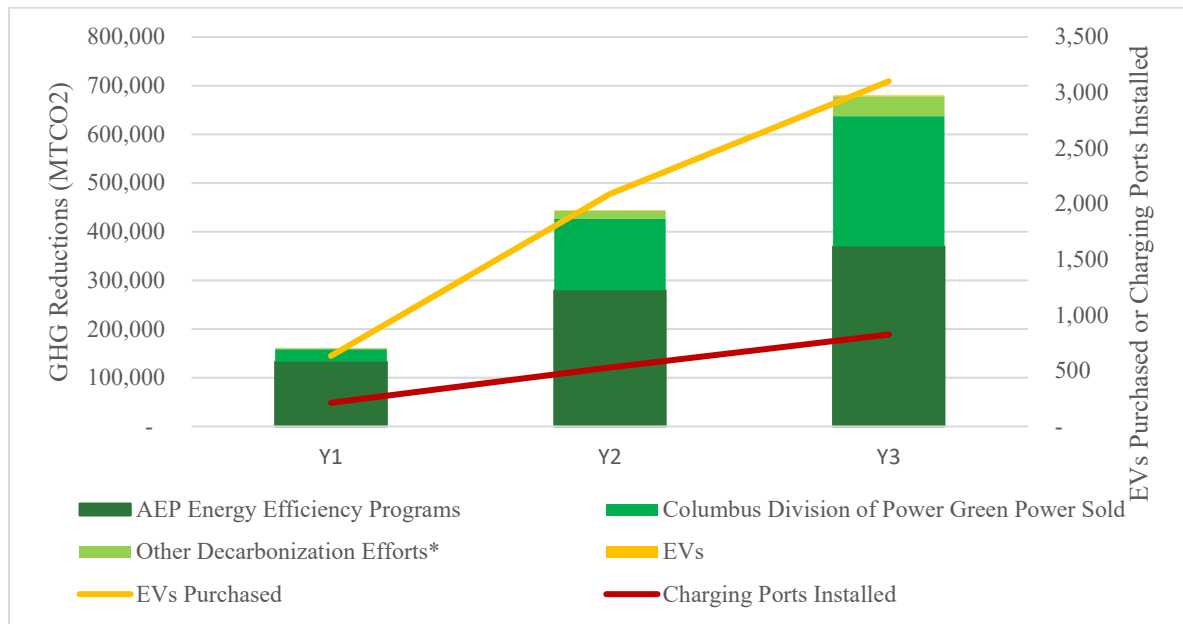
Figure 1: Smart Columbus Electrification Program Impact

Public/Private Partnerships

As the recipient of the grants, the City of Columbus worked closely with the Columbus Partnership, which led collaboration with the private sector and large employers. Through the Columbus Partnership's Accelerator Fund, more than $720 million in aligned smart city commitments from private, public, non-profit and academic institutions, provided capacity to generate an additional 108% ($298 million) in regional economic activity, resulting in 3,900 full and part-time jobs (Foley, 2019).

Consumer Electric Vehicle Adoption

Along with the Acceleration Partner program, Smart Columbus also created and deployed a robust suite of programs to advance electrification efforts in the region including the Ride & Drive Roadshow and the Electrified Dealers Program.

The Ride & Drive Roadshow test drive experience included a pre and post-drive survey where participants answered a range of questions on demographics, desirable vehicle characteristics, EV attitudes and vehicle purchase plans. The impact of this program will be felt for years to come as participants make their next vehicle purchase.

Smart Columbus wanted to ensure the leads had a high likelihood of turning into sales so the team created a program called the Electrified Dealer program to engage local car dealers. Initially, the program was able to increase the number of models available in Columbus

Smart Columbus built and hosted a website (https://smart.columbus.gov/), and deployed a cross-platform education/marketing campaign. These and other cumulative efforts are expected to influence future EV purchases those who have viewed or participated in EV education efforts continually purchase their next vehicle.

Fleet Electric Vehicle Adoption

In addition to the consumer and private fleet EV adoption efforts managed by the Columbus Partnership, the City of Columbus led efforts to increase public fleet and transportation network company (TNC) adoption. The City of Columbus made a large commitment to electrification by

introducing 200 EVs into the city's fleet. The success of the City of Columbus' fleet electrification program can be attributed to the collaboration of the many organizations involved in the procurement.

Quadrupling Regional EV Charging

Initially, the seven-county region had about 70 EV chargers. As of December 2019, 826 EV charging ports have been installed and another dozens more are expected to come online before the grant closes.

Lessons Learned

Smart Columbus was required to provide rigorous quarterly progress reports. Weekly and monthly reports were necessary to track progress and keep the grantor and stakeholders informed of the several facets of the program. As part of this reporting, many lessons learned were captured and are being shared through the Smart Columbus Playbook website. A few of the most impactful lessons learned are relayed below:

- **Educate Industry**: As smart city and electrification concepts are new and evolving, it is important to build relationships and knowledge base among local and regional stakeholders.
- **Take Time for Detailed Planning**: It is important to allocate sufficient time for detailed planning. In this case it involved things such as establishing/certifying baseline data, allocating, hiring, training, replacing staff due to attrition, identifying stakeholders, and detailing how impacts will be calculated.
- **Measure Performance**: It is important to define specific details for data collection for each priority, initiative and strategy and to establish the GHG baseline early in the program. A program of this complexity requires a certain amount of flexibility in order to evolve and incorporate new learnings and capitalize on opportunities.
- **Focus on Safety**: Safety plays a major role in electric vehicle supply equipment (EVSE) design.
- **Plan for the Future**: As projects are being executed, look farther ahead to future grant opportunities.

The key to Smart Columbus' regional success is the spirit of collaboration across public, private, non-profit and academic organizations. Several more lessons learned will be documented in a Smart Columbus Electrification Plan final report completed in July 2020.

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Decarbonizing the Largest Ferry Fleet in The United States: Washington State Ferries Journey Towards Zero Emissions

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ABSTRACT

Washington State Ferries (WSF) is undertaking an ambitious initiative to electrify their system with plug-in hybrid-electric vessels and terminal enhancements to achieve reduced environmental impact and energy costs. As the largest ferry system in the U.S. – carrying nearly 25 million people each year on 10 routes – WSF is leading the way in the marine industry by outlining and acting on a plan that will allow substantial emissions reductions. As the largest single consumer of diesel fuel in the State Government, implementation of system electrification is vital for Washington State to lead by example to address climate change. The benefits of system electrification extend beyond the government, ferry system, and ferry riders by improving air quality in the Puget Sound region and contributing to the significant greenhouse gas reductions required globally to support a sustainable future.

This presentation will address the overall system electrification program with a focus on the challenges and opportunities presented by this ambitious project. We will discuss the current state of electrification in the maritime industry, the engineering of new hybrid electric vessels as well as retrofitting of existing vessels, the engineering of the supporting charging infrastructure at the terminal facilities, and the partnerships needed with utilities and others to make this project successful. Additionally, the panel will address the necessary planning, financing, and executive support that continue to be key elements in the implementation of this long-term strategy.

Why Standardize Carbon Neutrality in Delivery of Complex Projects?

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ABSTRACT

The construction industry accounts for approximately a quarter of the global carbon emissions and is the largest consumer of materials and energy (Giesekam et al., 2016; Karlsson et al., 2020). These compelling statistics have engendered an urgency to transform the industry towards serious emission cuts to achieve carbon neutrality by mid-century. Carbon neutrality suggests achieving zero emissions by reducing emissions where practical and compensating for the remaining emissions by investing in carbon offset projects (IPCC, 2018).

This systematic review and meta-analysis sought to assess the extent of carbon emissions throughout the life cycle of complex building projects. This will guide in identifying areas where drastic changes are needed and facilitate decision making on practical decarbonisation opportunities to achieve carbon neutrality. The results of this analysis indicate a need to calibrate the performance of buildings in terms of both operational and embodied carbon emissions to reduce the whole lifecycle emissions. However, the absence of appropriate legislation on embodied emissions, unavailability of accurate and consistent databases, varying scope boundaries, as well as lack of interest in the impacts of embodied carbon emissions by relevant stakeholders make achieving this goal a challenge. There is currently no generally accepted methodology and standards for assessing embodied emissions accurately and reliably (Ibn-Mohammed et al., 2013). It is therefore paramount to streamline the carbon accounting standards and policies along with procurement strategies to address the whole lifecycle emissions of buildings. This will provide a solid reference for developing decarbonisation roadmaps for infrastructure developments; addressing the sustainability agenda.

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Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the threat of Climate Change.

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Sustainability Approach with Resiliency Planning in Transmission Line Engineering

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Keywords: Climate Change, Grid, Resiliency, Sustainability, Transmission Line

ABSTRACT

Due to evolving public issues relating to global climate change and changing socio-economic values, the traditional methods of transmission line routing, design and engineering are slowly becoming obsolete. There is a perception that electric utility companies are "out of touch" with society. As a result, utility companies are facing an increase in opposition to projects that are proposed. This increased opposition results in delayed permitting and licensing approvals and more public hearings which drive up project costs. To better align utility companies with the current social trends, utility companies need to start including sustainability and grid resiliency values in their projects.

Sustainability is generally defined as development which meets the needs of the present without compromising the ability of future generations to meet their own needs. Generally, sustainability is measured through three action dimensions: economic, environmental and social sustainability. Transmission line engineering needs to play an important role in minimizing adverse environmental impacts, providing economic benefits to shareholders and communities, and delivering electricity in a safe, reliable and efficient manner. Renewable resources and aesthetics are key sustainability concepts.

Grid resiliency is becoming ever more important in modern society. Society is becoming increasingly dependent on reliable power to power the plethora of electronics which are a part of our everyday lives. One of the largest challenges to grid resiliency is global climate change. With climate change the frequency and intensity of wildfires have dramatically increased. Sea level rise is also threatening infrastructure along the coastal areas - areas where a large majority of power generation facilities are located. Protection against adverse factors due to climate change needs to be considered in all grid resiliency discussions to ensure a high level of system reliability into the future.

Following a focused approach to define the importance of sustainability with resiliency planning in transmission line engineering, we have created guidelines and developed case studies. The goal is to help the utility industry to start considering sustainability and grid resiliency concepts in its transmission line engineering processes.

Technical Track Abstracts - Wednesday, December 8, 2021

Moderated by Theresa Harrison and Nancy Kralik

Sustainable Procurement for Infrastructure – Panel Discussion for the
International Conference on Sustainable Infrastructure (ICSI) 2021

Nancy Kralik, P.E., Env SP, LEED, F.ASCE[1] and Theresa E. Harrison, P.E., ENV SP, M.ASCE [2]

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ABSTRACT

In early 2020, the ASCE Committee on Sustainability's Policy Committee published "Sustainable Procurement for Infrastructure". The Policy Committee created this Technical Report to assist personnel in the sustainable procurement of materials and design and construction services.

The panel discussion will begin with a brief overview of ASCE's "Sustainable Procurement for Infrastructure" technical report, its structure and use. The introduction will also describe how to utilize the procurement language in contracts and purchase orders and how the suggested language can serve as the basis for additional sustainability conditions. The presentation will also discuss the project owner's requirements for a Sustainability Management Plan, the contractor's interpretation of those requirements and the potential cost implications.

The introductory session will be followed by six (6) panelists from various sectors of the industry (engineers, local, state, regional, and federal governments and agencies) who will consider the technical report and provide context for procurement in their organizations. The conversation will center around how sustainable procurement can be progressed and implemented in constructing infrastructure.

The technical report: "Sustainable Procurement for Infrastructure" is available from ASCE Publications: (https://ascelibrary.org/doi/book/10.1061/9780784483107)
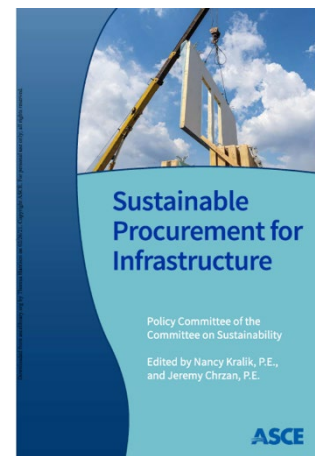
Track 2: Resilience (Part 2)

Moderated by Laura Patino

Planning for Climate Resilience in Coastal and Inland Wastewater Systems

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Keywords: Flooding, Planning, Resilience, Wastewater, Water, Wildfire

ABSTRACT

Impacts of climatic events to wastewater infrastructure in recent years have highlighted the importance of planning for resilience. Orange County Sanitation District and Los Angeles County Sanitation Districts have performed assessments to identify climate threats, assess vulnerabilities, and develop resilience measures to adapt existing wastewater facilities to climate change. Coastal and inland facilities were assessed, including six wastewater treatment plants, sixteen pump stations, and collection systems. Climate threats considered in the assessments included flooding, sea level rise, tsunami, wildfire, extreme heat, extreme winds, and drought. The collection of climate threats, vulnerabilities, and resilience measures have been summarized in climate resilience plans, which provide a systematic approach for adapting existing infrastructure to climate change. Comparison of resilience plans for coastal versus inland facilities identified flooding due to sea level rise as the main climate threat for coastal facilities while wildfire, localized flooding, and extreme heat posed the greatest threat to inland facilities.

Application of a Resilience Matrix Framework to Wastewater Treatment Facilities to Identify and Address Resilience Shortcomings

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ABSTRACT

Evaluating a system's resilience is an emerging tactic currently overtaking risk analysis due to its more all-encompassing approach that can be applied to more dynamic, complex systems. One major shortcoming to resilience is that it is not yet universally defined or applied, but tools such as Dr. Igor Linkov's Resilience Matrix are attempting to bridge this gap to make evaluation of resilience more practically applicable. This Resilience Matrix evaluates both physical and non-physical stressors across four domains: physical, information, cognitive, and social. It also assesses resilience in these domains temporally, per the National Academy of Science's four phases of: plan and prepare, absorb, recover, and adapt (Linkov et al. 2013). Because the concept of resilience has only recently been applied to wastewater treatment systems (WWTS), there are many gaps hindering the detailed study of the resilience of WWTS. In their wide-ranging literature review on WWTS resilience, Juan-Garcia et al. have identified many of these deficiencies. The most prominent gaps involve the lack of identification of all the potential stressors, physical and non-physical, that can impact a system, the lack of sufficient qualitative metrics to measure resilience, and the lack of consensus in the definition of resilience and the properties that indicate resilience (Juan-Garcia et al. 2017). Applying these lessons and incorporating Linkov's Resilience Matrix and management framework (Linkov et al. 2014), we determined that WWTS are currently high risk and low resilience, and address ways to incorporate the Resilience Matrix to address resilience deficiencies across all four domains and periods.

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A Methodology for Risk Assessment to Improve the Resilience and Sustainability of Critical Infrastructure with Case Studies from the United States Army

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ABSTRACT

Reliable performance of energy and water infrastructure is central to the mission readiness of the United States Army. These systems are vulnerable to coordinated attacks from an adversary as well as disruption from natural events. In addition, the Army oversees one of the largest portfolios of built infrastructure of any organization in the world, requiring significant resources to build, operate, and maintain assets. As a result of these combined factors, delivering resilient and sustainable infrastructure is of paramount importance to reduce the economic and environmental burden of national infrastructure while ensuring the capability of the United States Army. The objectives of this work were to investigate Army installations in North America, identify best practices for improving the resilience and sustainability of critical energy and water infrastructure, and develop a framework for analyzing the resilience of an installation, while building a modeling method to study the performance of an installation under varying resilience scenarios. This work was accomplished using a multi-layered decision process to first identify unique case studies from the 117 active-duty domestic Army installations. The relevant infrastructure at each selected installation was cataloged and investigated. Best practices were identified based on historical performance. A framework for analyzing and assessing the resilience of an installation was then developed to help inform stakeholders. This framework was developed with the intention of articulating the tradeoffs between resilience goals and resource requirements to achieve those goals. Metered energy and water data from buildings across the Fort Benning, GA were curated to inform the modeling framework, including a discrete-event simulation of the supply and demand for energy and water on the installation using ProModel. This simulation was used to study the scale of solutions required to address outage events of varying frequency, duration, and magnitude, the combination of which is described as the severity of outages at a given site. Stochastic modeling techniques were then used to vary the severity of outages to study system architectures that can help harden infrastructure against historical outages. The technologies considered as possible solutions to improve system architecture included, but were not limited to, solar PV, diesel generators, natural gas combined heat and power, batteries, and portable reverse osmosis systems. This project helps provide an operational framework to help installations meet Army Directive 2020-03, which states that installations must be able to sustain mission requirements for a minimum of 14 days after a disruption has occurred.

Recommended Options for Improving the Functional Recovery of Lifeline Infrastructure Systems

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ABSTRACT

As the United States government is planning a mega investment for its aged and new infrastructure, it is essential to offer technical tools for the assessment and optimization of funding allocation from a resilience perspective. As per the ASCE Infrastructure Report Card (2021), many of the country's infrastructure elements are at a critical state with their safety - even their very operability - being questionable. Responding to a request by the Congress, the NIST SP1254 Report (FEMA-NIST, 2021) discusses "better than code" design that includes functional recovery performance goals, requiring infrastructure to be maintained to quickly provide service to the population after earthquakes – and by extension other natural hazard events. While several state-of-the-art tools and methodologies to design and build new infrastructure or to retrofit existing ones are available, the prioritization of actions and optimization of spending the allocated budget in a way that targets return to service, and thus enhancing the national security, remains a major issue requiring further guidance. We have recommended options for improving the functional recovery of lifeline infrastructure systems included in the FEMA-NIST report, and relevant efforts that support the creation of resilience and post-event frameworks, as well as decision support guides and financial tools to address some of these options. Some of the challenges in combining the various developments in this field into a consistent methodology that can be regionally adopted by communities to meet functional recovery performance goals after extreme events have also been considered.

Track 3: People: Social, Society, Stakeholders

Moderated by Tera Haramoto and Barbara Luke

Social Justice is the Major Factor for City of Los Angeles Policymaking

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ABSTRACT

The growing social divide is a topic of much discussion these days. The U.S. is among the underachievers, in the industrial world's Social Justice Index ranked 36th of 41. The index is an effort to bring together all the indicators that reflect how fair and inclusive a nation is for its citizens, ranging from poverty levels for different age groups to environmental data. The indicators are pulled together into six major groups: poverty prevention, equitable education, labor market access, social inclusion, intergenerational justice, and health. The first three categories are given extra weight (Bershidsky 2019, Hellmann et al. 2019).

There are still limited available opportunities to participate in society in the USA. In the USA today there are hundreds of thousands of individuals and families living profoundly troubled lives marked by multiple disadvantages. In the last 10 years, the share of its population at risk of poverty remains the same at 17.8% (Statista 2021). Performance on intergenerational and interracial justice has worsened because of incoherent policies.

These are not new challenges, but they need a new approach. Centering and integrating of overlooked, vulnerable, or marginalized individuals and groups will lead to different considerations, methods, practices and resulting policies.

The New Approach

The Mayor of Los Angeles, Eric Garcetti said that he seeks to stem poverty and boost social justice in his vision for L.A.'s recovery from the pandemic in his April 2021 address to Angelinos. Mayor Garcetti offered his vision for helping Los Angeles emerge from the financial devastation of COVID-19, urging city leaders to commit to economic justice by pouring hundreds of millions of dollars into relief programs and ramping up initiatives that keep residents safe, employed and out of poverty, and creating practices and policies for integrating overlooked and vulnerable or marginalized individuals and groups. He also said he would take initial steps toward creating a pilot program for slavery reparations for Black Angelenos, by naming an advisory committee and finding an academic partner to help push the initiative.

Practices and Resulting Policies, Impacts on Engineering

In light of the staggering racial injustice shown by the George Floyd killing, Mayor Garcetti released Executive Directive 27 which speaks to the heart of the issues faced by employees of the City of Los Angeles as well as all of the City residents. The ED states that if changes are going to be made within the City they must start with the people that operate the City and each department was tasked to appoint a racial equity officer and create a report which looks at the

current demographics within each department and the establishment of goals to be completed or milestones set within the fiscal year that will advance the racial awareness and practices within each department.

The evaluation of all City of Los Angeles Departments clearly shows that the concept of equality and social justice is reached to very different levels within each department and vary considerably in each department's ability to create a truly inclusive culture. A strategic framework was created with a set of indicators being established and a number of goals declared in 2020 for the Bureau of Engineering (Engineering) lasting to 2022. The implementation of the indicators is being reviewed and evaluated for effectiveness. This reference framework provides for educational policymaking with emphasis on recruiting, retaining, and promoting a workforce that emulates the diversity found within the City.

