DMDU 2023

OCT 30 - NOV 1

DELFT

PROGRAM BOOKLET

A DECADE OF DMDU

LEARNING FROM THE PAST AND LOOKING TO THE FUTURE

final version (27.10.2023)

This programme was created based on the original version developed for the AMCOS conference booklet at:
`https://github.com/maximelucas/AMCOS_booklet`

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About

DMDU

The Society for Decision Making under Deep Uncertainty (DMDU) is a multi-disciplinary association of practicing professionals, scholars and students working to improve processes, methods, and tools for decision making under deep uncertainty, facilitate their use in practice, and foster effective and responsible decision making in our rapidly changing world. Our society is unique in its focus on developing, disseminating, and using these DMDU approaches across multiple policy domains such as energy, health, social and economic well-being, defense, water, environment, and transport.

Annual Meeting 2023

The 10th Annual Conference of the Society for Decision Making Under Deep Uncertainty (DMDU), is taking place at Deltares in Delft, the Netherlands from October 30th to November 1st 2023. The theme of this year's conference is "A Decade of DMDU: Learning from the Past and Looking to the Future."

Over the past decade, DMDU has experienced rapid growth in terms of technical methods, the number of academics and practitioners using DMDU approaches, and the diverse array of decision problems being studied. As we reflect on our achievements and look forward to the future, this conference aims to address the following topics: a) The Society's milestones and evolution over the past decade; b) The emergence of DMDU in new sectors and use cases; c) like health, spatial planning, and Artificial Intelligence; d) The development and uptake of tools and guidance for adopting DMDU into practice; e) DMDU's contributions to 21st century governance; f) Shaping the DMDU agenda for the coming decade.

Organizing committee

Jan Kwakkel	Marjolijn Haasnoot	Michelle Miro
Irene van Droffelaar	Julius Schlumberger	Julie Rozenberg
Sadie McEvoy	Rob Lempert	Nathan Bonham
Mark Workman		

Timetable

Monday, 30.10.

The schedules work with cross-references. Click on a session to get directly to an overview of the talks in that session.

	Patio	Ganges	Rhone	Yangtze
08:30 to 09:00	Registration and Coffee			
09:00 to 09:15	Welcome to DMDU 2023 by Jan Kwakkel and Marjolijn Haasnoot			
09:15 to 10:30	Keynote by Debra Roberts			
10:30 to 11:00	Coffee Break			
11:00 to 12:30	10+ years of adaptation pathways: from theory to practice	Spatial design and design-based approaches in delta management to address uncertainties in developing a long-term strategy	Climate Risk Informed Decision Analysis - experiences and developments	
12:30 to 13:30	Poster-Session (and Lunch)			
13:30 to 14:15	Keynote by Peter Glas			
14:15 to 14:30	Short Break			
14:30 to 16:00	Exploring the institutional contexts for effective DMDU	Info-Gap Methods for Planning, Design and Decision under Deep Uncertainty	Techniques for critical infrastructure assessment: ready for the 21st century in theory in practice?	
16:00 to 16:30	Coffee Break			
16:30 to 18:00	Enhancing Decision Making through Effective Visualization Techniques	Applying DMDU techniques to Global Systemic Risk Assessment	Stumbling Blocks and Stepping Stones: practical challenges and opportunities of using DMDU methods in the transport sector	
18:00 to 21:00	Dinner at Lijm and Cultuur			

Keynotes Orals Expert Panels Thematic Session Discussion Forum
Breaks informal session not used

Tuesday, 31.10.

The schedules work with cross-references. Click on a session to get directly to an overview of the talks in that session.

	Patio	Ganges	Rhone	Yangtze
08:30 to 09:00	Walk-In and Coffee			
09:00 to 09:45	Keynote by David Victor			
09:45 to 10:00	Short Break			
10:00 to 11:30	Recent Advances in Robust Decision Making and Its Applications	Climate Resilient Development Pathways I	Participatory DMDU I	
11:30 to 12:00	Coffee Break			
12:00 to 13:00	Advances and Applications of Scenario Discovery	Climate Resilient Development Pathways II	Participatory DMDU II	
13:00 to 14:00	Lunch			
14:00 to 15:00		DMDU practice	Exploratory Modelling	Developing pathways in complex multi-sector multi-hazard systems – Lessons from European pilot regions
15:00 to 15:30	Coffee Break			
15:30 to 16:30		Prospects and Challenges in Advancing Adaptation Pathways: A Discussion Forum	The Future of Integrated Assessment Models and their Role in Decision Making under Deep Uncertainty	DMDU and the Humanities
16:30 to 18:00	Tools and Software Market		DMDU Regional and Interest Groups Workshop (16:30-17:30)	Informal session organized by Pieter Bloemen (17:00-18:00)
18:00 to 20:00	Dinner at Deltares			

Keynotes Orals Expert Panels Thematic Session Discussion Forum
Breaks informal session not used

Wednesday, 01.11.