Benchmarks for social justice: assessing the fairness and the diversity of City's workplace participation - combining evidence with opinion of the civic group: To begin this work, a benchmark needed to be set to show the current demographics represented within Engineering. As shown in Figure 1 which represents all Engineering employees, the demographic makeup of the department shows a very diverse makeup at the new hire stage, however, those numbers began to shift significantly at the higher managerial positions. While Engineering is working hard to hire a diverse workforce, that diversity is not being represented in the promotional opportunities. With the formation of a diversity committee, flaws and weak areas such as the promotional gap were identified, and a set of goals were created to work on overcoming them. The goals were categorized within three benchmark groups, 1. Equitable Workforce, 2. Equitable Operations, 3. Equitable Services. The identified goals were all created with an emphasis on impacting the diversity and equitable practices within Engineering. To accomplish these goals, a civic group was formed with access to information and evidence, in line with the benchmarks (Figure 1), and its members were provided with the opportunity to express their views, which is helpful in monitoring fairness in the long run.
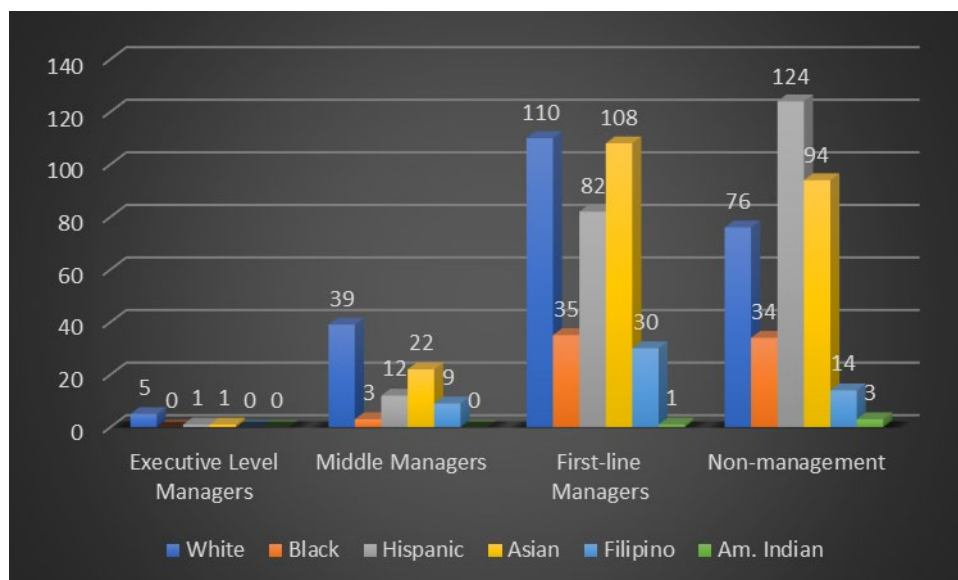
Figure 1. Engineering's Diversity Chart (City of Los Angeles BOE, 2020)

Social justice - achievement indicator for equity score card and sustainability: As there are frameworks and indicators that judge the overall sustainability of a project (i.e. LEED, Envision, etc.), Engineering is embarking on the creation of an equity framework for all

projects designed and constructed within the City of Los Angeles. Inspired by Mayor Garcetti's Executive Directive No. 27 and LA's Green New Deal, Engineering hopes to spearhead a look outward, finding ways to better assess and transform the department's contribution to a more equitable built environment. The first step is to understand the existing condition by creating an Infrastructure Equity Scorecard, then use that knowledge to pinpoint areas of inequity through mapping, and, in the long run, work more closely with communities to build the systems that best serve their needs and bring all of LA's infrastructure into the 21st century. An equity-first focus will impact the practice of hundreds of engineers and millions of residents across the City of LA. The Infrastructure Equity Scorecard and Mapping will initiate a conversation with all our contracting agencies and across public works, impacting billions of dollars of construction projects in all council districts. In the long range, the project will lead to more equitable distribution of resources by foregrounding a process that tracks infrastructure gains and losses and will give voice and agency to historically under-served residents.

With Mayor Garcetti's focus on building a more equitable City, Engineering is taking the lead in insuring that the City forces are focused on creating a more equitable workforce in addition to insuring equity is built into every project done by the City of Los Angeles.

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Do Infrastructure Deserts Exist?
Measuring and Mapping Infrastructure Equity in the City of Dallas

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ABSTRACT

Neighborhood infrastructure, such as sidewalks, medical facilities, public transit, community gathering places, and tree canopy, provides essential support for safe, healthy, and resilient communities. However, most related studies fail to fully capture the diversity of neighborhood infrastructure and only measure a single or a few infrastructure types when assessing its condition. Taking the first step to systematically examine the presence and condition of neighborhood infrastructure, we show that "infrastructure deserts" exist, which are low-income neighborhoods suffering significantly more deficient infrastructure. A generalized data-driven framework was developed and applied at the street-level for twelve types of neighborhood infrastructure in one metropolitan area: Dallas, Texas. The results show significant infrastructure inequities across income levels for most types of infrastructure. Statistical inference with a cumulative logit model predicts (with 95% confidence) that low-income neighborhoods (census block groups) are 2.2 to 3.5 times more likely to have eight or more types (highly deficient) of deficient infrastructure than high-income neighborhoods. The paper also reveals infrastructure inequities across race-ethnicity groups. A similar statistical model predicts that predominantly Hispanic and Non-Hispanic Black neighborhoods are substantially more likely to have highly deficient infrastructure than ones without predominantly underrepresented race-ethnicity (2 to 4.6 times higher for predominantly Non-Hispanic Black neighborhoods;1.5 to 3.5 times higher for predominantly Hispanic neighborhoods). This study addresses the methodological challenge of considering multiple infrastructure types and provides an insightful framework for infrastructure investment prioritization.

Improving Walkability by Focusing on Residents' Needs and Neighborhood's Built Environment

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Keywords: Built-Environment, Pedestrian, Sidewalk, Transportation Planning, Walkability

ABSTRACT

While the benefits of walkability are clear, it could be difficult how to determine the best approach to budgeting on sidewalk development decisions in order to maximize the efficiency of the investment. This paper presents a methodology and a tool to evaluate the walkability of different areas in a city by focusing on the gap between walking needs of residents and built environment of the neighborhood. To do that, we first characterize walkability and its greatest contributing socio-demographic variables, like trip purpose, number of vehicles in the household, and the age of individuals. Next, through running Principal Component Analysis, we define a unique index for walkability, which is used to find areas with greatest demand for walkability in their neighborhood through Hotspot Analysis. Finally, using the Pedestrian Environment Index as an indicator of walkability supply for the neighborhood, we identify the most efficient places to develop sidewalks by finding the gaps between demand and supply of walkability in each neighborhood. The results suggest that in the southern and western neighborhoods of Chicago the resident's walkability desire and need does not match with the built environment characteristics. In addition to providing an informative location-based measure for policymakers, the methodology opens avenues to address some equity concerns related to walkability and prioritizing neighborhoods for improvement based on the needs of the residents.

The Nexus of Sustainable Urban Design and Human Security

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ABSTRACT

The nexus between urban design and human security is intuitive, and simultaneously not well understood. We inherently understand that poor urban design results in crime, unrest, and poverty. We also understand that the provision of infrastructure services (clean water, wastewater disposal, and transportation) has the potential to lift populations out of poverty and improve human security. This study uses a qualitative approach to identify those elements of urban design that provide the greatest catalyst for improvements to human security.

Human security is a subset of national and international security. A failure to meet basic human security needs has been shown to be related to national and international conflict. Threats to human security, such as drought, famine, ethnic and religious strife, and resource conflicts, have caused numerous international and national conflicts in the last 30 years. Accordingly, it is an international security imperative to find solutions to design issues caused by urbanization to prevent conflicts from occurring. In a national security context, conflict prevention is far less costly in lives lost and in national treasure than conflict resolution.

This study aims to identify the best practices for urban design in the developing world and identify urban design approaches that have been successfully implemented in the world's most challenging urban environments. Identifying these techniques provides a roadmap for the rest of the developing world to follow as global urbanization trends continue. These urban design approaches provide a springboard to improved sustainability in an urban context, and with it, improved human security.

Strategies for Increasing Resiliency and Sustainability in Public Works

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ABSTRACT

Within the City of Los Angeles, Public Works' Bureau of Engineering (BOE) has explored strategies to increase sustainability in infrastructure design and delivery. These strategies include, firstly, effectively assessing program-wide engineering practices and policies to measure sustainable performance using the Envision framework. Envision is a framework of sustainable, equitable and resilient indicators developed to evaluate all aspects of civil infrastructure through all project phases.

Following this assessment, the BOE is now focusing on program-wide sustainable performance strategies in three key areas, including: 1) implementing sustainability management planning as part of the project delivery process; 2) reducing embodied carbon emissions as part of material procurement practices for construction materials; and 3) understanding equitable design in infrastructure.

As public agencies look to increase sustainable and resilient project delivery, a well-developed sustainability management plan, or policy, that prioritizes setting and monitoring sustainability goals through all project phases is critical in facilitating discussions during early planning/decision-making processes. This allows engineers, project teams, and stakeholders to consider innovative solutions focused on sustainability and resiliency. Reducing embodied carbon emission from construction materials is a major step towards the fight against climate change which has a global impact. And understanding equity in infrastructure takes into consideration community engagement processes as well as organizational commitments to equity from project teams that lead to building healthy and resilient communities.

These efforts can have industry-changing impacts that promote global advances in sustainable technologies, enhance public health and build more resilient communities through infrastructure designed with equity in mind.

Track 4: Planning, Procurement, and Finance

Moderated by Eric Bill

City of San Antonio - Climate Action & Adaptation Plan - 2050 Net Carbon Neutrality - Economic Analysis to Inform Policy Trade-offs, Costs, and Public Benefits

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ABSTRACT

The City of San Antonio is one of the fastest growing cities in the US - it won an American Climate Cities Challenge to implement the Paris Agreement and achieve carbon neutrality by 2050. In 2019, the City of San Antonio adopted SA Climate Ready, its first Climate Action & Adaptation Plan. In this plan, the City maps out a pathway to achieving net zero carbon emissions by 2050, while prioritizing clean air, public health, water quality and conservation, good jobs, transportation choices, clean and secure energy, and emergency preparedness. To realize the economic impacts of achieving the ambitious carbon goals, the City wished to explore broad-based outcomes from a variety of policy strategies. These mechanisms include building code changes to incentivize private action, and reinventing city buildings and open spaces as environmental and resilience generating locations. Economic analysis is a valuable approach to help draw quantitative insights towards trade-offs amongst these varied climate action policies. Six policies were identified by the Office of Sustainability as priority mitigations strategies due to their potential climate action impact:

1. Energy benchmarking for commercial and multifamily buildings
2. White roof and energy insultation building code
3. EV charger readiness building code
4. Solar PV roof readiness building code
5. Zero net energy (ZNE) municipal buildings
6. Urban agriculture

The economic analysis allowed the City to understand the long-term costs, benefits, and trade-offs of the policies across the financial, social, and environmental community impact outcomes using peer-reviewed, empirical estimations of the expected outcomes.

Innovative Economic Analysis and Triple Bottom Line Valuation of Multi-Purpose Green Infrastructure Assets and Lessons Learned for Future GI Project Planning

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ABSTRACT

With climate change exacerbating natural disasters, pandemic-driven fiscal deficits, and environmental damages becoming widespread, more than ever infrastructure is needed to create job opportunities, mitigate and adapt against hazards, and improve diverse ecosystems. Prudent planning plays an important role in scoping the most effective projects – those with the greatest social, environmental and community benefits, with a lens to the highest economic value. Empirical, evidence-based data in the form of science and economic analytics can support planners, policy makers, engineers, and stakeholders in making more informed, comprehensive project designs and funding decisions that maximize public value and create benefits across multiple dimensions. Analytical tools such as life cycle cost analysis (understanding full project costs over their life cycle) and cost benefit analysis (quantifying and monetizing social and environmental co-benefits) are all important tools that can help to inform better project design, greater funding, and quicker stakeholder buy-in. A Triple Bottom Line (TBL) approach brings these tools together to holistically value the social, environmental, and financial aspects of projects. The San Antonio River Authority received a Clean Water Act 319(h) grant from the United States Environmental Protection Agency, administered by the Texas Commission on Environmental Quality, to fund Green Stormwater Infrastructure (GSI) focused Master Planning in the Upper San Antonio River Watershed that would lead to improving water quality in the San Antonio River. To determine the multi-benefits from installing GSI Best Management Practices, the River Authority utilized the comprehensive TBL approach to maximize water quality benefits, alongside other social and environmental multi-benefits, including habitat improvements, urban heat island reductions, increased access to recreation, and climate change implications. With the increasing prevalence and damages of climate change becoming more visible by the day, more than ever this approach to planning is needed to ensure the desired outcomes from infrastructure projects are maximized for every dollar spent.

Table 1. Results Summary of All Sites (1-8) Net Present Value Over 50 Years Discounted at 3%

	Impact	Site 1 (Subbasin 70)	Site 2 (Subbasin 150)	Site 3 (Subbasin 260)	Site 4 (Subbasin 270)	Site 5 (Subbasin 310)	Site 6 (Subbasin 330)	Site 7 (Subbasin 420)	Site 8 (Subbasin 560)
Financial	Capital Costs	-$318,400	-$263,700	-$754,800	-$132,700	-$155,000	-$263,800	-$181,900	-$2,481,000
	Operations & Maintenance	-$450,800	-$543,600	-$1,498,000	-$161,900	-$194,300	-$185,400	-$240,600	-$811,100
	Replacement Costs	-$223,379	-$190,590	-$530,795	-$57,342	-$68,835	-$68,624	-$89,051	-$284,379
	Residual Value	$21,100	$12,700	$35,500	$3,830	$4,600	$4,590	$5,950	$19,000
Social	Flood Risk	$850	$400	$1,156	$72	$221	$93	$221	$647
	Education	$30,915	$0	$30,915	$30,915	$30,915	$0	$0	$0
	Urban Heat Island	$6,700	$3,080	$8,610	$930	$1,120	$1,110	$1,440	$4,620
	Open Space - Recreation	$7,410	$3,250	$1,190	$190	$1,200	$0	$0	$0
	Water Quality - Induced Recreation	$2,126,544	$1,668,031	$2,731,634	$295,244	$354,365	$353,296	$458,359	$767,218
Environmental	Air Pollution from Sequestration	$880	$400	$1,130	$120	$150	$150	$190	$600
	Carbon Emissions from Sequestration	$71,100	$32,700	$91,300	$9,860	$11,800	$11,800	$15,300	$49,000
	Trash	$17,209	$7,846	$22,017	$2,278	$2,784	$2,784	$3,797	$11,895
	Water Quality - Pollutant Loading Reduction	$4,298	$4,412	$11,507	$934	$1,027	$1,363	$982	$3,194
	Pollination	$4,480	$2,062	$5,754	$622	$747	$744	$966	$3,087
	Financial NPV	-$971,479	-$985,190	-$2,748,095	-$348,112	-$413,535	-$513,234	-$505,601	-$3,557,479
	Social NPV	$2,172,419	$1,674,761	$2,773,505	$327,351	$387,821	$354,499	$460,020	$772,485
	Environmental NPV	$97,967	$47,420	$131,708	$13,814	$16,508	$16,841	$21,235	$67,776
	Triple Bottom Line-Net Present Value (TBL-NPV)	$1,298,907	$736,991	$157,118	-$6,947	-$9,206	-$141,895	-$24,346	-$2,717,218

Public-Private Partnerships for Environmental, Social, and Governance Projects: How Private Funding for Infrastructure Can Produce Mutual Benefits for Companies and the Public

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ABSTRACT

The current concern for climate change and social equity in the United States, highlighted by the global COVID-19 pandemic, has increased public attention on environmental, social, and governance (ESG) issues. One of the primary challenges the country faces is the issue of infrastructure, which has a profound impact on environmental and social conditions. Private entities have an opportunity to address ESG factors and improve climate resiliency, environmental justice, and economic opportunity through public-private partnerships (PPPs) that are focused on America's aging infrastructure. It is also an opportune time to initiate infrastructure projects as they align with the Biden Administration's aggressive climate change and economic stimulus plans. This study utilized publicly available information, including sustainability reports, news sources, and research papers, to explore examples of PPPs and current ESG trends, with a focus on environmental criteria, and demonstrated how private investment in infrastructure can produce mutually beneficial results for the private entity and society.

Track 5: Sustainability in Transportation Projects

Moderated by Veronica O. Davis

The Envision® Rating System and its Impact on Transit Agency Projects

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Keywords: Design, Planning, Resilience, Sustainability, Transportation

ABSTRACT

The Institute for Sustainable Infrastructure (ISI) Envision® certification system evaluates the sustainability of infrastructure projects. Envision provides a comprehensive framework to assess how effectively a project has incorporated sustainability considerations.

While the Envision system can be applied to infrastructure projects of all types and sizes, sustainability practices within transit agency projects provide unique and challenging conditions. Agencies are incorporating Envision early in the design and planning process in order to meet their sustainability goals. This tool has proven an invaluable resource to help them communicate and validate their sustainability commitments.

Anthony Kane of the Institute for Sustainable Infrastructure provides an overview of Envision and the certification process. Thomas Abdallah, PE, LEED AP, of New York's Metropolitan Transit Authority Construction and Development (MTA C&D) discusses the evolving impact of using the rating system on recent and upcoming projects and provides specific examples of Envision in practice within the agency. James Heeren, PE, ENV SP, Senior Environmental Engineer at Dewberry, moderates this session which features an overview of the Envision certification and rating process overall, and offers insight as to how the system is being applied to specific projects.

Partially Prestressed GFRP-Reinforced Concrete Piles in a Continuous Flat-Slab Bridge Structure: Inducing Resilience of Civil Infrastructure

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ABSTRACT

Constructability, durability, sustainability, resiliency, and Life Cycle Assessment (LCA) criteria of innovative glass-fiber reinforced polymer (GFRP) reinforcing for structurally reinforced pilings, bridge substructure, bridge superstructure, and soldier-piles bulkhead seawalls are of utmost importance for the longevity of our civil infrastructure systems, components and structural elements alike. This sentiment is echoed herein by a recently completed, first of its kind, GFRP-RC 3-span continuous flat-slab bridge and a soldier-pile bulkhead-seawall with GFRP-RC precast panels, in the State of Florida, USA.

Additional points of interest include the GFRP-RC for the CIP end-bents, intermediate bent caps, and bulkhead caps. The traditional approach includes the installation of grade-60 carbon-steel rebar with three inches or more of concrete cover and a class IV concrete with additional pozzolan material such as silica fume, metakaoline or ultrafine fly ash, especially in the splash zone. As part of this research effort and recently completed bridge project, the utilization of GFRP bars in lieu of the conventional grade-60 carbon-steel rebar in most bridge components and elements, with reduced concrete cover and eliminating the need for pozzolan material in the concrete mix design, is of great benefit. Utilization of the GFRP bars, especially within the splash zone, in South Florida's very aggressively classified marine environment provides an extended time window for required maintenance and substantial cost savings. The primary benefits are a significantly increased service life of the bridge substructure and superstructure and bulkhead-seawall. LCA criteria for unique component/element assemblies have also been investigated.

Finally, constructability and the feasibility of driving of pre-stressed GFRP piles for FDOT bridge structures were demonstrated and documented via Pile Dynamic Analysis [PDA], Pile Integrity Testing [PIT], and ground acceleration vibration monitoring during pile driving for the Ibis Waterway/23rd Avenue bridge in Broward County. Creep testing complemented the field documentation for the installed permanent tieback system at both end bents.

Partially prestressed GFRP-concrete pile constructability

Sustainability and resiliency of the built environment is of significant interest and importance in research, laboratory testing, and field-implementation of GFRP and carbon-fiber reinforced polymers (CFRP) for this Ibis Waterway/23rd Avenue bridge substructure and superstructure, as are constructability, efficiency of installation, and component durability. The overall constructability and performance characteristics of this bridge are documented further in Figure 1, which demonstrates the use of coiled GFRP bars, installation, prestressing, and constructability (including pile driving) of the 0.457m x 0.457m (18in. x 18in.) square GFRP-concrete piles. Partially prestressed GFRP-concrete piles were successfully cast at the precast yard, then constructed and driven at the bridge site, while maintaining FDOT pile driving stress limit compliance as specified by the design and plan approval teams.

(A) Coiled GFRP bar boxed delivery to site

(B) Coiled GFRP bar Casting-Bed insertion

(C) Cage-Assemblies

(D) Coiled-GFRP Prestressed in Beds

(E) Pour of GFRP Piles

(F) GFRP-Cages Crane lifted into Casting-Beds

(G) Stressed Coiled/Cage GFRP-bars

(H) Concrete Placement at GFRP-Piles

(I) GFRP at time of stress release (cut)

(J) GFRP Pile Bed Removal

(K) Pile at Driving Time

Figure 1. Coiled GFRP installation and successful partial prestressing of GFRP piles

Bridge site GFRP-RC substructure and superstructure

Constructability aspects of the bridge substructure and bridge-superstructure were detailed and documented in the field and validated via laboratory testing of the GFRP materials utilized for this project. Figure 2 shows some of the substructure's and superstructure's constructed components.

(A) GFRP-Seawall

(B) Driven GFRP Piles

(C) Tieback Grouting
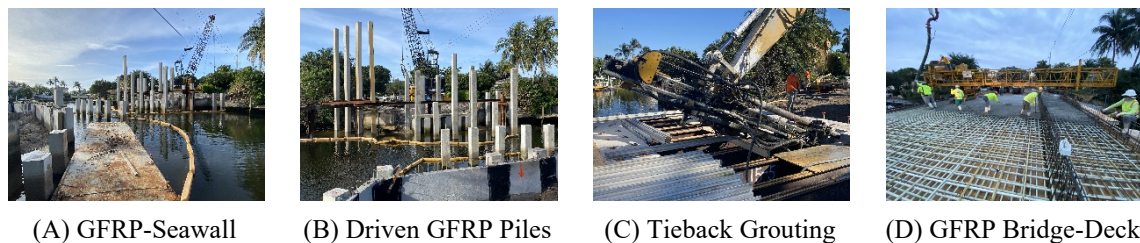
(D) GFRP Bridge-Deck

Figure 2. Construction and installation of precast GFRP seawall with panel sections, driven GFRP piles, tieback-grouting, creep-monitoring and GFRP bridge-superstructure deck installation with sensor placement

To complement this research effort, LCA criteria for evaluating "green" construction were addressed, comprising the essential raw materials and resources, processing, manufacturing,

distribution, usage, and end of life with final disposal stages. The realization of total life cycle impacts as determined via LCA is essential and necessary to realizing carbon-neutral construction goals and can be validated through ISO 14040 and 14044 Standards.

The use of ISO 14040 and 14044 Standards is deemed beneficial with respect to obtaining a highly desirable level of reliable, relatively unbiased data analysis and consistency of results.

In summary, "Lessons Learned" about the sustainability, constructability, and driveability of GFRP-reinforced piles in relatively loose to very dense soil conditions is showcased in this project.

Design Ideals for Extreme Heat Resiliency: Applications in Public Transit Systems

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ABSTRACT

Urbanization and climate change are forcing an increasing number of people around the world to live in extreme conditions, especially extreme heat. Unaddressed, extreme heat can have profound negative impacts on the infrastructure upon which society relies. Public transit and other essential systems must be designed such that they can withstand extreme heat events, ensuring that users remain comfortable and the system is protected from degradation. Burns & McDonnell has been collaborating with a major United States county transportation authority to suggest and implement into new light rail designs features that ensure extreme heat resiliency for the system. These features can be found in all components of the light rail system including the track, overhead catenary lines, vehicles, and stations/platforms. For example, track damage can be forestalled by adding automated weather stations and track-side probes that monitor temperature data in remote areas of track, and passenger platforms can be made cooler by evaluating alternative deck section designs that reduce concrete mass and thus reduce heat absorption. Extreme heat resiliency has also been explored in the context of bus system design through the optimization of street furniture placement. Building on these examples, this study focuses on the importance of designing infrastructure systems with extreme heat resiliency, applications of how this has been done for public transit systems, and how these applications can be adapted to other projects. It is crucial that infrastructure systems be designed to withstand and recover from extreme heat events, whether they are expected or not.

Management Practices and Data Tools for Large, Multi-Discipline Infrastructure Projects Pursuing Envision Certification

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ABSTRACT

Infrastructure clients are increasingly embracing the Institute of Sustainable Infrastructure's rating system, Envision, reflected in current Request for Proposals. Envision is suitable for all types of infrastructure projects from bridges to water-treatment plants to airports, both large and small projects. This abstract addresses use of the Envision framework and recommendations for managing the credits and documentation that are useful for any project and all rating systems. The framework provides the design team a method of incorporating funding requirements of resilience to climate change and addressing social justice and equity. The study focuses on large, multi-discipline projects that test the management skills of the sustainability team. The management tools presented here allow a project to incorporate sustainability and resiliency into the project in a manner of supporting the work of all disciplines. The project that helped develop this documentation system was the LaGuardia Airport CTB Replacement Project, awarded Envision Platinum.

INTRODUCTION

With 64 credits available and multiple levels of achievement, the evidence submission process for Envision certification can appear to be burdensome. A robust evidence tracking system using Microsoft Excel (or similar), developed at project outset, properly prepares the team to use Envision as intended – a stimulus for incorporating sustainability and resilience during project design. Using data management functionalities existing in Excel, i.e. pivot tables, our team developed an evidence tracker tool to sort and organize multiple rating systems credits and project deliverables to see sustainability through discipline-specific and project-wide lenses.

This tracking system is able to integrate additional ratings systems like LEED and Parksmart, keeping Envision as the umbrella sustainability framework, ensuring minimum achievement for comparable credits and facilitating cross-rating system synergies. The Evidence Tracker can also provide additional dashboard tools for data management in the context of hybrid infrastructure-building projects. Furthermore, early application of sustainability and resilience credit requirements improve project value by requiring the design team to think about the fullest range of operating and environmental conditions over the project lifespan.

MANAGEMENT SYSTEMS

Large transit projects are interdisciplinary, often requiring building disciplines, architecture/MEP/structural, and site engineering with civil/traffic/landscape. Deliverables can have multiple lead designers and authors contributing to a single document or design package

of construction drawings, specifications and reports. Sustainability experts need to track the individual pieces of evidence associated with the credits they are pursuing while simultaneously supporting the designs by working with each author to implement sustainable design strategies. Resilience credits in Envision and other rating systems further require designers to consider significantly different future climate variables. Climate change impacts base flood elevation, heat duration and storm events experienced by the project in its lifespan, typically 75 years into the future. Envision is suitable to implement sustainability for these large projects, as the scale of infrastructure demands a broader reach to include categories not covered under other rating systems. For example, owners and design teams can address how a community is impacted by the project, what interdependencies of power, water, and communications impact the resiliency of the completed facility and the importance of sustainable strategies for operations and maintenance.

Sustainability experts cannot simply work with discipline leads within their own design silos but must support collaborations between leads to identify byproduct synergies; for example, processing demolition debris into recycled concrete aggregate (RCA) for achievable credits such as Envision's Leadership LD1.4 Pursue Byproduct Synergies and Resource Allocation RA1.3 Reduce Operational Waste. The efficacy of Envision and sustainability planning relies on sustainable planning through the entire project's lifecycle from conceptual design to design milestones and to final design submission, and evidence tracking becomes integral to ensuring the target credits are being achieved with substantive documentation of a strategy, and that the strategy is being revisited regularly by the sustainability team. However, with a large scope, infrastructure projects can also come with a larger frequency of design changes that can move these documented strategies and evidence around.

Pivot Tables for Managing Credits, Project Documentation, and Discipline Leads
Taking in all of these moving pieces, pivot tables with Microsoft Excel or Google Sheets can organize sustainability planning by utilizing the variables including: Target Rating System Credit, Document Title, Project Area/Work Order, Discipline, and Lead/Author (see Figure 1).
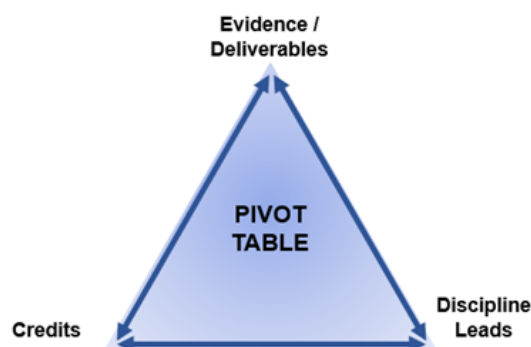
Figure 1. Conceptual diagram of the data relationships managed by a pivot table

Adjusting how fields are sorted in the pivot table allows for data analytics through comparative analysis of how the different fields (column headers) relate to each other. Take a Roadway Lighting submittal as an example. This one submittal can be utilized for multiple credits. There are a multitude of ways that submittals can work for multiple credits and for multiple work orders (or work areas/boundaries).

The sustainability expert can use the existing data set and knowledge of credit requirements to add more sustainability rating systems as applicable (see Figure 2). In addition, the United States Green Building Council (USGBC) has resources that identify and discuss synergies between longstanding rating systems such as LEED and Parksmart.

	B	C	D	E	F	G
1	Submittal	WO	Envision Credit	SIG Credit	Lead	Discipline
59	Roadway Design Plan	C	QL 1.1 Improve Community Quality of Life	IS-20 USE TRANSPORTATION SYSTEM MANAGEMENT		Roadway Design
60	ITS Master Plan	C	QL 1.1 Improve Community Quality of Life	IS-20 USE TRANSPORTATION SYSTEM MANAGEMENT		ITS
61	ITS Master Plan	C	QL 1.1 Improve Community Quality of Life	IS-21 USE TRANSPORTATION SYSTEM TECHNOLOGIES		ITS
62	Roadway Lighting Plan	C	QL 1.2 Enhance Public Health & Safety	IS-17 OPTIMIZE TRAFFIC SAFETY		Roadway Lighting
63	Traffic Signal Design	C	QL 1.2 Enhance Public Health & Safety	IS-17 OPTIMIZE TRAFFIC SAFETY		ITS
64	Roadway Design Plan	C	QL 1.2 Enhance Public Health & Safety	IS-17 OPTIMIZE TRAFFIC SAFETY		Roadway Design
65	ITS Master Plan	C	QL 1.2 Enhance Public Health & Safety	IS-17 OPTIMIZE TRAFFIC SAFETY		ITS

Figure 2. Screenshot of additional data fields demonstrating applicability of a single Submittal (column B) across multiple rating systems including Envision and Sustainable Infrastructure Guidelines (SIG – rating system specific to Port Authority New York New Jersey projects)

Sorting the pivot table or filtering the data set based on the five Envision categories can narrow down the submittals available for comparison and to more easily identify potential synergies. Pivot tables specifically allow for a flexible, instantaneous reorganization of information for tracking and accountability to maximize sustainability.

Additional data analytics has the potential to craft dashboards for sustainability planning by adding columns with submittal status values.

CONCLUSION
Sustainability and resilience are inherently all-inclusive, touching every aspect of a project from funding to planning, design, construction and every phase of its lifecycle. The Envision framework and suite of credits is a starting place for managing sustainable infrastructure projects of all sizes and types. The Quality of Life credits support funding requirements for social justice, equity and stakeholder engagement. The Climate and Resilience credits support funding and policy requirements for addressing climate change issues. Key to successful tracking and collaboration across all disciplines is the sustainability plan is establishing a single file using pivot tables and data tools. This management system for credit evidence and linking evidence with multiple fields enables the sustainability professional to approach a large and interdisciplinary project with an organized vision. Regardless of the multiple project types and rating systems, the data management system provides efficiency of credit documentation without redundancy. Pivot tables specifically allow for a flexible, instantaneous reorganization of information for tracking and accountability to maximize sustainability. In this manner, sustainability and resilience become the backbone of the project, linking and supporting all disciplines on the project.

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Gordie Howe International Bridge: P3 Project Leadership Vision to Enhance Sustainability Performance

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ABSTRACT

When the $5.7 billion (CAD) public-private partnership opens to the public in 2024, the Gordie Howe International Bridge project is anticipated to be one of few river crossing projects and the first international border crossing project to achieve an Envision award from the Institute for Sustainable Infrastructure.

The project's sustainability strategy includes an overall sustainability management plan and a twofold certification approach: LEED for the two Port of Entry plazas and Envision for the Main bridge and Michigan Interchange. An extensive integrated process includes the Owner (WDBA), Owner's Engineer (Parsons), Developer (BNA), and Design team (AECOM) to refine and document sustainable strategies over the course of the design-build phase.

Close collaboration led to increased Levels of Achievement for credits targets across the Envision rating system, in particular in the Quality of Life and Climate and Risk categories. Emphasis is placed on:

- Advantages of a combined prescriptive and performance approach driven by the Project Agreement, which defined sustainability objectives and mandated certification levels, while allowing the Developer to develop detailed strategies in the Sustainability Management Policy.
- Complexities of implementing multiple rating systems within a single project, e.g., defining relevant key performance indicators and associated benchmarks and targets.
- Sustainability benefits achieved due to close collaboration and relationship-building among project team members, e.g., leveraging planning phase and other Owner-driven initiatives to advance the ISI award target.
- Opportunities and challenges presented by the P3 project delivery method.

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Technical Track Abstracts - Thursday, December 9, 2021

Track 1: Transportation Systems

Moderated by Theresa Harrison

Baking Resilience into Transportation Planning

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ABSTRACT

By its very nature, transportation infrastructure is a long-term investment, and its assets must serve the test of time. Time is not the real issue, however; it is how the system responds to and recovers from the stress and shock of natural and manmade events that determines its resilience. Resiliency allows the bridge or roadway to be efficient, reliable, and safe throughout its expected lifespan, which is important from financial and safety perspectives.

To ensure that resilience is incorporated into the transportation planning process, planners must understand four aspects:

- The definition and meaning of resilience;
- How best to raise the awareness of the need for resilience;
- An approach to incorporate resilience in transportation planning; and
- The areas where resilience best fits in the established transportation planning process.

Resilience is better understood by identifying criteria to support its essence and then using the criteria to assess the potential issue and subsequently the solution to fit the geography and situation. Today we utilize transportation infrastructure that was built by the previous generation. The phrase "we are building it for the next generation" can be the lens through which we view the long-term benefits for transportation and our mobility needs and then incorporate resilience into infrastructure and system performance. We need a resilient mindset to build a resilient transportation system.

Resilience is the Future of Transportation Networks

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ABSTRACT

The design of resilient transportation networks constitutes a paradigm shift toward systems that address natural hazards considering future climate change scenarios. This remarkable pivot from a reactive toward a proactive approach recognizes the cost of inaction and the socio-economic benefits of proactivity. Three projects present powerful models for building a resilient transportation future:

AECOM developed the SWIFT (Sustainable Ways to Integrate Future Transportation) modelling tool based on data-driven, performance-based and scenario planning that enables agencies to take proactive approaches and understand how transportation systems perform under extreme duress and unique circumstances, and to prepare them to create effective contingency plans.

The Ecuadorian National Road Network (NRN) was conceived as a system integrating the country by connecting the most important population centers and facilitating the movement of strategic goods and services. AECOM developed a strategy to design a robust NRN enabled to resist and adapt to the hazards to which it is exposed, providing continuity in the mobilization of goods and services offered to the main economic sectors and a focused a response for cities.

California State Route 37 is an important regional highway, connecting the northern California San Francisco Bay Area sub-regions. Addressing traffic congestion relief, sea level rise, flooding and ecology, AECOM led a team that broke traditional barriers in forming a technical working group of transportation planners, engineers, ecologists, regulatory agencies, environmental organizations, and others to ensure a multi-benefit cohesive resilient transportation system.

Driving the Future of Transportation Planning Through Emerging Trends

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ABSTRACT

Understanding emerging global and domestic trends, such as economic growth, evolving climate changes, energy resources and socio-demographics, as well as advances in technology and sustainability practices, is a critical step in preparing transportation planners and practitioners to respond to future challenges—and opportunities—facing the transportation industry. Burns & McDonnell supported the US National Cooperative High Research Program (NCHRP) in carrying out a series of research projects to identify and evaluate seven strategic long-term issues, in the coming 30-50 years, predicted to impact local government agencies, including the US State Departments of Transportation. These research projects, known as *NCHRP 20-83*, prepared transportation leaders to anticipate, and better respond to, new challenges and enabled transportation agencies in the US to shape the future by addressing emerging trends in their decision making.

To promote the integration of *NCHRP 20-83* in future transportation planning, Burns & McDonnell developed a multi-part "Foresight Series" which synthesized thousands of pages of research into a set of simple and compelling messages. The Series further prepared planning agencies for the future by outlining strategies to adapt to the uncertainty of seven strategic issues:

1. Economic Changes Driving Future Freight Transportation
2. Expediting Future Technologies for Enhancing Transportation System Performance
3. Long-Range Strategic Issues Affecting Preservation, Maintenance, and Renewal of Highway Infrastructure
4. Effects of Changing Transportation Energy Supplies and Alternative Fuel Sources in Transportation
5. Climate Change and the Highway System: Impacts and Adaptation Approaches
6. Effects on Socio-Demographics on Travel Demand
7. Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies

Small Changes, Large Effects: Interconnected Infrastructure Networks in Food Supply Chain Disruptions and Multi-Modal Transportation Solutions

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ABSTRACT

Critical infrastructures, in particular, transportation, energy and water, are key supports for supply chains generally and specifically food supply chains. A framework is developed for representative connectivity among the three infrastructures and food systems in terms of interconnected nodes and links and their properties, expanding prior research. The framework is used to illustrate how the convergence of several infrastructures often results in small connections producing large effects on interconnected infrastructures. These effects in turn can increase food system vulnerability to extreme events, often heightened by human behavior in relation to changes in vulnerability.

Methods are based on illustrative cases for food disruptions after (and not including) agricultural production encompassing processing, packaging, storage, distribution, and consumption. These cases include the COVID-19 pandemic and extreme weather events that have disrupted energy, transportation, and water through losses of transfer locations or facilities both above and below ground with impacts upon food systems. Food system examples include effects on components at the product, packaging, and equipment levels. Food supply chains are important given the extensive resources used to maintain them in emergencies and extreme events to avoid permanent and temporary food deserts and bottlenecks that often have human survival implications. Restoration time is analyzed as a critical component of the disruption and restoration phenomena and these are related to links and nodes most effective in system restoration, particularly interconnected ones.

Results focus on interconnectivity-based disruptions and ways to unbundle interconnections through more adaptive routing such as multi-modal transportation and decentralized energy systems. Such adaptive methods can prevent interconnection-related catastrophic failures by increasing system capacity to absorb shocks. Understanding these processes is an important step to support community and other stakeholder engagement in preventing or mitigating food supply chain disruptions created by supply and demand imbalances and panic reactions.

Track 2: Sustainability of Buildings and Other Structural Systems

Moderated by Krishna Reddy

Enhanced Investigation of Material Flood Damage to Support Multi-Scale Flood Loss Prediction

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ABSTRACT

Current practice of flood loss prediction presents limitations in accurately predicting building flood losses at multiple scales. While whole-building estimates can more accurately predict high-level losses (i.e. large groups of buildings), a significant analysis error is revealed with small-scale (i.e. individual or small groups of buildings) investigation. A more robust, data-driven, building damage model is presented based on elucidating a more fundamental understanding of flood damage to material components commonly used in construction. The model framework is based on a component-level damage database composed of data collected from experimental analysis. Structures with standard construction materials were built and incrementally flooded for short periods of time. Material component damage was defined based on material reparability, which was determined through indicators, such as moisture intrusion, corrosion, and contamination. The framework for the flood loss prediction model is designed to incorporate damage uncertainty and is capable of analysis at multiple scales. This study not only provides a fundamental understanding of material damage, but also develops a more effective modeling tool for building community resilience through flood risk analysis and hazard mitigation planning.

Mapping Standards and Rating Measures of Structural Green Roofs for Socio-Environmental Life Cycle Assessments

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ABSTRACT

Deployment of green roofs in building structures has gained popularity as a sustainable practice to partially mitigate climate change consequences through reduction of environmental footprints and to enhance the economic and social values of these built infrastructures. Various standards highlight design, construction, maintenance, and operation challenges and opportunities for green roofs. Further, building codes and regulations consider changes in loading, thermal, acoustic, and fire demands and capacities associated with green roofs. These changes are not necessarily aligned with each other. Hence, decision-making procedures for application of green roofs involve a comprehensive analysis of all structural, social, environmental and economic parameters. Sustainability rating systems provide an opportunity to simplify comparative evaluations of green roof systems, incorporating a broad range of parameters in an integrated system. This study maps sustainability credits to green roof standards for an occupied structural roof. The study incorporates the contribution of the green roof to the performance of the building envelope, like thermal performance. Provided guides complement this mapping to evaluate the effectiveness of the mapping and highlight challenges in the life cycle assessment process. Conclusions facilitate discussions on objective performance measures of green roofs for different structural systems and occupancies.

Future Projected Changes in Moisture Index over Canada

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Keywords: Building Design, Climate Change, Climate Model, Moisture Index

ABSTRACT

As a consequence of global warming, buildings in Canada and around the globe are expected to face unprecedented climate over their design lives. The Moisture Index (MI) is a climate-based indicator currently used in the National Building Code of Canada (NBCC) to guide the design of building wall assemblies for acceptable durability performance. The MI comprises of a wetting index (WI) defined as the total annual rainfall normalized by a value of 1000 mm, and a drying index (DI) defined as the drying potential of a location normalized with respect to the drying capacity at Lytton, British Columbia which is about 4.35g/kg.

This study calculates future changes in MI across Canada under 2 and 3.5°C of global warming. Fifteen realizations of bias-corrected climate data simulated by the Canadian Regional Climate Model (CanRCM4), following RCP 8.5 is used for the calculation of MI for a historical time period (1986-2016) and future time periods commensurate with 2 (2034-2064) and 3.5°C (2062-2092) global warming. Bias correction of the CanRCM4 large ensemble is performed with reference to a gridded observational climate dataset: WFDEI, using a multivariate bias correction method: MBCn. The value added from the bias correction step is evident as the MI values calculated from bias-corrected CanRCM4 data are closer to the MI from gridded observations than the raw (uncorrected) CanRCM4 data as seen in Figure 1.