The schedules work with cross-references. Click on a session to get directly to an overview of the talks in that session.

	Patio	Ganges	Rhone	Yangtze
08:30 to 09:00	Walk-In and Coffee			
09:00 to 10:30		DMDU and energy (transition) I	DMDU and Cities	Emerging fields in DMDU
10:30 to 11:00	Coffee Break			
11:00 to 12:00		DMDU and energy (transition) II	Equity and Justice	Sea level rise I
12:00 to 13:00	Lunch			
13:00 to 14:00		Policy Relevant Uncertainty Analysis in Energy System Modeling: An Expert Panel Debate	DMDU in health applications	Sea level rise II
14:00 to 14:15	Short Break			
14:15 to 15:15	Panel on the DMDU future			
15:15 to 15:30	Closing by Marjolijn Haasnoot and Jan Kwakkel			

Keynotes Orals Expert Panels Thematic Session Discussion Forum
Breaks informal session not used

Overview of talks in sessions

Monday | 11:00 to 12:30 | Patio | back to schedule | to the abstracts

10+ years of adaptation pathways: from theory to practice

11:05	Key risks and illustrative adaptation pathways for Europe	Veruska Muccione
11:18	Innovations in State-Aware Dynamic and Adaptive Infrastructure Pathways and Multi-Actor Robustness Diagnostics	Lillian Lau
11:31	Decision Making Under Uncertainty using DAPP: Lessons from New Zealand	Judy Lawrence
11:44	The values of adaptation pathways for planning under adaptation limits	Saskia Werners
11:57	Dynamic Adaptative Pathways for Crisis Management	Tina Comes
12:10	Climate, COVID, Water and Wine: Pathways for adaptation to multiple stressors	Nick Cradock-Henry

Monday | 12:30 to 13:30 | Patio | back to schedule | to the abstracts

Poster-Session (and Lunch)

12:30	Timely adaptive strategies for fugitive interception: a comparative analysis.	Irene S. van Droffelaar
12:30	Robust Strategies for Disaster Risk Financing in a Changing Climate	June Choi
12:30	Decision-Making Under Deep Uncertainty in Cyber Disaster Preparedness	Ponnoly, Joseph
12:30	Assessing portfolios of Carbon Dioxide Removal options under Deep Uncertainty	Quirina Rodriguez Mendez
12:30	Identifying equitable adaptation pathways at scale: the Baltimore Social-Environmental Collaborative	Antonia Hadjimichael
12:30	Modeling northeast Atlantic marine food webs under future global change scenarios.	Amy Shurety
12:30	Transparency on underlying values is needed for useful equity measurements	Adam Pollack
12:30	Law… What is it good for? Uncertainty something	Alexander Stanley

12:30	Exploring cooperation and coordination mechanisms in regional coastal adaptation planning under uncertainty using an agent based model	Catherine Knox
12:30	Exploring disaster risk management pathways in complex, multi-risk systems using DAPP-MR	Julius Schlumberger
12:30	Poverty and land use transitions in Latin America and the Caribbean	Sara Turner
12:30	Implications of budget policies and other constraints on urban adaptation: The case of extreme heat impacts	Ali Eyni
12:30	Risk Information Contamination from Levees As An Explanation of the Levee Effect	Parin Bhaduri
12:30	Using Multidisciplinary Analysis to Develop Adaptation Options against Extreme Coastal Floods	Xinmeng Shan

Monday | 14:30 to 16:00 | Ganges | back to schedule | to the abstracts

Info-Gap Methods for Planning, Design and Decision under Deep Uncertainty

14:35	Info-Gap or/and Probabilistic Analysis for Robust Long-Term Flood Management	Maria Mavrova-Guirguinova
14:48	Forecasting residential sprawl under uncertainty: An info-gap analysis	Dani Broitman
15:01	An info-gap approach to explore the robustness of Egypt's water supply from the High Aswan Dam	Anna Murgatroyd
15:14	Assessing uncertainty in the natural rate of interest: Info-gap as guide for monetary policy in the euro area	Yakov Ben-Haim
15:27	Cost-effective portfolio allocation across quarantine, surveillance and eradication using info-gap theory	Yang Liu
15:40	Improving watershed adaptability under large uncertainty of climate change: a case study on the conservation of the Japanese freshwater crab (Geothelphusa dehaani) in the Takasaki river watershed, Japan.	Hiroyuki Yokomizo

Monday | 14:30 to 16:00 | Rhone | back to schedule | to the abstracts

Techniques for critical infrastructure assessment: ready for the 21st century in theory in practice?