It is highlighted in this study the importance to choose an appropriate value to normalize DI with, because when DI exceeds 1, the definition of MI fails as MI increases with increases in DI. Consequently, it is demonstrated that using the maximum drying potential value for normalization addresses this issue and ensures that the value of DI always remains less than or equal to 1 in the future. The maximum drying potential values associated with the historical and future time-periods of the 15 CanRCM4 realizations were calculated and the maximum value among them (5.4 g/kg) was used as the normalization factor for the calculation of DI. Therefore, more realistic values of DI, MI and their future projected changes were obtained by comparing future time-periods with the historical period as presented in Figure 2. The percent changes can then be imposed on the historical MI given in the NBCC, resulting in future projected MI values at the locations specified in the building code.
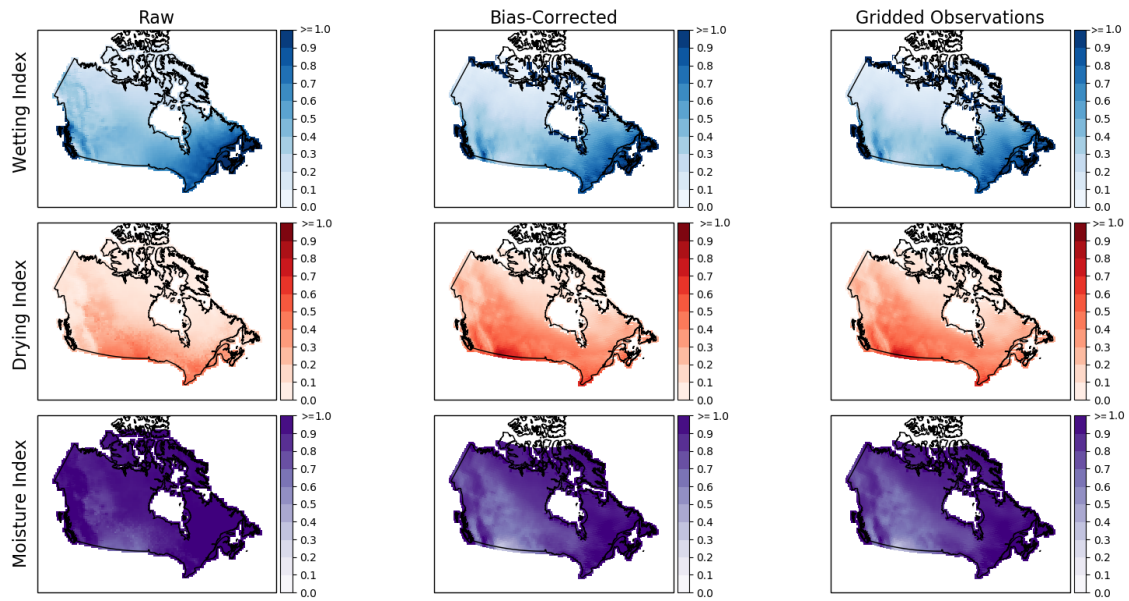
Figure 1. The historical (1986-2016) ensemble 31-year average DI, WI, and MI calculated according to the NBCC method using Raw CanRCM4, bias-corrected CanRCM4, and WFDEI.
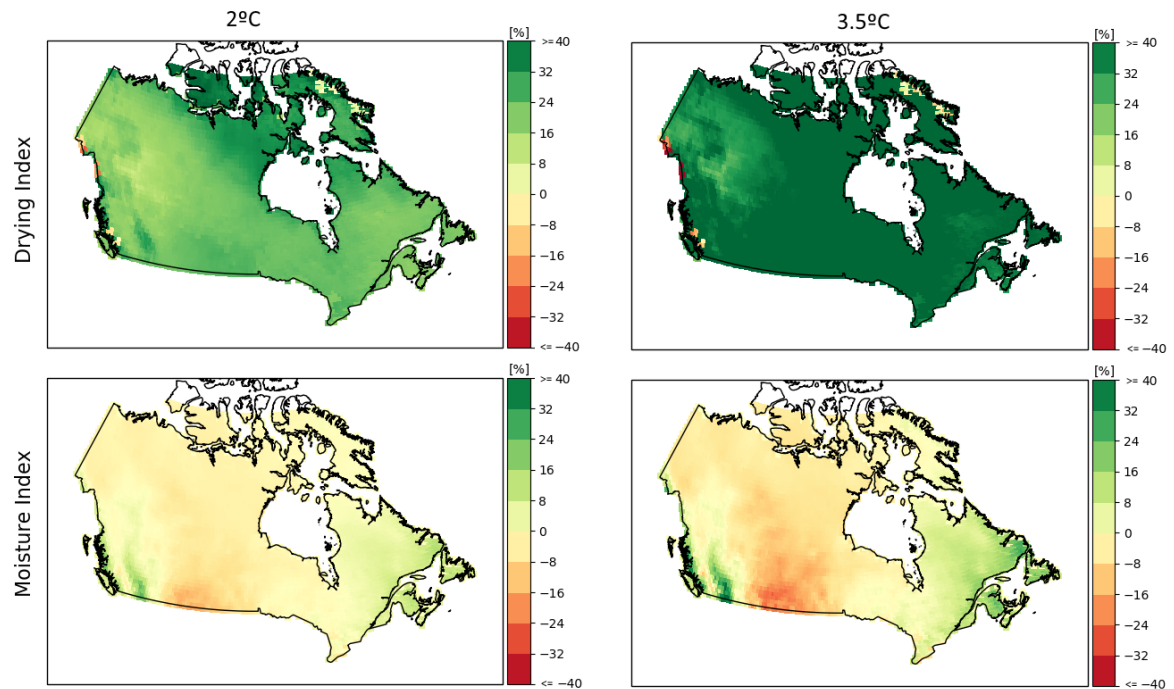
Figure 2. Projected future percent changes in DI and MI obtained when maximum drying potential value (5.4 g/kg) is used for the calculation of DI.

Results indicate that the coastal and great lakes regions of Canada will have increased MI, whereas prairies and northern regions will in the future have decreased values of MI. The current design requirements suggest that a capillary break is required between the exterior cladding and the backing assembly of the wall for those buildings located in regions having MI

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> 1 and where the heating degree day (HDD) is ≥ 3400, and also when MI > 0.9 with HDD < 3400. This implies that in the future there will be a greater number of locations that satisfy these conditions and thus will require the design of the wall assembly to incorporate a capillary break.

Table 1. Province-wide distribution of NBCC locations among the two categories: a) HDD < 3400 and moisture index (MI) of > 0.90, and b) HDD ≥ 3400 and the MI is > 1, provided in NBCC (2015) and under 2 and 3.5ºC global warming.

Province (Total number of locations in Table C2)	Number of locations with HDD < 3400 and MI > 0.9			Number of locations with HDD ≥ 3400 and MI > 1		
	NBCC (2015)	2ºC	3.5ºC	NBCC (2015)	2ºC	3.5ºC
British Columbia (108)	47	62	65	12	0	0
Alberta (55)	0	0	0	0	0	0
Saskatchewan (31)	0	0	0	0	0	0
Manitoba (24)	0	0	0	0	0	0
Ontario (229)	0	67	126	2	0	2
Quebec (125)	0	2	50	24	51	41
New Brunswick (17)	0	0	8	10	17	9
Nova Scotia (25)	0	11	25	25	14	0
Prince Edward Island (4)	0	0	3	4	4	1
Newfoundland and Labrador (18)	0	0	7	12	14	7
Yukon (9)	0	0	0	0	0	0
Northwest Territories (17)	0	0	0	0	0	0
Nunavut (16)	0	0	0	0	0	0

Incorporating Holistic Sustainability and Resilience into Civil Engineering Projects

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ABSTRACT

Investing in sustainability and resilience in the context of civil infrastructures systems delivers value by reducing disruption, speeding recovery, connecting our communities, supporting our way of life, delivering productivity gains and economic growth, reducing environmental impact, and providing enhanced protection. However, these types of investments are not codified, leaving stakeholders asking "how"? Four projects contextualize how design, planning, and operation of civil infrastructure projects can deliver social, economic, and environmental value to communities.

Measuring community capitals. Inherent to all communities are six capitals, namely, built, social, human, political, natural, and financial. Community resilience and sustainability assessments should work across all six capitals in evaluation and planning. Civil infrastructure is a major part of the built capital whereby it plays an important role in supporting the other five capitals. To date, metrics associated with standardized civil engineering procedures and guidelines relate to physical properties and the function of the finished project. For example, engineers evaluate bridges on the number and width of lanes (i.e., capacity) and the loads that they can carry. Similarly, they evaluate buildings on compliance with applicable building codes, fire ratings, and zoning regulations. While these metrics are important, it is difficult for taxpayers or developers to see the linkage to life, safety, health, and welfare outcomes, particularly at the scale of a community. This failure to create linkages undermines a popular awareness of the important role that infrastructure plays in our daily lives. It is not enough for engineers to provide a design that functions, they must also contribute to sustainable development as stewards of the natural environment while also incorporating distributional equity and procedural justice considerations of the communities they serve and support.

The application of measuring broader social and economic outcomes is gaining traction, particularly on large projects that provide both positive and negative impacts on communities. The American Society of Civil Engineers Infrastructure Resilience Division Committee on Social Science, Policy, Economics, Education, and Decision (SPEED) focuses on integrating social science and economics into the planning, design, and

management decisions surrounding physical infrastructure projects. With two representatives from the SPEED committee, this session will present one timely SPEED project that focused on identifying metrics that allow for quantification of socially driven outcomes into civil engineering projects within the discourse of resilience. The project reemphasizes that investing in resilience in the context of infrastructure systems delivers value by reducing disruption and speeding recovery; connecting communities; supporting our way of life; delivering productivity gains and economic growth; reducing environmental impact; and providing enhanced protection. Such metrics spanning the community capitals can be employed in various project phases, including planning, design, and operations, for individual projects. The metrics can also be used for a community-wide assessment across infrastructure projects to evaluate sustainability and resilience capacity, and measure how these capitals are disrupted after a disaster event.

Social equity and environmental justice. Social equity and environmental justice are getting national attention with President Biden's issuance of Executive Orders 13985 and 14008. Numerous federal agencies are gathering data and interacting with civic leaders, policy makers and the general public to support the goals articulated in each Executive Order. The information and data will provide an opportunity to examine social equity and environmental justice in a community's ability to bounce back from disasters.

In the U.S., disaster recovery is stricken with inequities. This is observed through the ever-present intersection of physical and social vulnerability that exists before disaster strikes, which leads to those with the least resources to recover being hit harder and more often by disaster, and results in exacerbated inequalities. An example of such disparities is the City of Lumberton, NC, a diverse community with median income far below the U.S. average. Lumberton suffered extensive flooding following Hurricane Matthew in 2016 and again following Hurricane Florence in 2018. On-going research by two panelists shows that household dislocation is as much of a function of flood damage as of race and ethnicity. Applying a spatial lens to explore social equity and environmental justice issues as they relate to flooding, the spatial intersection of the racial distribution within Lumberton and flood prone areas is evident. More poor, black, and American Indian residents live in the floodplains, compared to wealthier, white residents living North of the Lumber river at higher elevations.

These relationships are common in the U.S. To assist communities in being better prepared for disasters, NIST is developing tools to address social equity and environmental justice. Use of these tools with infrastructure projects requires an inclusive process that engages stakeholders that understand and represent the diverse community values, culture, and needs, and may include: representatives from the local government, such as community development, public works, and building departments; public and private developers; owners and operators of buildings and infrastructure systems; local business and industry representatives; representatives of community organizations, non-government organizations, health and educational institutions; and other stakeholders or interested community groups, such as residents of public housing.

Hurricane Sandy. The recovery process after Superstorm Sandy was unique in that the most heavily affected region (the greater New York Metro area) is rich in financial resources and political capital as compared to many other parts of the country. As such, the region approached long-term recovery and resilience in a number of unique ways. The federal government, the states of New York and New Jersey, New York City, and even

some of the smaller municipalities in the region have access to significant expertise related to resilience planning and engaged in a number of innovative programs designed to help communities recover from Sandy, while at the same time injecting future resilience into all of these efforts. This resilience mandate originated in part from the federal government, best embodied in the Hurricane Sandy Rebuilding Strategy developed by the Hurricane Sandy Rebuilding Task Force, and found its way into on-the-ground efforts ranging from HUD's Sandy Recovery Infrastructure Resilience Coordination Group as well as the agency's National Disaster Resilience Competition, the New York Rising Community Reconstruction Program, and New York City's Special Initiative for Rebuilding and Resiliency.

In all of these efforts the recovery process was in large part an opportunity to rebuild infrastructure and to radically rethink infrastructure planning and design for a new era of increased risk by prioritizing innovative design solutions, cross-jurisdictional collaboration, community participation, and holistic solutions emphasizing economic, social and environmental co-benefits. Some important drivers of this approach include planning and engineering expertise available in the region and a combination of top-down and bottom-up factors including a federal emphasis on resiliency, a long history and culture of local planning, experience with previous disasters, and a strong civil society sector intent on promoting a just and equitable recovery, among other factors. At the same time, these successes have been limited by the enormous costs inherent in some of the necessary resilience strategies, the region's complex political fragmentation, congressional restrictions, and other factors that must continue to be addressed.

Community housing project. The "We Can Make" Community Housing Project was born as a 'bottom-up' response to community demands and concerns about housing need in Knowle West, one of the most deprived areas of Bristol, UK. We Can Make uses an asset-based approach to re-imagine "how to do housing" differently in Knowle West. It starts with the know-how and resources the community already has, and uses a process of co-design to work with people to develop the tools to do housing on their terms. They call this approach "urban acupuncture" – where people with particular needs opt in to using a small piece of land to meet their housing needs.

We Can Make is about much more than just delivering housing "units". It is important that the process of building new homes contributes to the wider economic regeneration of the neighborhood, including creating new jobs and skills for local people. We Can Make uses Modern Methods of Construction (MMC) and they have developed a community fabrication space, KWMC: The Factory, as a neighborhood housing factory. They provide training for local residents and tradespeople to learn new digital construction skills. Architects and residents have worked together to create the designs for the first two We Can Make homes. Many resilience and sustainability metrics were utilized to capture individual, community and broader project benefits including social, economic, and environmental value.

Track 3: People: Social, Society, Stakeholders (Part 2)

Moderated by William Kelly

The Promise of Shared Electric Autonomous Mobility (SEAM) to Close Mobility Gaps for Vulnerable Populations

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ABSTRACT

As a consequence of our population living longer, society must work to accommodate the needs of older people. One of the most pressing needs for older people is mobility. Safe and convenient mobility is critical to maintaining physical and mental health, as well as avoiding social exclusion. Declining physical capabilities and mental acuity cause older drivers to cease driving, placing them at greater risk for social exclusion due to mobility gaps. Shared Electric Automated Mobility (SEAM) has the potential to provide sustainable mobility solutions for vulnerable older people populations. SEAM can help close mobility gaps that cause social exclusion, thereby improving social sustainability. In addition, SEAM has the potential to provide improved access to economic activity for the older people, improving economic sustainability. However, older drivers must be accepting of both shared and automated mobility options to fully leverage the potential advantages of these technologies. This study identifies barriers to the use of mobile and vehicle technology amongst older populations as well as a proposed framework of strategies for mitigating those barriers.

Using Integrative Design as a Lean Tool in Sustainable Infrastructure Development

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ABSTRACT

Without doubt, a high percentage of inefficiencies and poor deliveries in infrastructure development are traceable to poor planning and ineffective coordination particularly at the design stage. Aside from the cost impact that has become a worrisome debate in many projects, post construction life cycle activities can be unsustainable in the loop of these inefficiencies. At the early phase of pre-development, it is critical for project teams to understand many facets of the development including the community at large, and environmental stressors that affect their health and well-being—this is what an integrative design process can do.

This study aims to review the use of integrative design as a lean tool in infrastructure development to achieve sustainability. A commercial mixed-use development in West Africa's biggest city, Lagos, was used as a case study by critically evaluating the impact of integrative design on the project sustainability score card. A hypothesis to reflect the significance of integrative design in achieving its sustainability was tested using lean impact matrix and chi-square statistical analysis of teams' feedback from brainstorm sessions and questionnaire with results showing a near 95% significance of impacts.

Social Equity as Concept & Practice in Sustainability Certification Systems

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ABSTRACT

Awareness of equity and social justice issues has improved in recent years, but 2020 has significantly magnified these concerns. In light of the disproportionate impact of climate change on vulnerable populations and more general concerns about the unequal distribution of costs and benefits from infrastructure projects, there is a growing need to focus on social sustainability issues. Sustainability rating systems have always promoted a Triple Bottom Line approach to analyzing project costs and benefits with a goal of creating value for all community stakeholders, but the three parts of the triple bottom line may not have received equal consideration in that equation. This presentation will describe an analysis of multiple prominent sustainability rating systems, to determine how and to what extent they incorporate aspects of social equity.

The goals of the presentation will be to: describe how sustainability rating systems define social equity, illustrate how social equity as an idea is translated into rating system credits and criteria, discuss how applying rating systems to projects may help achieve social equity, even if not explicitly stated as such, and highlight gaps where additional attention to social equity might improve rating systems' triple bottom line impact.

The Inspiration of Power: Art, Culture, and Distributed Renewable Energy Infrastructure

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Keywords: Art, Education, Energy, Equity, Renewable, Social

ABSTRACT

The great energy transition is having an aesthetic impact on the visual landscapes of our cities and countryside. This trend will increase as we construct the sustainable infrastructures required to meet the climate challenge. In the early days of electrification, power plants were by necessity located in the hearts of our cities because transformers were not yet sophisticated enough to raise the voltage for efficient long-distance transmission. As a consequence, these power plants were designed by architects to be beautiful contributions to public space. Because these power plants were highly polluting of their local environments, we centralized power generation to remote areas as soon as long-distance transmission became possible. As these power houses left the city, they also left their relationship to art and to architecture. They instead became pure utility and severed their connection to human culture.

This divorce of power generation infrastructure from design and culture has continued into the present with the deployment of renewable energy landscapes that strive only to produce the cheapest kilowatt-hour. In some cases, this utilitarian approach has led to push-back within communities that find themselves in close proximity to large-scale solar and wind installations.

Recognizing the power of community-centered design, public art, and creative placemaking in this context, we can begin to take a proactive approach to the influence of renewable energy on our constructed environment. We can give city and regional planners new tools with which to integrate sustainable infrastructures into transportation corridors, waterfronts, urban farms, and other public places, providing a range of social co-benefits while improving resilience and reliability of our new low-carbon electricity grid.

The Challenge
The world faces the challenge of overseeing an energy transition to renewable sources that does not repeat some of the mistakes and unintended consequences of past infrastructure development. With trillions of dollars in near future investment and low risk returns for solar deployments, it is critically important that the opportunity for wealth generation be offered to a broad array of stakeholders. Recent energy modeling has demonstrated the value of distributed energy resources over centralized renewable energy installations. Large, centralized power infrastructures also create problems related to land use as energy landscapes are increasingly competing with other interests such as agriculture, recreation,

visual resources stewardship, land conservation, forest preservation, and biodiversity. Distributed energy assets ease the burden on long-distance transmission lines, improve resilience and reliability, and offer opportunities for energy demand services. But with the shift of energy infrastructure back into population centers comes a heightened responsibility to fit these systems into the cultural fabric of our communities in productive, inspiring, and beautiful ways.

Introduction to the Land Art Generator

Founded in 2008 with a mission to advance a just and equitable energy transition in response to the climate crisis, the Land Art Generator Initiative (LAGI) helps design places for people that share land use with distributed renewable energy generation and other sustainable infrastructures. The Land Art Generator works closely with communities to deliver sculptural installations that have the added benefit of renewable power generation. In addition to providing kilowatt-hours of electricity to the grid, Land Art Generator artworks provide a range of social benefits, including economic development and education, and are designed to address issues of energy poverty and environmental justice.

LAGI provides context-specific and culturally relevant design solutions for distributed energy that reflect the needs of the community by utilizing a variety of project delivery models. These include design competitions, direct commissions, calls for proposals, Solar Mural artworks, and participatory design processes with communities. Open design competitions for Dubai/Abu Dhabi (2010), New York City (2012), Copenhagen (2014), Santa Monica (2016), Melbourne (2018), Abu Dhabi (2019), and Fly Ranch (2020) have brought in over 1,200 designs from more than eighty countries.

LAGI Projects as Disruptive Innovations

The design brief for LAGI design competitions calls for site-specific works of art that capture energy from nature, cleanly convert it into electricity, and transform and transmit the electrical power. More recent competitions have expanded the brief beyond energy to include other sustainable infrastructures, including water, food, shelter, and waste. Consideration must be made for the safety of the viewing public and for the educational activities that will occur on site. The design should be constructible (rather than theoretical), and it must respect the natural ecosystem of the design sites.

Each year LAGI offers a unique, yet universally applicable typology that can be replicated within other similar conditions in other cities. The project has so far investigated urban gateways, landfills, brownfields, coastal sites, master plan overlay, city portals, and rural high desert.

Examples include projects such as *The Solar Hourglass* (Figure 1), a concentrated solar power plant that feeds the equivalent of a thousand homes with clean energy while inspiring the public with a positive and inspiring message about our post-carbon future. It reminds us that there is still time to avert the worst effects of climate change if we can all work together.
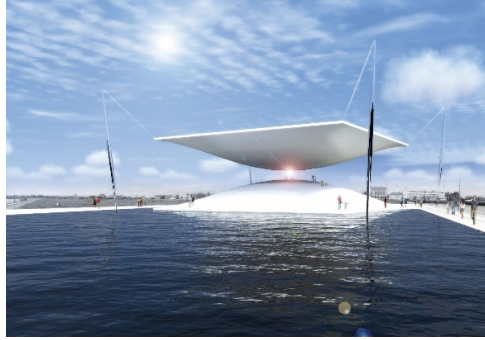
Figure 1. *The Solar Hourglass*, designed by team Santiago Muro Cortés

Equity and Social Justice

The Land Art Generator works directly with communities to assess interest, needs, and develop design ideas for integrating renewable energy or other sustainable infrastructure into neighborhoods. The workshops provide an opportunity for citizens of all ages to re-think their relationship to electricity consumption and production. The innovative and artful applications of sustainable technologies can spark the imaginations of young people and trigger curiosity in science, technology, engineering, and math. LAGI programming is a great example of STEM to STEAM and project-based learning. Through the process of designing their own land art generator, middle school and high school students show applied understanding of concepts like energy conversion efficiency and capacity factor. At the same time, they are applying knowledge of form, shape, color, and touching on aspects of urban planning and whole systems design, exactly the kind of skills needed for jobs in the twenty-first century.

How to Break Ground

With hundreds of feasible ideas in the portfolio of Land Art Generator design challenge proposals, the time is now to begin deploying these regenerative artworks at scale. Barriers to implementation, though, include funding and jurisdictional approval. What might at first seem like a challenge could become an opportunity with the right kind of hybrid development model. By merging the verticals of energy infrastructure, civic art, and human-centered mixed-use development, we can identify economies of scale and efficiencies, but it will require a redefinition of how we approach sustainable development and collaboration across disciplines that are typically siloed from one another. Burns & McDonnell brings infrastructure engineering experience while navigating public, private and environmental obstacles to bring projects from ideation to creation. This experience, combined with the disruptive vision of LAGI, will apply the innovation necessary to identify a path to implementation.

Conclusion

Cities can define themselves in the energy transition by creating new visual icons and cultural markers of what renewable energy infrastructure looks like. Vibrant and livable cities attract more business, investment, and long-term residents. Civic art that employs renewable energy technology as the media for creative expression and education will pay back its own embodied carbon footprint and cost of installation. This new way of thinking about art in public space and energy landscapes will bring forward cultural landmarks that will be visited by future generations to remember this important time in human history when we rose to the challenge of climate change.

All the Easy Roads Have Been Built – Building Social Capital for More Resilient Communities

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Keywords: Communities, Engagement, Outreach, Planning, Public, Social

ABSTRACT

Communities are more resilient when everyone's interests are considered while making decisions that impact the public. Consistent investment in social capital and being willing to have hard conversations about controversial infrastructure projects can generate long-term value during the planning and construction process.

We explore the concept of social capital and lessons learned on how agencies and project teams can build trust and build projects that respect communities. We discuss best practices and lessons learned from large transportation infrastructure projects and touch on how to continue to build social capital and respond after a major crisis or disaster, such as the COVID-19 pandemic. We also provide insights on understanding community values, gathering meaningful input for decision-making, and overcoming issues and challenges that threaten to erode trust and halt project progress.

Track 4: Materials and Construction Components

Moderated by Imisioluseyi Akinyede

Impacts of Material Properties on the Resilience of the Built Environment

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ABSTRACT

Our communities rely on their infrastructure to provide services of shelter, energy that includes electricity and fuel, water, communication, and movement of people and goods. The design and performance requirements of critical construction materials and engineered systems need to consider hazards from both: (1) acute loads due to winds, earthquakes, fires, and water intrusion, and (2) long-term exposures to environmental stressors which include ultraviolet radiation, freeze-thaw, relative humidity, deicer salts, or cyclic thermal expansion and contraction. There are many hazards to communities, and this study provides materials-related examples for roofing for wind protection, residential modifications for flood protection, and bridge strengthening. These are just three examples of many where new materials or improved materials can have a significant social and economic impact to building a community with greater resiliency, i.e. preventing the loss of life and property.

Insurance claim data and field studies have shown that older asphalt shingle roofs typically have more damage in disasters and other weather events when compared to newer roofs. Premature failure of asphalt shingles is a concern because 55% of roofing sales are for these shingles. Furthermore, the IBHS's member companies state that asphalt shingles are a primary loss driver during weather events.

Wet floodproofing can be defined as permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding by allowing floodwater to enter the structure. The basic characteristic that distinguishes wet floodproofing from dry floodproofing is that it allows internal flooding of a structure as opposed to providing essentially watertight protection. Such measures may require alteration of a structure's design and construction and the use of flood-resistant materials.

Bridges have become a weak link in the US transportation network due to deferred maintenance. As indicated by the Department of Transportation, the number of freight vehicles on the US highways is going to continue to increase in future years; that increases stresses on the US roadways and bridges, which degrades the bridges' performance. Due to the high replacement cost of bridges, strengthening existing bridges instead of bridge replacement is a lower cost alternative. New materials are being developed to increase resilience from hazards, including earthquakes, and provide durability, high strengths, and longer life to bridges. This study will review options including ultra-high-performance concrete, corrosion-resistant reinforcement, high performance steel, composites, and improved coatings.

The Significant Sustainable Benefits Afforded by Geosynthetics in Key Infrastructure Applications: A Review

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ABSTRACT

For decades geosynthetics have been utilized in infrastructure projects worldwide to improve the performance of the ground via, for example, drainage, reinforcement and stabilization. The inclusion of geosynthetics has generally been driven by reduction in construction costs and time and significantly this is typically characterized by a reduction in the volume of imported bulk construction materials like sands and gravels. This can be associated with more efficient performance of the geosynthetic systems or the ability to use marginal materials in conjunction with geosynthetics. In more recent times the considerable sustainable benefits gained from the reduction of these bulk materials have been noted and several specific studies have demonstrated large environmental savings via a range of geosynthetic applications.

The sustainable benefits include preservation of limited natural resources (e.g. gravel), emission and energy savings from the reduction in transport of bulk materials, reduction in onsite excavation and placement activity and reduction in construction programmes. Theoretical and case study examples are provided demonstrating significant sustainable benefits for a range of geosynthetic materials and infrastructure applications.

It is concluded that geosynthetic solutions offer such a clear and significant opportunity for more sustainable infrastructure development that there is a strong case to consider their inclusion in all such projects.

Addressing Embodied Carbon as a Sustainability Issue and Implementing New Technology to an Industry that Resists Change

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ABSTRACT

Embodied carbon is a commonly known phrase that encompasses greenhouse gas emissions due to the production, manufacturing, and use of building materials. With the construction industry's adherence to traditionalist methods, decreasing the environmental impact of standard concrete and high-carbon building materials seems like an insurmountable feat. Despite the resistance, innovative technologies are being developed to combat the carbon footprint of traditional building materials and the benefits of these technologies are irrefutable. Concrete alternative technologies such as reclaimed asphalt pavement (RAP), CO_2 injection, enhanced fly ash, and carbon nanotubes have been researched and shown to have a net positive impact economically and environmentally on smaller scaled projects. Beyond just concrete alternatives, embodied carbon solutions include using fewer finish materials, maximizing structural efficiency, using salvage materials, and minimizing waste. The biggest challenge will be widespread implementation to an industry that resists change. Embodied carbon is a sustainability issue that can be solved through these innovative solutions if they can be implemented into an industry that has not historically made sustainability or environmental resiliency a priority. However, with our increasing focus on energy conservation, green building design, and sustainability incentive programs, the importance of decreasing embodied carbon will grow as well.

Improvements in Building Energy Savings through Two-Layer Phase Change Materials (PCM) Systems Tailored for Different Indian Climate Zones

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ABSTRACT

The incorporation of phase change material (PCM) in the building envelopes through micro/macro encapsulated forms has been shown to reduce the energy consumption in maintaining the thermal comfort for the occupants. However, the amount of energy savings is not proportional to the thickness of the PCM layer added to the building envelopes owing to the inefficient phase conversion (melting/freezing) during the diurnal thermal cycles. In addition, incorporating a single thick PCM layer presents a challenge from the construction point of view. In this research work, a proper combination of PCMs in the form of a two-layer system is proposed to improve the overall energy savings efficiency and is compared with the single-layer system.

The primary objective of this work is to find the appropriate PCM (melting temperature, enthalpy) to be incorporated in two-layers systems in building envelopes located in different weather conditions using numerical simulations in terms of energy saving and thermal comfort. The study has been carried out for buildings (residential apartment buildings, partially air-conditioned) located in major Indian cities representing different types of climatic conditions, namely, New Delhi (composite), Jodhpur (hot and dry), and Chennai (warm and humid). The results show average 20% - 26% savings in cooling energy consumption due to incorporation of optimized combinations of PCM layers. The thermal properties of PCM determined experimentally are used as input properties. Numerical simulations for these buildings with PCM layers are performed using the EnergyPlus (V9.4.0) program through conduction finite difference (ConFD) solution algorithm with fully implicit scheme.

Track 5: Local Lessons: Learning from One Another

Moderated by Gridelda Gonzales

The Roadmap to Resilience for Small to Medium Size Communities

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ABSTRACT

Resilient communities keep families safe, provide opportunities for improved livability and promote long-term stability. Even so, smaller to medium size communities often face unique challenges compared to their larger city counterparts when implementing resilience initiatives. These challenges can exacerbate a community's lack of preparedness and increase barriers to effective resilience planning.

The "Roadmap to Resilience" was developed to support such communities on their paths towards resilience with a focus on improving access to affordable, reliant, and resilient energy services and funded through a grant from DOE. As part of the "Roadmap" development process, the Cities of Rolla, St. James, and Stockton in the state of Missouri were engaged as partner communities. Partner organizations included the Consumer Council of Missouri (CCM), Midwest Energy Efficiency Alliance (MEEA), Municipal Public Utility Alliance (MPUA), Office of Public Counsel (OPC) and Renew Missouri. The Cities of Rolla and St. James were also selected for development of case studies built off of the Roadmap. The "Roadmap" features its six guiding actions to navigate resilience efforts for small to medium size communities, funding strategies, and opportunities for collaboration to implement effective resilient solutions.

Merced Avenue Greenway Project: A Model for Future Greener Urban Streets

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ABSTRACT

The Merced Avenue Greenway Project aims to improve stormwater management and water quality along a 1.1-mile stretch of Merced Avenue in the City of South El Monte, California. The project also aims to decrease flood risk, increase vegetative cover including habitat restoration, improve active transportation through enhanced pedestrian and bike mobility, and reduce urban heat island effect. The project has a significant community outreach component and encourages ongoing educational and project development participation by community members, the key benefactors of the project. The combination of these project objectives coupled with the fact that the City of South El Monte is a severely disadvantaged community will provide immense community and societal benefits that will aid in the mission of creating resilient communities.

This presentation will benefit the professional community by apprising and educating the audience on how this project serves as a pilot effort in developing design standards for future urban street retrofits in Los Angeles County to include climate change resilient stormwater Best Management Practices (BMPs) and urban greening elements. Additionally, the presentation covers the varying community outreach strategies utilized in order to keep stakeholders informed and involved during the project. The project is at the forefront of incorporating stormwater BMPs into urban street retrofits, and the proactive efforts in community outreach and education throughout the project promote a sustainable future for stormwater management.

Integrated Resilient Design for an Urban Wilderness Park

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Keywords: Drought Resilience, Flood Resilience, Parks, Rainwater Harvesting, SITES, Water Reuse

ABSTRACT

Population growth and resultant urbanization have dramatically increased in Houston over the last 30 years in parallel to increasing severity of flooding and drought. Conservation of green spaces that respond to extreme events is now more critical than ever. As development closes in on remaining undeveloped land and floodplains, these spaces must meet multiple objectives. Memorial Park is a 1,500-acre urban wilderness park in the center of Houston, TX. Recent park redevelopment focuses on conserving and maintaining the historical and ecological landmark while providing amenities that are resilient to impacts of climate change such as flooding, fire, hurricanes and drought.

Memorial Park Eastern Glades is designed for sustainability and resiliency, highlighted by the site's central feature—a 5-acre constructed lake. This multi-functional lake provides storage for the site's non-potable water reuse system as well as aquatic habitat, storm water treatment and flood control benefits to the site and community. Eastern Glades utilizes Green Stormwater Infrastructure to capture and route runoff from hardscape through a series of vegetated collection systems prior to discharging to the lake.

In addition to water resiliency, this project also includes restoration of native habitats to intercept, transpire, and infiltrate rainfall. These ecosystems include mixed pine-hardwood forests, savanna, and wetlands. In recognition of integrated sustainable design and resiliency, this project is currently pursuing certification through the Sustainable SITES Initiative. Through certification this project aligns its design and development with functions of healthy ecosystems, water quality/quantity management and public engagement.

Josey Lake: Transforming Stormwater Management into an Amenity

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ABSTRACT

Josey Lake Park is a signature, 140-acre recreational greenspace that provides concurrent accessibility to nature and activities while also serving as a regional connector to neighboring communities and commercial developments. While its primary functions are stormwater detention and conveyance infrastructure, the design objective was to take land typically designated for infrastructure and turn it into an exceptional amenity with various ecosystem types and multiple levels of active and passive recreation. Through close collaboration between the client and consultants, a stormwater detention system was envisioned as a highly functional, aesthetic, and sustainable space. Several other items were taken into consideration including long-term maintenance costs, varying ecologies, and wildlife habitat, improving stormwater quality, and providing an area suitable to host community events.

Development in the Houston metro area requires responsible planning and engineering of stormwater detention facilities. Recent events punctuate this fact now more than ever. However, detention facilities need not be trapezoidal shapes with 3:1 slopes and channelized flowlines. By mimicking nature, these facilities can not only provide their baseline function of flood prevention and conveyance, but also provide social, environmental, and economic benefits.

Taking into consideration various inundation events, strategically placed program elements throughout the site utilize all available land down to the static water elevation. Approximately 80% of Josey Lake Park is located below the 100-year flood elevation.

Reference:
Josey Lake Case Study: https://clarkcondon.com/resources/josey-lake-case-study/

Technical Track Abstracts -
Friday, December 10, 2021

Track 1: International Coalition on Sustainable Infrastructure

Content Presented Live

Moderated by Cliff Davidson and Mikhail Chester

Urban Infrastructure: Reflections for 2100

Cliff I. Davidson*[1], Mikhail V. Chester[2], Sybil Derrible[3], Lynette Cheah[4], Matthew J. Eckelman[5], Kris Hartley[6], Nadine Ibrahim[7], Shoshanna Saxe[8], Yoram Shiftan[9] and Alona Nitzan-Shiftan[10]

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Keywords: Climate Change, Infrastructure, Sustainability, Transportation, Urban Design

ABSTRACT

The book *Urban Infrastructure: Reflections for 2100* edited by Sybil Derrible and Mike Chester contains a wide variety of ideas for sustainable infrastructure that could be envisioned if cities are rebuilt. In this extended abstract, we present ideas from nine of the chapters in this unique book, which will be discussed by their respective authors at ICSI.

"The City of 2100: An Idealistic Look" (Cliff I. Davidson) An idealized city 80 years from now located in upstate NY would be largely self-sufficient, growing and processing food from two sources: agricultural crops from surrounding farmland in Central NY and fishing in the Great Lakes. The population would be roughly steady-state at a level determined largely by the amount of food and water available. People would live close to places of work, schools, medical centers, churches, grocery stores, and other necessities of life. The availability of public transportation and rideshare would make private vehicles unnecessary. Energy would be generated using wind and solar in the region. Travel would not be common; family members would live in the same region, and meetings with colleagues elsewhere would be arranged via electronic media. With the high population density in the central city and absence of suburbs, much of the land would be undeveloped forest needed to provide ecosystem services as well as hiking, camping, and other recreation. The ecological footprint of a typical resident in this city would be a small fraction of what it is in 2021.

"The Great Infrastructure Decoupling" (Mikhail V. Chester) At the dawn of the twenty-first century the world is changing fast. Yet our core infrastructure systems remain rooted in principles that assume long term sustainability. The growing chasm between what our infrastructure can do and what we need them to do represents a decoupling that threatens the viability of the systems that we often take for granted. There are two paths forward. In the first we operate under business-as-usual conditions and make marginal changes to infrastructure that do not meaningfully address this decoupling. In this vision infrastructure continue to provide value (albeit diminishing) and where demands are not met new players and

technologies emerge, a decentralization of control. In the second path we commit to modernizing infrastructure to meet the rapidly changing conditions and associated uncertainty in the future. This path will be difficult but will position services for the betterment of future societies. Which path do we choose?

"Peace Day in Saint Pierre and Miquelon" (Sybil Derrible) What is infrastructure but a support to provide for our needs as humans and as a society? To reflect on the future of infrastructure, we can reflect on how we will evolve as humans. The short story follows a kid in the French archipelago of Saint Pierre and Miquelon on July 14, 2100, for Peace Day. Like all kids, this one has a lot of energy and seeks to have fun with friends and family. In the story, through the experience of this child, we learn how home technology may evolve. We learn how people may travel. We learn how electricity and water may be distributed. We also learn how culture may evolve in the twenty-first century, and how, despite impressive advances in technology, getting together and sharing moments and a good meal remain timeless and central to who we are as humans.

"How will city dwellers get around in 2100? Personas using future mobility services" (Lynette Cheah) In user-centered design processes, personas are sometimes developed to better understand how potential users will make use of new products or services. Personas are fictional characters projected into future settings and situations. By identifying and characterizing representative users, designers and planners can better address their diverse needs and concerns. In this chapter, we get to know four different personas living in future Asian cities. We explore how these individuals interact with urban transport infrastructure and achieve their mobility needs. While it is not possible to predict how city residents will travel in year 2100, we can imagine their urban lifestyles through these personalities.

"The Future of Today's Infrastructure" (Matthew J. Eckelman) In a future of new technology, materials, and modes, what will become of our current infrastructure that is no longer needed? Will we simply build our new infrastructure on top of what we have, perpetuating the land use decisions and ecological impacts of past generations? Or will we adapt these spaces and use valuable rights of way to tie our communities together in new ways, as we have converted old canals and railroad beds to recreation and commuting paths? While visions of future cities often center on marvelous new creations, the greatest opportunities in the future of infrastructure may be in cleverly repurposing what we have in the present. Case studies from around the world show potential benefits and pitfalls of different approaches to obsolete infrastructure.

"Urban infrastructure and the politics of crisis" (Kris Hartley) In this era of global crisis and potential for productive renewal, it is appropriate to contemplate the prospects of the rationalist policy project amidst growing political and epistemic instability. While contestation in how policy problems are named and framed is blandly evident in the operations of public organizations and their interactions with society, infrastructure provides a clearer and more embodied illustration of the facts-values interface and fading promise of policy rationalism. This presentation reflects on the moral hazard of technocratic fundamentalism through the lens of 'fortress infrastructure' – a tool of escape for the privileged that works only by exploiting the society it leaves behind. The presentation concludes by making broader points about the co-evolution of competing epistemics, infrastructure as a technocratic solution to existential and behavioral problems, and the cyclicality of 'human progress.'

"Only you know if we did it" (Nadine Ibrahim) To create future sustainable cities, we know what needs to be done today, but we are not moving as fast as the urgency of the climate crisis would demand. This chapter picks up on the message in "A letter to the future" engraved on the memorial plaque in 2019 commemorating the loss of the glacier Okjökull, that ends with the statement "Only you know if we did it". Part prose and part poetry, the setting of the chapter is the year 2100, and presents a vision for an optimistic future where climate targets were met, cities were built for the convenience of people not the comfort of cars, and circular economies were created by consuming less and reusing more, and finally we had the cities that we've always dreamed of living in. We're far off course relative to the prediction engraved on the plaque, though we acknowledge the science and evidence that exist today that urge us to take action. It was largely the younger generation that pushed us to make such bold decisions in renewable energy, building science, transit, water conservation, waste disposal, forest management, among many others. When revisiting the plaque in 2100, we knew we finally did it!

"Detours and Funiculars: Towards sustainable urban transport infrastructure in 2100" (Shoshanna Saxe) One of the great hopes of working on sustainable infrastructure is that we have all the tools we need to get to sustainability, and one of the great frustrations is that we fail to use them. "Detours and Funiculars: Towards sustainable urban transport infrastructure in 2100" – a riff on the well known children's game Snakes and Ladders – makes visceral these hopes and frustrations through leaps forward and slides backwards on the board. The funiculars are low tech and well known (long term planning, automobile road use charges, bike infrastructure); the detours well trod (highway expansion, single family zoning). The more players who make their way to the end of the board and sustainable transport infrastructure, the bigger the win for all.

"Mobility and the City in 2100" (Yoram Shiftan and Alona Nitzan-Shiftan) We envisage the future city to adjust the physical form of the present-day city and specifically the urban infrastructure we know today, to accommodate new mobility technology in ways that ensure the best livability of its people. We illustrate an urban center of a metropolitan area and its transport system and discuss the policies and behavior of travelers that keep the city vibrant, sustainable, and just.

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Track 3: Standards, Technology, and Modeling

Moderated by Krishna Reddy

Will it Work? Examining Alignment of Four Infrastructure Solutions with the Draft *ASCE 73: Standard Requirements for Sustainable Infrastructure*

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ABSTRACT

This study examines ASCE's draft sustainable infrastructure standard – *ASCE/COS 73: Standard Requirements for Sustainable Infrastructure* – to assess its alignment with current construction and design practices. A team of students and faculty from the United States Military Academy applied the draft document to four current and planned infrastructure projects. The scope of the study included an analysis of a university dormitory, a mass-timber residential skyrise, a ferry port expansion, and a multi-purpose mass-transport project. The objective was to assess alignment of the draft standard with current construction and design practices, not to assess or rate the projects themselves. The research team generated questions and gathered information from project owners and key leaders through surveys, interviews, and shared files. Both quantifiable and non-quantifiable measures were used to assess alignment with the sustainable infrastructure outcomes presented in the draft standard. The results indicate the draft standard challenges infrastructure development toward needed sustainability practices, while still being achievable within the current state of design and practice in the construction industry. Additionally, the study identifies recommendations for future studies using ASCE/COS 73.

What Does Sustainable Infrastructure Mean…. and What Should it Mean?

Josh Jacobs

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ABSTRACT

Sustainability is a word that gets used to mean so many different things. But what does sustainability mean in today's environmental social governance (ESG) world? Have you looked at the embodied carbon in your specifications; has the equity of the community been taken into account; have you looked at the transparency required in the Sustainability Accounting Standards Board (SASB) standards? Where does the triple bottom line come into the conversation around your infrastructure projects? If you are simply asking for the amount of recycled content in your materials....you are falling behind where the world is. We will look at the state of the market in regards to sustainable infrastructure rating systems or standards such as Envision, ASCE 73 (in development), SASB, and other tools from around the world to decipher what sustainable infrastructure means today. Then we will have an interactive session on what can and should be included in truly sustainable infrastructure of tomorrow.

Using Design Automation to Make Smarter Infrastructure Decisions: An Engineer Learns to Code

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ABSTRACT

Roughly 50% of the world's population lives within 50 miles of the coast, which is expected to increase to 65% by 2040, increasing demands on public and private sector infrastructure. The UN anticipates the need for hundreds of millions of dollars in adaptation infrastructure on an annual basis. Concrete remains by far the most utilized construction material on earth and remains an essential component of most adaptation infrastructure. However, concrete has its own environmental footprint, and adaptation infrastructure often comes at the expense of biodiversity and natural processes. Looking especially at the waterfront, a range of innovations have been proposed from traditional dikes and armoring and massive mechanized infrastructure to biocompatible materials, ecosystem engineered armoring and water-cleaning floating islands. We propose to use digital automation tools to optimize coastal shoreline armoring for ecological cost and benefit. The split focus is on the author's own personal journey and how busy professionals can learn new skills, along with a look into more advanced outcomes that can be achieved when you partner with the pros. As technology progresses, we have a growing availability of satellite and aerial data at our disposal. This opens up many possibilities to provide innovation in industry to protect our coastlines.

Assessing Climate Change Uncertainty for Infrastructure Planning with Physical-Parameter-Based State-Space Models and Bayesian Inference

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ABSTRACT

Predicting future climate conditions is crucial for improving community resilience and engineering adaptations against climate change. Underestimated climate change can induce managers to adopt insufficient mitigation measures, while overestimated climate conditions can lead to higher costs and less efficiency in engineering adaptations. Substantial progress has been made in the scientific community to improve climate models and climate model projections (Eyring et al. 2016), although these projections were not developed specifically for any practical applications and there is a substantial barrier in translating climate model results into engineering practice. Climate model projections are affected by the deep uncertainty with different sources such as natural variability, model uncertainty, and scenario uncertainty (Hawkins and Sutton 2009). At the same time, more and more climate model projections are becoming available (Deser et al. 2020), with new, recently-developed future climate scenarios (O'Neill et al. 2017). Translating these climate model projections into actionable information for engineering is an urgent and critical task to perform.

The main objective of this study is to assess climate model projection uncertainty with statistical time series analysis and Bayesian inference for engineering decision-making and infrastructure planning. This work aimed at assessing the performance of different climate models based on historical observation data, reducing model projection uncertainty by selecting best-performed models, and providing improved future climate information. The dependence of future climate projection uncertainty on the availability of observation data can be assessed, allowing the adoption of more flexible engineering planning schemes. While the overall objective is to facilitate the analyses of regional climate for forecasting the rate of occurrence with extreme events, some preliminary results with the analyses on the global average temperature series are available and are presented. The overall approach of applying the time series analysis and Bayesian inference is expected to be applicable for regional climate assessment.

This work utilized a state space model (SSM) approach to model time series of temperature anomaly, integrating physics-based parameters. Using statistical time series models serves as a useful alternative for forecasting the time series of climate variables according to the previous work (Lai and Dzombak 2021). Consistent with a simplified global energy balance model, the physical-parameter-based SSM provides a parametric form to evaluate

the available climate model simulations with a set of parameter values for individual models, as presented in Figure 1 as an illustration. Both the number of global climate models (currently 36 models are used) and the number of simulation runs from each model are relatively large (up to more than 100 simulation runs for one future scenario), facilitating the analyses using SSM.

The evaluation of the model performance and the estimation of future climate projections follow a Bayesian model averaging approach. Under the same parametric form of SSM, the estimated parameter values from individual climate models are used to calculate the marginal likelihood for these models based on historical observation data and this marginal likelihood is combined with the sets of posterior parameter values (across all models) to obtain climate projections.

The SSM approach can assess the performance of climate models and provide improved climate projections for engineering applications. With the framework of the Bayesian model averaging and the integration of physical parameters, the best performed climate models or the sets of corresponding parameter values can be selected to reduce both the projection uncertainty for the variable of interest and the uncertainty with respect to the individual physical parameters. An example is provided in Figure 2 as an evaluation result for the projection uncertainty with different availability of historical data. With this application of physical-parameter-based technique and further development in modeling of regional climate and other climate variables, the SSM is expected to be a useful approach to facilitate assessing projection uncertainty and to help improve engineering decision-making by combining with other techniques such as those presented in Pozzi et al. (2017).
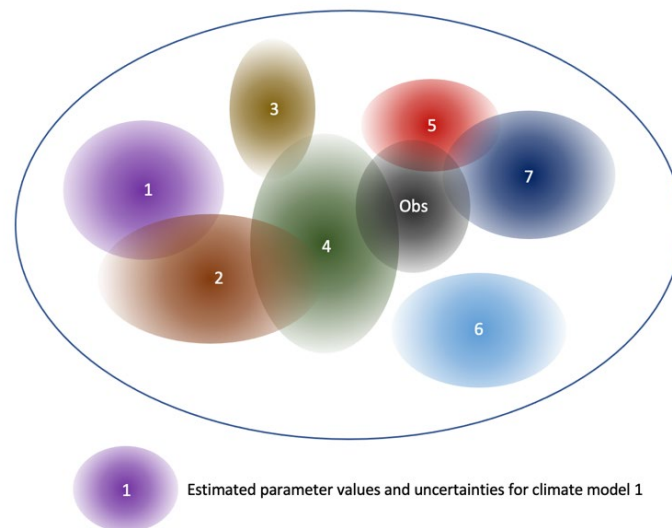
Figure 1. A conceptual framework for evaluating climate models in a two-dimensional space. The same parametric form of SSM is used to assess different climate models, by the estimation of parameter values for the SSM and their uncertainties (presented as the different ellipses). The Bayesian model averaging approach is then applied to evaluate the individual model performance and to provide improved projections based on historical observation data.
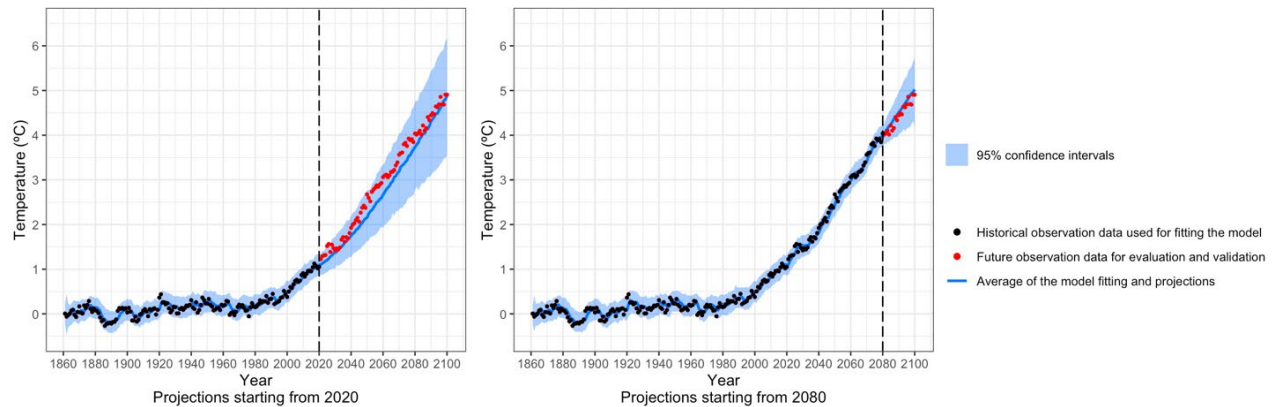
Figure 2. Examples of projection uncertainty for the global average temperature anomaly series using different lengths of historical data (up to 2020 on the left and up to 2080 on the right) for evaluation of climate models. Simulation series from climate model ACCESS1.3 were used as the synthetic observation data in this figure. The projection uncertainty can be reduced when additional observation data become available and used for assessing climate model simulations.

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Track 4: Materials and Construction Components (Part 2)

Moderated by Sabrina Moore

Changes in New Pipe Acceptance Standards are Paving the Way to Sustainable Infrastructure

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ABSTRACT

How many times have you heard, "The sewer and water pipes are nearing the end of their useful life"? Or seen decay curves that recommend repairs, rehabilitation, or renewal programs to re-invigorate networks for the next 100 years? Disruptive technologies are showing that pipe decay curves are not necessarily the best way to prioritize rehabilitation.

In fact, new technologies are showing that poor installation and rehabilitation cause most pipe defects or failures. Confronted by the proverbial 'pothole in the middle of the road,' utilities are sometimes faced with repairing or replacing pipelines that were just renewed, representing a detour on the way to smart water sustainability.

As industry insiders have long known, lenient inspection standards do not require pipes to be delivered as watertight. With many utilities allowing contractors and construction firms to self-certify new and rehabilitated pipes based on guidelines established by pipe manufacturers and suppliers that sponsor accreditation programs, results can be questionable.

Aided by machine-intelligent technologies, utilities are finding defects at joints and customer service connections – not pipe wall failures or fractures – that should have been addressed at installation, on pipes that senior managers might have seen installed or rehabilitated earlier in their careers.

Several leading U.S. utilities are adopting machine-intelligent pipe investigation tools to assess new installations and rehabilitation. Representing a contradiction to long-held assumptions and beliefs, they often find pipes leaking more after rehabilitation than before rehabilitation. Changes in new pipe acceptance standards are paving the way to sustainable infrastructure.

Estimating the Effectiveness, Benefits, and Costs of Reflective Asphalt Coatings for Mitigating Extreme Heat in a Desert Urban Environment

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ABSTRACT

Given urbanization and a changing climate, extreme heat (exacerbated by the urban heat island effect) is a hazard with which many cities must increasingly grapple. In addition to human health impacts, extreme temperatures have been linked to a range of other adverse impacts, including increased energy/water use and infrastructure damage. As a result, adapting to climate change and mitigating extreme heat conditions have become critical sustainability goals for many cities. Municipalities targeting temperature reductions have begun experimenting with heat mitigating infrastructure. For example, Maricopa County in Arizona has implemented reflective asphalt coatings in certain locations with the goal of lowering urban temperatures and providing health and economic benefits to county residents.

This study uses meteorological measurements in conjunction with empirical and dynamical modeling approaches to: 1) quantify the impacts of reflective asphalt coatings on surface energy balance and near-surface air temperature; (2) model the potential cooling impacts derived from large-scale application of the reflective coating across Maricopa County; and (3) estimate/compare the costs and benefits (e.g., impacts on energy and water use, human health, etc.) of the county-scale implementation of the reflective asphalt coating. Considering Maricopa County's position as one of the hottest urban areas in the United States, the results and insights gathered from this study can serve as an exemplar for many cities that are likely to face warmer and drier conditions in the coming decades. Ultimately, this work can also help contribute to a more holistic and multi-faceted understanding of county-level heat mitigation strategies.

Recycling Waste Plastic in Roads: Opportunities, Challenges and Potential

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Keywords: Asphalt Pavement, Recycled Plastic

ABSTRACT

With the increased focus on recycling of waste materials in infrastructure construction and maintenance, there is an ever-increasing interest in the recycling of waste plastic in the production of asphalt mixtures for road and other pavement surfacing. However, there are many types of plastic and only some are compatible with asphalt production. Some plastics are capable of extending the mineral aggregate in asphalt mixtures, while others can improve the mixture properties, but they increase the resistance to rutting and cracking. The most valuable plastics can extend and improve the bituminous binder in the asphalt mixture, effectively replacing the synthesized polymers that are commonly used to improve moisture resistance, temperature susceptibility, crack resistance and deformation resistance. Despite these potential benefits, there are many challenges, associated with the categorization of different plastics and their associated effects, as well as the sourcing of consistent and uncontaminated plastic supply. Other challenges include the digestion and stability of plastic in the bituminous binder phase when the wet mixing process is used. It is also essential to confirm and demonstrate that asphalt mixtures containing recycled plastic do not increase the fume generation during construction or chemical leachate of road surfaces during service. These challenges must be resolved if the potential for recycling plastic in road and other pavement asphalt layers is to be fully maximised in the future.

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Objective Comparison of Sustainable Asphalt Concrete Solutions for Airport Pavements

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ABSTRACT

There is an increasing interest in sustainable infrastructure, including pavement structures and materials. Replacing the high-cost materials used for producing cementitious concrete and asphalt mixes provides the greatest return on the investment. For flexible pavement surfaces, this means replacing of the new aggregates, virgin bituminous binder and synthesised polymers commonly used to produce asphalt concrete mixes. Using a triple bottom line approach, the economic, social and environmental cost of different asphalt mixes, containing one or more of recycled asphalt, crumb rubber, processed plastic and crushed glass, were objectively compared. It was concluded that recycling asphalt provides the greatest single opportunity for more sustainable airport asphalt surfaces, with a triple bottom line cost 30% lower than the standard asphalt mix. However, the relative financial cost of the new and recycled materials, as well as the recycled material content, had a great influence on the triple bottom line cost of the various recycled materials, relative to that of the standard asphalt mix.

Sustainability Rating of Internally-Cured Concrete in Marine Environments Using Service Life Prediction Models

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ABSTRACT

The vulnerability of concrete in marine environments causes premature failure and shortened service life and decreases the resilience of concrete infrastructure in response to secondary hazards like earthquake and fire. Existing literature confirms the superior performance of structural lightweight concrete using rotary-kiln
produced expanded aggregates in these environments, including tidal and spray zones. Further, internal curing using fine lightweight aggregate contributes to the durability enhancement of normalweight concrete through addressing shrinkage and early-age cracking. These contributions are manifested in transport properties of concrete mixtures, as valuable inputs for service life prediction models. This research utilizes experimental data and service life modeling outcomes to highlight the benefits of internally-cured concrete in marine environments. The methodology employs a service life prediction model to perform parametric studies and render trends associated with mixture properties and climate characteristics. Results include sustainability performance measures including energy inputs and greenhouse gas emissions to assess the infrastructure. Conclusions help design and management professionals to recognize and evaluate opportunities to reduce the environmental footprints of concrete materials and to enhance the sustainability and resilience of marine infrastructure using sustainability rating guidelines.

Track 5: Contaminants and Repurposing Waste

Moderated by Julia Clarke

Sustainability Aspects of Coir-Fiber Geosynthetic Rolled Erosion Control Products

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Keywords: Coir Fiber, Geosynthetic, RECP, Soil Erosion, Sustainability

ABSTRACT

Geotechnical engineering is one of the most resource intensive engineering disciplines. Projects consume vast amounts of resources, change landscapes, and interact across socio-centric (human capital and social expectations), eco-centric (natural resources and ecological capacity), and techno-centric (engineering) boundaries. Improving the sustainability of geotechnical processes is important and necessary for the continued development of resilient communities.

This presentation will provide a unique perspective into the three aspects of sustainability (socio-centric, eco-centric, and techno-centric) for a commonly used geotechnical engineering product: coir-fiber geosynthetic rolled erosion control products (RECPs) (see Figure 1.) RECPs are temporary degradable materials manufactured into rolls that are used to minimize soil erosion and enhance the growth of vegetation on bare soil slopes. Coir fiber, obtained from coconuts, is produced around the world and plays an important role in marginalized rural communities.

A case study was conducted of the coir fiber industry in Kerala, India. Kerala has an abundance of natural resources, including coconuts, backwaters for processing coir fiber from coconuts, and low-income workers. More than 40% of rural women in Kerala work in the coir industry.

This three-pronged sustainability study (see Figure 2) began in Kerala, India, with interviews with women coir workers from three different rural villages to gain an understanding of how the industry impacts them, their environment, and how their products enter the local market. The study included interviews with local manufacturers and state agencies to gain an understanding of how locally produced coir fiber and products enter the national and global markets. Finally, the technical components of coir-fiber RECP development and product performance were evaluated through an extensive laboratory rainsplash erosion study conducted at Syracuse University to evaluate the properties and performance of coir-fiber RECPs and their ability to protect and enhance natural soil resources.

Insight into the advantages and challenges of the sustainability of these products in rural communities and globally was gained.
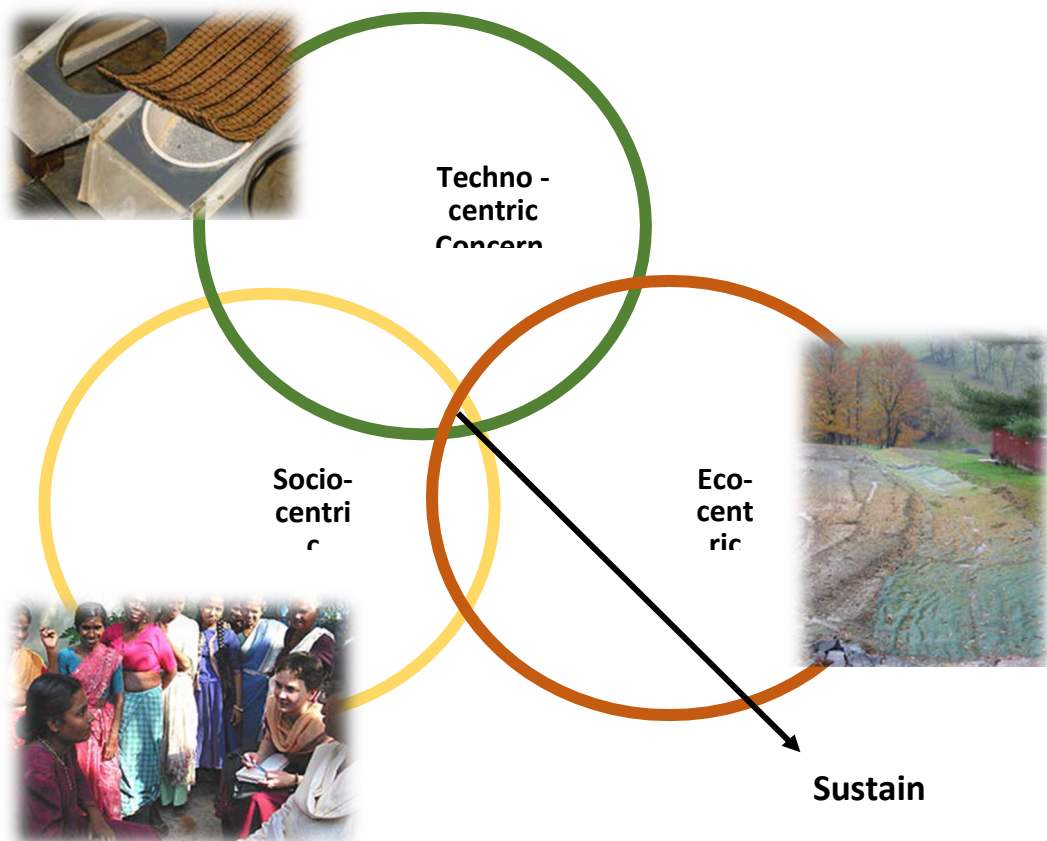
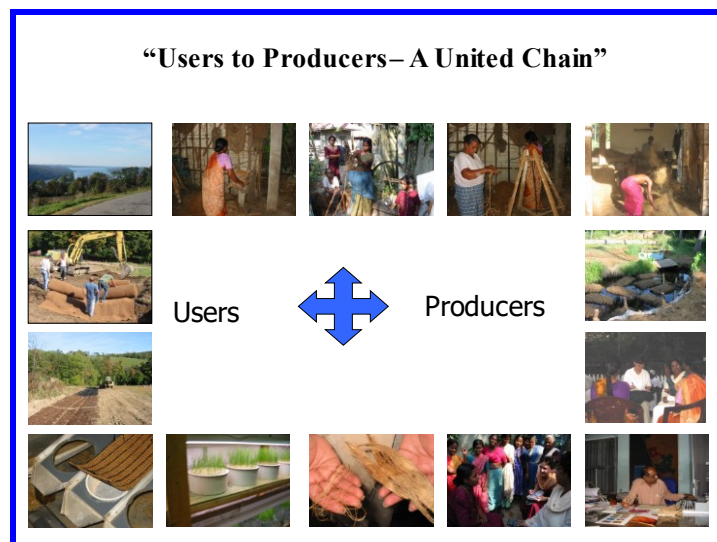**Figure 1**. Three aspects of sustainability.

Figure 2. Users to producers – a united chain.

Incorporating Spatial Scale into Resilience Ratings
for Sustainable Post-Disaster Material Management Systems

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ABSTRACT

Natural disasters generate large quantities of debris and waste materials (Brown et al. 2011) such as the mixed debris in Figure 1. If not managed properly, these materials pose a significant risk to human health and the environment. Critical, yet often overlooked, fugitive gases are emitted from post-disaster materials over various spatiotemporal scales following disasters. Post-disaster debris management activities such as collection, transport, processing at temporary storage areas, and final disposal also contribute to emissions through fossil fuel combustion (Wakabayashi et al. 2017). Despite these adverse impacts, post-disaster recovery efforts have primarily focused on advancing rapidity, resourcefulness, redundancy, and robustness throughout all stages of the debris collection, storage, and ultimate management lifecycle (Bruneau et al. 2003). While these resilience principles are important for disaster response, the principles alone fail to directly prioritize the climate impacts of post disaster materials and management activities that can intensify future disasters. Disaster waste management systems will benefit from integration of sustainability principles that foster resilience while providing long-term effective and enhanced system performance (e.g., Gillespie-Marthaler et al. 2019), hereafter termed "sustainable resilience".
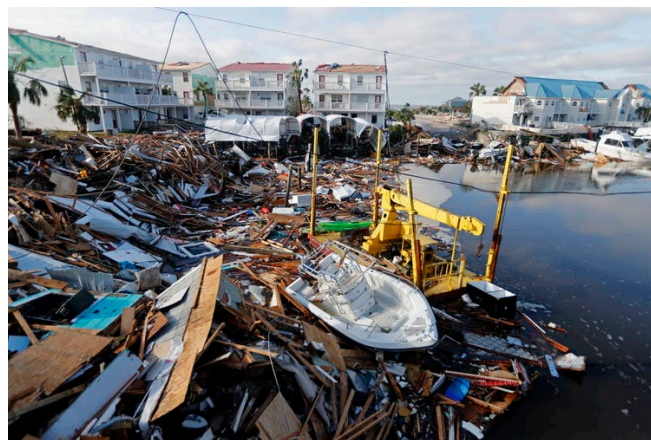
Figure 1. Debris in Florida after Hurricane Michael (from Derrible et al. 2019)

In this investigation, a novel framework is introduced to provide sustainable resiliency to

post-disaster material management systems. The framework incorporates two specific advancements: i) climate impacts of the waste materials and their management and ii) a spatial scale in addition to the time scale. The performance of the disaster waste management system is quantified using an overall sustainable resilience index (SRI). The SRI (Eq. 1) is defined as the combination of two primary metrics that characterize the sustainable resilience of the system: i) the climate impacts resulting directly from the debris and waste materials (EM_1, tonnes CO_2-eq. emissions); and ii) the climate impacts of the disaster waste management system operations, including collection, transport, temporary storage, recycling/recovery, and landfilling (EM_2, tonnes CO_2-eq. emissions). The performance of the system, in terms of the overall SRI, is made a function of time t by using existing resiliency analysis (Figure 2a) (Munoz and Dunbar 2015, Yodo and Wang 2016) and newly introduced distance x from the most critically affected region (focal point) of the disaster (Figure 2b). Higher values of the SRI indicate a management system that actively lowers the operational and debris/waste material-specific climate impacts.

$$SRI(t,x) = \left[\frac{1}{EM_1(t,x) + EM_2(t,x)} \right] \qquad (1)$$
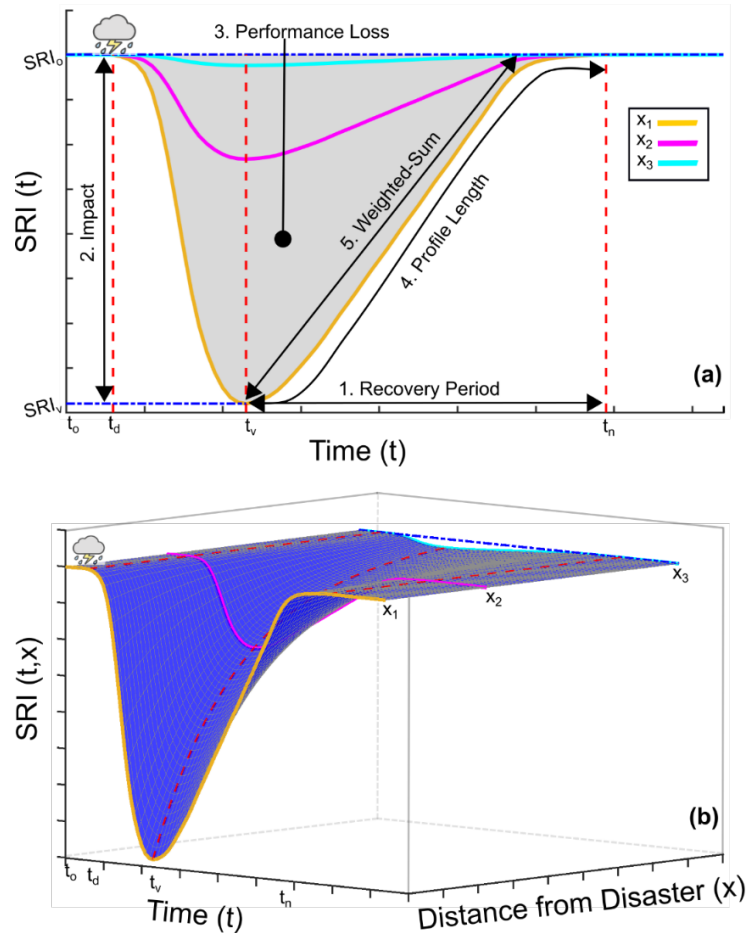
Figure 2. System performance with: a) time (adapted from Yoda and Wang (2016), originally by Munoz and Dunbar (2015)), b) time and distance from the disaster focal point

Prior to the disaster, the baseline SRI of the waste management system in the disaster affected region (SRI_o) includes existing emissions from collection/transportation routes and the waste management infrastructure (i.e., landfills and recycling/recovery centers). At the time the

disaster occurs (t_d), there is an abrupt decrease in the SRI to the vulnerability state SRI_v. The magnitude of this decrease in the SRI is typically strongest near the disaster focal point (x_1) and dissipates progressively towards the edges of the affected region (x_2, x_3). During the recovery period (t_v to t_n), the SRI starts to increase as a temporary debris management operation (TDMO) is established to collect, process, and manage the debris and waste materials (i.e., the recovery curve). The recovery effort ends when a steady state in the waste management system performance is re-established at or above baseline SRI.

The five common resilience dimensions are recovery period (RP), impact (IM), performance loss (PL), profile length (PrL), and weighted sum (WS). The 2D relationships that represent the dimensions (Figure 2a) are modified to account for the system performance on various spatial scales (Figure 2b) extending radially from the disaster focal point (x_1, x_2, x_3). An overall weighted sustainable resilience score (j) is developed to link all of the quantitative dimensions presented in Eq. 2. The weights (w_{1-5}) are determined using the modeling scheme presented in Munoz and Dunbar (2015).

$$\varphi = w_1 \times RP + w_2 \times IM + w_3 \times PL + w_4 \times PrL + w_5 \times WS \qquad (2)$$

The SRI(t, x) and the associated j will vary significantly spatially and temporally as a function of the community and disaster event characteristics. For example, the variations of the response surface as well as the reliability state are highly influenced by regional demographics (e.g., population density), disaster type and intensity, as well as the availability and condition of existing waste management infrastructure (e.g., age, type, capacity). Incorporating distance from the disaster event in the development of SRI allows for including: geographic spread of disaster impact zone; geographic distribution and density of waste management infrastructure; regional topography; variation of population density and associated civil and industrial infrastructure with distance from the disaster event; and directionality from disaster (as the function of distance will change on a radial basis depending on a specific cardinal direction). The features of the recovery surface as well as the vulnerability state (Figure 2b) will depend on the efficiency and preparedness of the management system; accessibility and connectivity of the transportation network for waste transfer; design and establishment of TDMO facilities; allocation of waste to recycling/recovery centers; and waste disposal in available landfills. Ultimately, this framework can be applied to optimize the sustainable resilience properties of disaster waste management systems on a community- and disaster-event-specific basis.

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Geotechnical Engineering Contribution for Sustainable Dredging

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ABSTRACT

In coastal areas and harbors, dredging activities are increasingly required for maintenance issues, investment purposes and to improve environmental conditions. Hence, dredging represents a routine necessity but, at the same time, it produces huge amounts of resulting materials (dredged sediments) that need to be periodically handled and safely placed somewhere. To get an idea of the involved volumes, in 2015 the annual dredging requirement for the major commercial harbors in Italy amounted to almost 130 million cubic meters (PCM, 2014).

In this scenario, it is critical to set up a sustainable management design of dredged materials which envisages the preliminary characterization of the sediments, analysis of their level of contamination, scheduling of excavation operations, sorting of equipment, and adoption of a reuse application. The management plan should be site-specific and designed in advance, also by foreseeing the collaboration between different expertises (geotechnical and hydraulic engineering, biology, chemistry etc.).

To follow a sustainable dredging strategy, management of sediments should be based on conceiving them not as a waste but rather as a reusable resource (as such or properly treated) for engineering purposes. These solutions are expected to result in lower economic and environmental impact, since they reduce the exploitation of quarries and avoid disposal of sediments in landfills if contaminated.

In the past, dredged sediments were directly discharged offshore, but this practice, although the cheapest, is no longer recommended, since it can "presumptively" alter the aquatic environment (Miller, 1998); besides, the unconfined open-water displacement does not provide a new beneficial fate to the resulting material.

Several sustainable management alternatives are currently viable depending on the physical-chemical characteristics of dredged materials and on their level of pollution. Nourishment is certainly the most desirable option for uncontaminated ones: it involves their placement directly onto a beach or into the shallow areas near shore, to control coastal erosion. Other innovative beneficial uses convert dredged sediments in raw materials for road construction (Siham et al., 2008), bricks fabrication (Mezencevova et al., 2012), self-consolidating concrete preparation (Rozière et al., 2015), and landscaping and agricultural applications (Miller, 1998).

If dredged sediments are contaminated, they can be placed in a submerged disposal site and then covered with a layer of clean material (capping): the disposal can be done directly onto a flat surface or into an excavated subaqueous pit to provide lateral containment (Miller, 1998). Also, unconventional biological treatments have been proposed to remove organic and inorganic contaminants from sediments (Mulligan et al., 2001): these are very promising solutions but, owing to their high costs and to their inefficacy to neutralize all the contaminants present, they have been scarcely used hitherto.

One of the most used management practices for contaminated sediments is confined disposal (Miller, 1998). It consists in building a secure containment structure (confined disposal facility, CDF) within the port and then filling it with dredged muds, to finally integrate it into the port infrastructure. Dimensions and configurations of the CDF depend on the dredged material volume, pollution levels, and disposal procedure, as well as on local regulations. Often a CDF is the only alternative that is found to be both environmentally and economically acceptable (Bailey et al., 2010). A CDF can represent a sustainable opportunity of resources optimization and harbors modernization, since expansion works usually require large quantities of filling material which can be supplied by means of a careful planning of dredging activities.

However, when dealing with dredged materials fillings, their behavior after placement cannot be neglected. This is especially true for hydraulically dredged fine-grained sediments which typically exhibit very high water contents, high compressibility and poor mechanical properties, when poured into a CDF. They firstly settle at high void ratios, then self-weight consolidation starts, during which they undergo significant volume changes upon reaching the normally consolidated state (De Lillis et al., 2019 and 2020). Soils in such initial conditions require mechanical improvement to become suitable for reusing the area. Indeed, if subjected to overloads, they can experience high settlements and substantially modify their compressibility and permeability characteristics, which should be thus experimentally determined (Liu and Znidarcic, 1991; Krizek and Somogyi, 1984). Therefore, there are geotechnical aspects that a proper CDF management design should consider. First of all, a complete geotechnical characterization should be performed both *in situ* and in the laboratory, to correctly assess the consolidation process. Secondly, optimization of the operational sequences is necessary, with a view to save time, costs and resources. Finally, the selection of the optimal ground improvement technique is a critical step, as it should be effective in accelerating the consolidation process.

The whole management process is here examined with reference to the Ancona Harbor (Italy), where a CDF was built to collect contaminated sediments from several ports of the central Adriatic Sea, and then to reclaim the area for port commercial activities. This is certainly a sustainable, forward-looking design solution that has combined the need of widening the harbor spaces with the availability of resulting materials which would otherwise be landfilled. The CDF is situated in the commercial dock of the Ancona harbor; it covers an area of 95,000 m^2 and has a volume capacity of about 180,000 m^3. A sectorization of the usable volume has been planned to optimize the filling and consolidation procedure: each sector after filling can be consolidated while filling the adjacent one. In such a way the CDF can be made available for the intended use in a shorter time after overall filling. Its construction has been very complex and required some innovative solutions, as reported in Felici et al. (2017). Owing to the fine-grained nature of the dredged sediments, the

selected consolidation technique has been a preloading embankment coupled with prefabricated vertical drains (Felici et al., 2020). The CDF is currently being filled and, in a completed sector, a full-scale field test has been set up to study the consolidation process (Felici et al. 2018).

By referring to the Ancona experience, the study illustrates how geotechnical engineering is crucial to the dredging management cycle, allowing the reuse of filled areas by providing site-specific innovative solutions.

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Phytoremediation: A Cost-Efficient and Environmentally-Sound Remediation Technology for Widespread Applications

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ABSTRACT

Environmental remediation of groundwater and soil can quickly become a logistically challenging and costly pursuit. Commonly used remediation technologies include thermal desorption, excavation, chemical oxidation, pump-and-treat, soil vapor extraction and others. Factors such as site location, geologic conditions, geochemical conditions, extent of contamination, and type of pollutants all contribute to the selection of a remediation technology and the overall cost. Unfortunately, current methods come at a high cost regarding materials, off-site processing, and transportation, as well as the negative environmental impacts including accelerated soil erosion, unintended toxic byproducts, and changes to the site ecosystem. Phytoremediation is a unique bioremediation technology that uses plants and microorganisms to destroy contaminants in soil and groundwater. This technology is less costly than traditional in-situ and ex-situ remediation methods while being a more environmentally considerate option. Specifically, phytoremediation reduces soil erosion, maintains soil fertility, and increases overall soil health and biome, while being the most aesthetically pleasing remediation option to the public. Phytoremediation is a sustainable and environmentally resilient replacement for traditional remediation methods.

Life Cycle Assessment of Sediment Control Devices

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ABSTRACT

Sediment control devices (SCDs) are used to manage stormwater runoff and deposition on active construction sites to prevent contamination of waterbodies by suspended solids, nutrients, and heavy metals, which are extremely toxic to the receiving ecosystem. Enriched nutrient concentrations can cause excess growth of plants and algae which also cause severe reductions in water quality and threaten aquatic vegetation and animals due to the transport of chemicals sorbed to suspended solids, which can raise toxicity levels. Due to these detrimental impacts, substantial efforts are spent on liquid/solid separation to retain solids, nutrients, and metals on land before discharge to receiving streams. Currently, silt fence is the most frequently implemented method for erosion control in the early phases of construction projects, with the Georgia Department of Transportation installing approximately 1.0 – 1.5 million linear feet of silt fence per year. However, silt fences, which are composed of silt film and woven geotextile, typically manufactured from polypropylene (Figure 1), rely heavily on fossil fuels for manufacture. Minimal studies have been carried out to compare the feasibility of alternative SCDs that are biodegradable and less fossil fuel dependent. Consequently, the goal of this study is to conduct a cradle-to-grave life cycle assessment (LCA) to compare the environmental impacts of five sediment control devices, including silt fence (type A), high flow silt fence (type C), compost socks, straw bales, and mulch berms. Field and laboratory experimental results were used to assess SCD performance and are paired with the LCA database Ecoinvent 3.2 to model the lifecycle of each SCD using Simapro 9.0 software. The findings of the study indicate that overall low global warming and acidification potentials as well as low aquatic toxicity levels demonstrated by mulch berms suggest their use as a more sustainable alternative to a geosynthetic silt fence.

Figure 1. Type A (left) and Type C (right) silt fence during the test.
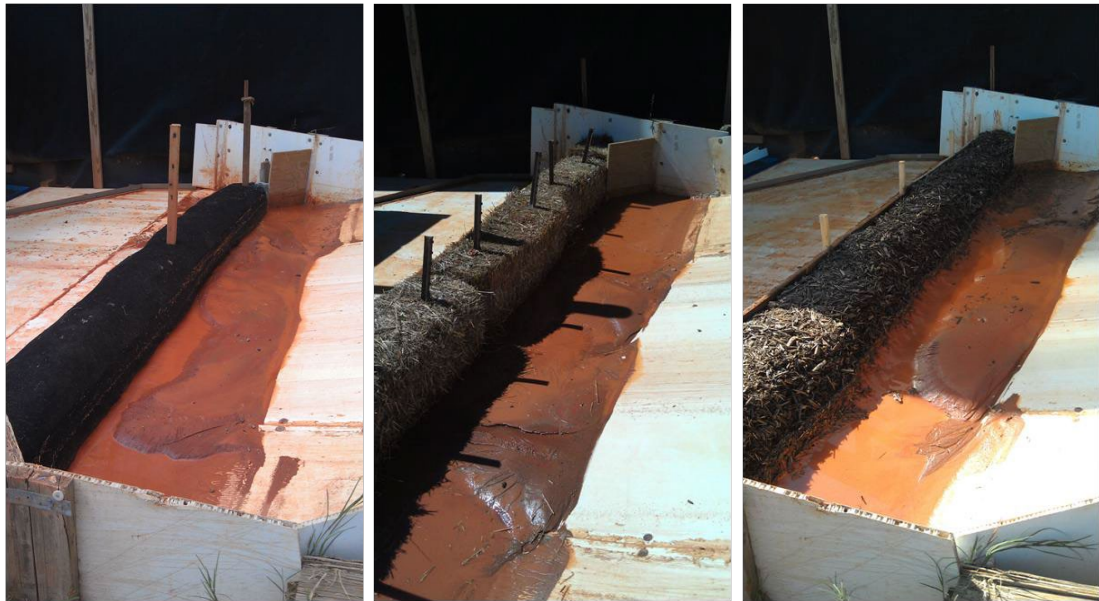

Figure 2. 12-in compost sock (left), straw bales (middle) and mulch berm (right) after the test.

Posters at ICSI 2021

December 6 - 9, 2021

BIM/GIS Integration for Regional Railways Asset Management

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Keywords: BIM GIS Integration, Building Information Modelling (BIM), Geographic Information Systems (GIS), Infrastructure Management, Railways, Risk Assessment

ABSTRACT

Raising awareness on climate change and modern urban challenges has increased attention on infrastructure asset management (AM). The Sustainable Development Goals (United Nations 2015) and The European Green Deal (European Commission 2019) plan to make the world economy sustainable. An essential aspect of reaching this result is the greenhouse gases (GHG) emission reduction, so one of the main challenges is to reduce transport emission and its negative impacts on the environment and human health. Rail is sustainable, and it can play a major role in achieving the decarbonisation target. Moreover, the number of people taking the train is growing and fulfilling a greater demand for rail transport means to improve the service offered, in terms of quantity and quality. In Italy alone, more than five million people (Istat 2019) take the train to study or work daily, and this number is growing over time. Data from the last decade demonstrate that more investment in rail infrastructure means a greater number of users (Legambiente 2021). This is even more true considering the regional rail transport: although there is a general increase (+5,1% from 2010 to 2019), the situation is intensely fragmented based on single regional strategies. Local railways transport, mainly used by commuters, needs a management strategy. In fact, different intervention works are necessary, such as railway track adaptation and electrification. Supported by new technologies, the key to handle the problem of renovation and management of regional railways is the digital transformation, which provides a series of opportunities for a positive conversion of the transport sector (Tsakalidis et al. 2020). In particular, the focus is to test the potential of a Building Information Modelling (BIM) and Geographic Information Systems (GIS) integrated system employed to manage this type of existing infrastructure. The aim is the construction of a system that can be used across different phases of the process: analysis of the existing condition, comparison with regulatory requirements, simulation of different intervention scenarios, and management of the realized one. The use of BIM/GIS frameworks and the possibility to have model details and contextual data can support decision-making processes in operation and maintenance at macro and micro levels (Wang et al. 2019). As part of this framework, this study wants to deepen the connection between failure probabilities and consequences in regional railways infrastructure, proposing a work-in-progress methodology to quantify the impacts of different maintenance interventions.

The proposed methodology aims to analyse the combination of failure probability and consequences in order to have a quantification (economic, social, or environmental) of different maintenance strategies (Figure 1).
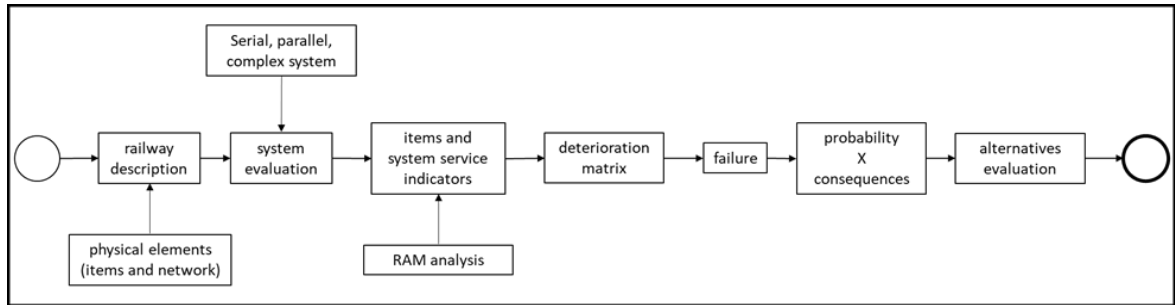

Figure 2. General methodology to evaluate the connection between failure probability and consequences

Railway description is the first step, and it consists in the subdivision of the railway in single elements, linear and point elements (Papathanasiou et al. 2018). The second step is the system evaluation. The configuration of the components in a system determine different ways to value the indicators. The next step is the deterioration matrix, through the definition of discrete condition states and the use of a deterministic model. Failure will be calculated considering the probability and the consequences. The combination of these values defines the quantification of risks on service. These analyses will help support the decision-making process to evaluate different alternative interventions and choose the best one.

The first part of the methodology presented was tested on a Southern Italy regional railway's real case study: Ferrovie Appulo Lucane (FAL). The principal objective was to define the railway track's actual status by analysing the railway items. A first attempt of RAM analysis was carried out using public data provided.

Figure 3. FAL railway line with stations and stops. (Ref. system: EPGS 4326 WGS 84) Data sources: rail lines and junctions from National and Regionals geodatabases; administrative boundaries from ISTAT.

The use of data from three Geoportals led to having different attribute tables. Before

starting the analysis, it was necessary to standardize the attribute tables in order to have the same level of information. Standardized data allows one to analyse and classify physical rail elements by type: point (station, stop, level crossing, terminal, switch) and linear (at ground, bridge, tunnel, underpass).

Reliability, Availability and Maintainability (RAM) analysis gives probabilistic values about an item's overall level of service (BSI 2017). For the case study presented, the starting point was research of data and information about the categories that compose the railway. The FAL Service Chart (from 2015 to 2019) and Management System documents were consulted. Since no data are now available about single sub-items, RAM analyses were made starting from the number of maintenance works. For this study, the system (the whole railway) was considered composed of only two subsystems (in series), one in the Basilicata region and one in the Puglia region. A double analysis was carried out, considering both the maintenance indicators (corrective and preventive). The first step was to evaluate the number of interventions per time unit, in this case the year. Maintainability can be considered as an average of these values. Reliability was considered as the inverse function of maintainability. Availability is the ratio between reliability and the sum of reliability and maintainability. The overall RAM results are given in Table 1 for both maintenance indicators.

Table 1. Results of RAM analyses for Basilicata (left) and Puglia (right) regions

Maintainability (M)	Reliability (R)	Availability (A)
median of CI/tu	1-M	$T_i/(T_i+t_i)$
0,024	0,976	0,977

Maintainability (M)	Reliability (R)	Availability (A)
ar. mean of PI/tu	1-M	$T_i/(T_i+t_i)$
0,030	0,970	0,971

This study represents the first step of wider research. Further work will consider a Markov model to determine the deterioration of the items and the impact hierarchy to define the consequences of different intervention strategies. All the resulting data will be used to give information to the integrated BIM/GIS digital model.

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The Critical Success Factors for Precast Segmental Superstructure Construction for Metro Project Systems in India

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ABSTRACT

This research identifies Critical Success Factors (CSF) for precast segmental superstructure (viaduct) construction for Metro project systems in India. Based on literature review and expert interviews a list of 66 CSF were identified and grouped into 10 categories. An empirical questionnaire survey was conducted with relevant experienced practitioners in India. A total of 240 questionnaires were sent out of which 77 responses were received. Collected responses were analysed using a relative importance index. The research findings indicate that clients' funding availability, material availability, and land acquisition are the most important factors in viaduct construction. This study will help stakeholders of the projects to apportion appropriate resources on the most important factors to avoid unsuccessful projects.

Eat Prosperity Campaign

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ABSTRACT

Global mean surface temperatures and global methane emissions have steadily risen over the past 40 years. Residential food waste deposition has increased by as much as 30% since the beginning of COVID-19 pandemic, and landfills are reaching capacity more quickly as up to 40% of food is thrown into the trash (USDA, 2010). A residential food disposal collection campaign to recycle food waste and carbon emissions could be implemented to grow economically sustainable algae on landfills. NASA Surface Attached BioReactor (SABR) technology optimizes growth performance of algae and reduces the capital expenditure by 69% compared to clear polyvinyl chloride (PVC) photobioreactors, and the landfill infrastructure reduces the operational costs for growing algae by 42%. The novel Eat Prosperity food waste collection and landfill biodiesel model may outcompete standard drilling methods, yielding revenue greater than $100 million a year and divert more than 200,000 tons of municipal solid waste a year, per county landfill. The Eat Prosperity model for food waste collection provides a significant abatement of global greenhouse gas emissions potential within a communal behavioral change. By allowing residents within communities the opportunity to recycle at the source of disposal and actively participate, business-as-usual estimations of global greenhouse gas emissions could be offset by as much as 47 $GtCO_2$ in 20 years compared to current 2030 projected estimates.

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Evaluating Wildfire Mitigation Strategies for Utility Distribution Poles

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Keywords: Aging, Climate Change, Mitigation Strategies, Utility Distribution Poles, Wildfire

ABSTRACT

Wooden utility poles provide the backbone of U.S. electric-power and telecommunications systems. However, they have suffered severe damage from natural hazards including hurricanes and wildfire, resulting in power outages, unplanned replacement costs, and a range of public safety issues. Studies of wooden utility poles' performance in hurricanes have been fairly common, but parallel research involving wildfires has been minimal, despite utility companies spending millions of dollars addressing wildfire damage, at a replacement cost of between $10,000 and $20,000 per pole (including the old pole disposal, material cost of new poles, transportation, installation, and electrical system transferring). Moreover, this problem is likely to become more severe in the future due to climate change-related warmer, drier conditions, more frequent droughts, and extended fire seasons. Therefore, it is imperative to find effective strategies for mitigating damage to wooden utility poles in wildfire-prone regions. Previously proposed mitigation strategies have included replacing wooden utility poles with steel, concrete, or fiberglass ones; coating or wrapping them with passive fire-protection materials; and increasing efforts to clear vegetation around them. It is difficult to conclude that one mitigation strategy is superior to others without a comprehensive assessment. A framework was developed to evaluate the lifetime cost effectiveness of mitigation strategies for utility distribution poles exposed to wildfire, taking account of a wide range of influential factors and their uncertainties, e.g., climate change, aging of wooden utility poles, and supply-chain issues. The application of the developed framework was illustrated through a case study of a typical wildfire-prone region.

Building a Framework for Resilient Stakeholder Engagement to Support Equitable Infrastructure Project Outcomes

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Keywords: Community Engagement, Equity, Infrastructure, Policy, Resilience, Transportation Planning

ABSTRACT

The goal of this research is to develop a resilience-based stakeholder engagement framework for transportation infrastructure development that provides equitable outcomes for all stakeholders. We present a preliminary comparative case analysis examining the relationships, power structures, and dynamics of civic infrastructure present within communities of color, that have historically been negatively impacted by transportation infrastructure projects. Two highway projects are examined, the North Central Expressway construction of the 1940's and the current-day I-345 bridge replacement project in Dallas, TX. A historical analysis of the decline of the North Dallas Freedman's town, a historically Black neighborhood, includes an evaluation of socio-economic factors, stakeholder interdependencies, and resulting distribution of benefits. Possible improvements for the current-day I-345 community impact assessment and public involvement processes are then identified. Preliminary findings from the comparative case analysis are used to develop a modified sensing, anticipating, adapting and learning (SAAL) framework that applies a resilience lens to the community engagement and public involvement processes. Building resilience for civic infrastructure is expected to create feedback mechanisms that support equitable transportation infrastructure development. This research highlights the ways in which transportation infrastructure development can contribute to social inequities, and opportunities for civic infrastructure to support equitable outocmes. It is expected that study findings will contribute to improved outcomes for stakeholders involved in transportation infrastructure development, and reveal pathways for long-term equity in project outcomes.

Limitations for Transport Infrastructure in Colombia During the Development of Projects Related to Non-Conventional Renewable Energy Sources (NCRES)

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Keywords: Clean Energy Auctions, Colombia, Renewable Energy, Spatial Analysis, Transport Infrastructure

ABSTRACT

Colombia within its long-term action plan considers the progressive integration of new generation projects by NCRES with the aim of diversifying the energy matrix and contributing to mitigate the effects of climate change. The purpose of this research is to identify the quality status of the existing transport infrastructure of the territories for the development of solar and wind projects awarded in the energy-supply contracting auctions carried out in 2019. An accessibility analysis is carried out to identify the coverage of the systems and their limitations. For this study, a spatial analysis is performed estimating the density surfaces that reflects where the investigated variables are concentrated, using Geographic Information Systems (GIS) and the Kernel Density tool. Given the locations of the newly awarded NCRES projects, it would be possible to prioritize investments in transport infrastructure to optimize the logistics of the solar and wind parks under development.

Project 11: Navigating the Waters that Define Houston's Path Forward

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ABSTRACT

The Port of Houston drives $802 billion in annual national economic value, sustains more than three million U.S. jobs, and is the nation's number one port in foreign waterborne tonnage.

Since 2010, the Port of Houston Authority has been planning the next major channel improvements, working with Congress, the Army Corps of Engineers and private industry partners. The Houston Ship Channel expansion – Project 11 – will widen the channel by 170 feet along its Galveston Bay reach, from 530 feet to 700 feet. It will also deepen upstream segments to 45 feet, make other safety and efficiency improvements, and craft new environmental features.

Expanding the Houston Ship Channel is critical to safely and efficiently sustaining national energy security, domestic manufacturing growth, thriving U.S. exports, and expanding job opportunities. It is one of the most vital waterways in the country, connecting the nation's largest petrochemical complex to the globe. The waterway has more deep-draft ship visits than any other port in the country, and nearly 200,000 barge transits every year as well. As energy and manufacturing exports increase and vessel sizes grow, improving the channel is nationally important.

This project, a major civil engineering effort, will create a more resilient, sustainable economy for Houston, the surrounding region, and the nation.

Use of Regional Air Temperature Observations and Forecasts to Assess Effect of Water Temperature Change in Drinking Water Distribution Systems

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Keywords: Climate Change, Distribution System, Drinking Water, Temperature

ABSTRACT

Non-stationary climate conditions as a result of climate change such as extreme weather events can lead to substantial challenges for design, operation, and management of infrastructure, as much existing infrastructure was designed and is operated based on historical climate conditions (ASCE-CACC 2015). Drinking water supply systems are vulnerable to regional climate change (Vogel et al. 2016). The effects of ambient air temperature change on drinking water temperature in distribution systems merit particular attention, as water temperature is a key parameter affecting the various physical, chemical, and biological processes that determine water quality (Agudelo-Vera et al. 2020).

The main objective of this study was to investigate the effects of ambient air temperature changes on water temperature and quality in drinking water distribution systems (DWDS). The positive correlation between ambient air temperature and DWDS water temperature was assessed and then further utilized to provide daily drinking water temperature estimates. Separate methods of estimating temperature-related water quality parameters were identified and assessed with the input of water temperature estimates to evaluate the effects of water temperature change on water quality. The analyses were conducted with the objective to provide an overview and preliminary assessment of generally expected changes in DWDS water temperature and water quality parameters across different locations with respect to interannual ambient air temperature changes.

Measurements of water temperature at seven locations in different U.S. states and measurements of some temperature-related parameters at Washington D.C. were used to validate, calibrate, and assess the estimation of water temperature and water quality parameters. Similar to soil temperature estimation (i.e., using ambient air temperature and soil depths for calculation), a DWDS water temperature estimation model – developed by the National Renewable Energy Lab (NREL; Burch and Christensen 2007) – was used and assessed to provide water temperature estimates.
Figure 1 shows the results of water temperature measurements and estimates from the NREL model for Washington D.C. using both standard parameters and further calibrated ones. Using the standard parameters for the NREL model can provide reasonable estimates, while further calibration of the model with local measurements can further improve the estimation (~50% reduction in these cases).

City-level observations (Lai and Dzombak 2019) and near-term forecasts (Lai and Dzombak 2020) of ambient air temperature were then utilized to evaluate both historical and future changes in DWDS water temperature at particular locations. The analyses were conducted for 93 U.S cities to assess the spatial variation in the changes of water temperature as presented in Figure 2, although such analyses were not calibrated with local temperature measurements and the evaluation of particular cities is subject to limitations. According to the NREL model, the estimated changes in annual average levels of DWDS water temperature are determined by the average changes in air temperature, and thus the results of estimated water temperature changes in Figure 2 are equivalent to the local air temperature changes.

Using the DWDS water temperature estimates, this work assessed the effects of water temperature (or air temperature) changes on several temperature-related water quality parameters including chlorine decay rates and concentrations of one disinfection by-product (DBP). Similar to the estimated changes in water temperature, the results suggest modest changes in the assessed temperature-related water quality parameters. The results were consistent with some general expectations, e.g., the effect of temperature on rate of reaction generally follows the Arrhenius expression and small changes in temperature have small effects on reaction rates.

While the overall effect of interannual air temperate changes on the water temperature and water quality in DWDS is not estimated to be substantial, several findings from the analyses merit particular attention, including that the increase of water age can amplify the effect of water temperature changes and that the aggregate temperature effect on inter-related aspects of water quality (such as chlorine decay, DBP formation, and bacterial activity) can lead to higher risks than the results suggested from assessing individual parameters. To advance understanding of the challenges related to higher
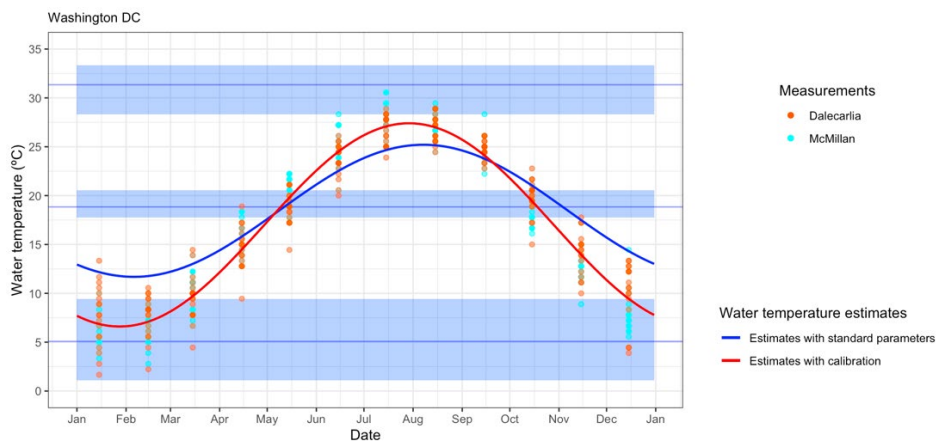

Figure 1. Water temperature measurements from two treatment plants (USACE 2019) and the water temperature estimates from the NREL model for Washington DC. Three shaded bars present the reported annual maximum, average, and minimum water temperature in drinking water quality reports (DC Water 2019) for 2003-2017.

water temperature in DWDS and to ensure appropriate adaptation of DWDS in design and management, the effects of increasing air temperature and climate change on DWDS water temperature and quality merit more attention and further studies.
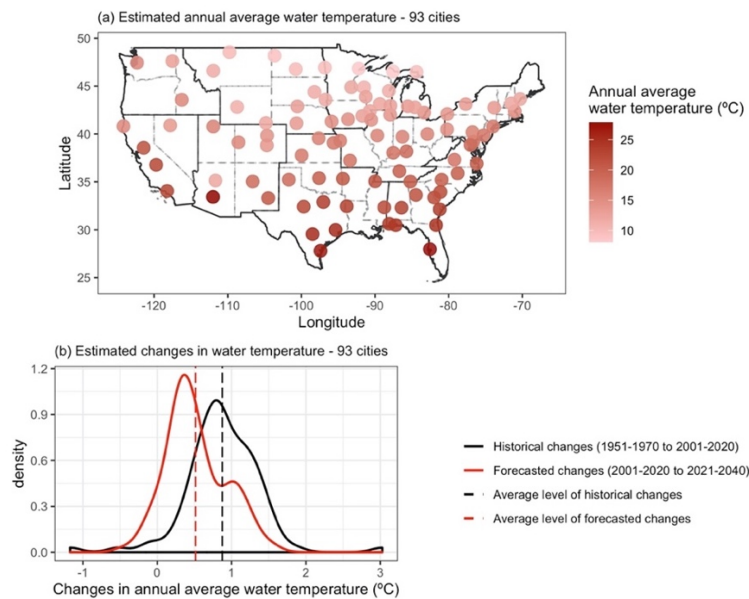
Figure 2. Estimated annual average DWDS water temperature and water temperature changes for the 93 U.S. cities (presented as probability density functions among the 93 cities).

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Tornado Resilience: Latest Developments at the National Level

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ABSTRACT

Tornadoes kill more people per year in the U.S. than hurricanes and earthquakes combined, and tornado fatalities overwhelmingly occur inside buildings. Annual insured catastrophe losses caused by tornadic storms exceed those caused by hurricanes and are nearly double the estimated annual losses caused by earthquakes. Despite these alarming statistics, building codes and standards do not consider tornadoes as a design condition (with very limited exceptions, e.g., storm shelters and safety-related structures of nuclear power plants). While the nation has made significant improvements in tornado forecasting, detection, and warning in recent decades, these changes alone will not lead to a more tornado-resilient nation. A much more comprehensive approach is needed, beginning with the development of tornado hazard maps for the US that accurately characterize the tornado hazards and including explicit consideration of these hazards when planning and designing our built infrastructure.

This presentation will provide a brief overview of tornadoes, their climatology, and impacts. It will then explore recent developments for improved tornado hazard characterization, design methods and standards for buildings and structures to resist these hazards. The main focus will be on development of the new chapter on Tornado Loads for *ASCE 7-22 Standard: Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, including a new generation of probabilistic tornado hazard maps that consider spatially-based estimates of tornadic winds. Design requirements for tornado shelters will also be discussed, including major changes to ICC 500-2020, the ICC/NSSA Standard for Design and Construction of Storm Shelters.

A Resilient Traffic Signal Control System Using Artificial Intelligence

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ABSTRACT

Typical traffic signal systems are actuated-type using a detector on the upstream of the stop line. It usually works better than the fixed-time system in mitigating traffic delay but can significantly increase operation and maintenance cost. Recently, researchers have tried to integrate artificial intelligence in the system to make it smarter and more cost-effective. However, these studies were still limited to simplified assumptions. Road users' behavior and decisions are the result of imprecise and vague information input that are often difficult to measure due to various preferences, decision variables, or other constraints. Especially in extreme weather conditions, which are being exacerbated by climate change, or other emergencies when traffic patterns are abnormal, the typical traffic signal system may not meet the high traffic demands and may lead to severe delays and safety issues. To improve resiliency, an intelligent traffic signal with efficient automatic control technology is required. Fuzzy logic, a precise artificial intelligence algorithm to deal with the imprecision input, can better simulate humans' cognitive ability in decision-making and can also be automated based on the in-situ condition.

This study was to investigate a method to apply fuzzy logic into traffic signal control system and build a reliable mathematic model. MATLAB software was used to create and evaluate the model. After membership functions were established for two traffic data inputs and two outputs, thirteen fuzzy rules were built based on typical traffic conditions and assumptions. These rules were initially evaluated by checking the control surface's smoothness and slope consistency using the fuzzy toolbox. The Mamdani controller and the Centroid method were applied to calculate the output and convert it into precise traffic timing change. The built model was tested using some random traffic inputs. The solution turned out to be reasonable and may better handle high-demand traffic. However, this simplified model still needs further improvement by adding more inputs such as turning movements, adjusting the membership functions, as well as the fuzzy rules before implementation.

Physical Modeling of Wave Height Attenuation through Flexible Vegetation

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ABSTRACT

Forty percent of the world's population lives within 100 kilometers of the coast and is threatened by sea level rise and extreme weather events associated with increasing global temperatures and climate change. These hazards exacerbate the vulnerability of coastal communities to shoreline erosion and damage by waves and flooding. This project focused on the effectiveness of flexible vegetation as a non-invasive, sustainable, and resilient shoreline protection alternative. An idealized physical model was designed and constructed in a wave flume (Fig. 1a). Water surface elevations were measured seaward and leeward of the vegetation and for a baseline case subjected to multiple wave conditions, at two different water depths, to determine the effect of vegetation emergence and submergence on wave attenuation. Emergent vegetation resulted in smaller average and significant transmission coefficients ($K_{t,mean}$ = 0.60 -0.70 and $K_{t,significant}$ = 0.32 - 0.39) and greater wave height percent differences, compared with those calculated for submerged conditions ($K_{t,mean}$ = 0.82 -0.91 and $K_{t,significant}$ = 0.73 - 0.90) (Fig. 1b). Therefore, wave attenuation was greater for emergent vegetation due to interruption of the entire wave profile.
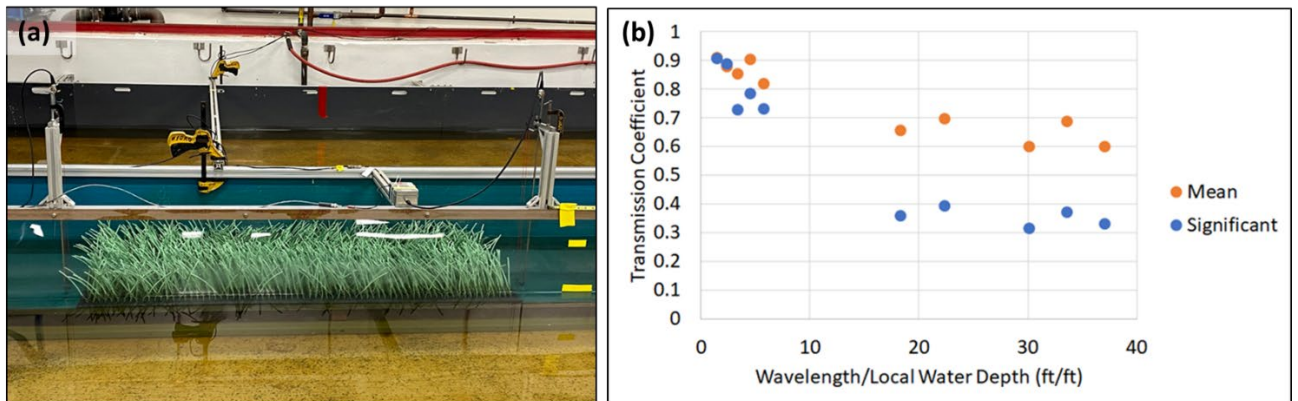
Figure 1. (a) Idealized physical model of flexible vegetation with apparatus for measuring wave attenuation; (b) transmission coefficient K_t vs. ratio of wavelength to local water depth for mean (orange) and significant (blue) wave heights