14:35	Keynote: Experiences and lessons learned from working with infrastructure operators	Thomas Bles
14:48	Tipping points in European road networks due to river floods? A robustness assessment using percolation analysis	Kees van Ginkel

15:01	Exploration of the consequences of climate change and possible adaptation strategies in the Rotterdam-hinterland transport corridor	Anoek de Jonge
15:14	Identifying adaptive pathways by surrogating computationally expensive agent-based models: spatial planning for the technological shift in transportation in Singapore.	Orlando Roman
15:27	Towards a 15-minute city under deep uncertainty	Mikhail Sirenko
15:40	Use of an arche type approach to implement DMDU in data poor and low capacity situations	Thomas Bles

Tuesday | 10:00 to 11:30 | Ganges | back to schedule | to the abstracts

Climate Resilient Development Pathways I

10:05	The state of Climate Resilient Development Pathways In Europe's cities - and pathways forward	Sadie McEvoy
10:21	Long term decisions under deep uncertainty in the Dutch delta – the search for transformative delta management	Lilian van den Aarsen
10:37	Climate resilient development pathways for farmer producer organisations in semiarid India	Arjuna Srinidhi
10:53	Climate resilient development pathways in the Hindu Kush Himalayan region	Edward Sparkes
11:09	Household adaptation to climate hazards: how bounded rationality and behavioral uncertainty produce adaptation deficits	Alessandro Taberna

Tuesday | 10:00 to 11:30 | Patio | back to schedule | to the abstracts

Recent Advances in Robust Decision Making and Its Applications

10:05	Multi-Objective Decision-Making: Understanding the Users' Explainability Needs	Zuzanna Osika
10:21	Value personas-based quantitative decision support: An approach to identifying robust compromise strategies in multi-facetted decision problems	Ingo Schönwandt
10:37	Conservation planning for climate change amid deep uncertainties	Alexis Rutschmann
10:53	Water Governance in the Ganges-Brahmaputra Basin Amid Uncertainty	Nihar Chhatiawala
11:09	Robust Management of the Lower Most Mississippi River	Patrick Kane

Tuesday | 10:00 to 11:30 | Rhone | back to schedule | to the abstracts

Participatory DMDU I

10:05	Towards participatory decision-making under deep uncertainty: benefits and research challenges	Karoline Führer
10:21	Exploring the potential of serious gaming for enhanced DMDU implementation	Ruben Akse
10:37	DMDU Inception: How to get users to undertake DMDU and Robust Decision Making without realising it	Richard Bendall-Jones
10:53	Moving adaptively from models to decision tables	Abel Immaraj
11:09	Towards Democratizing DMDU	Will Mobley

Tuesday | 12:00 to 13:00 | Ganges | back to schedule | to the abstracts

Climate Resilient Development Pathways II

12:05	Societal feasibility of adaptation pathways	Rutger van der Brugge
12:21	Transitioning to a resilience approach to managing environmental water under a variable and changing climate	Avril Horne
12:37	Leveraging DMDU Tools for Redesigning and Transforming Complex Social Systems	Tim McDonald

Tuesday | 12:00 to 13:00 | Patio | back to schedule | to the abstracts

Advances and Applications of Scenario Discovery

12:05	Identifying Decision-Relevant Future Scenarios for Emergent Societal Phenomena	Patrick Steinmann
12:21	Multi-actor, multi-impact scenario discovery of consequential narrative storylines in human-natural systems	Antonia Hadjimichael
12:37	A clustering and instance selection method for interpretable multi-class scenario discovery	Katerina Tang

Tuesday | 12:00 to 13:00 | Rhone | back to schedule | to the abstracts

Participatory DMDU II

12:05	Climate Change and the Nile River Basin: A Cross-cultural Approach to Deep Uncertainty in Environmental Policy Analysis	Arthur Petersen
12:21	Collaborative modeling for the sustainable management of water resources in the face of an uncertain future – The Guayubin Basin Story	Jennifer Olszewski

12:37	Advancing climate neutrality of the Hague City's transport system by DMDU Framework and Participatory Methods	Karoline Führer1

Tuesday | 14:00 to 15:00 | Ganges | back to schedule | to the abstracts

DMDU practice

14:05	Gearing up to govern under deep uncertainty - Comparing government's tools to support policymaking of complex issues in Europe	Elias Kock
14:17	Can We Predict Long-Term Policy Decisions?	Detlef Sprinz
14:29	DMDU Thinking in Practice: Lessons Learned From a Decade of Louisiana's Comprehensive Master Planning Process	Jordan R. Fischbach
14:41	Practitioner perspectives on accommodation and retreat in response to climate change in the Netherlands	Caroline M. Kraan

Tuesday | 14:00 to 15:00 | Rhone | back to schedule | to the abstracts

Exploratory Modelling

14:05	Exploratory modelling of stochastic land use cover change (LUCC) future scenarios for spatial planning	Orlando Roman
14:21	Exploratory modelling to identify patterns of urban vulnerability in Mexico City	Yosune Miquelajauregui
14:37	Automatic Identification of Outlier Ensembles in the Exploration of Uncertain Futures	Amal Sarfraz

Wednesday | 09:00 to 10:30 | Ganges | back to schedule | to the abstracts

DMDU and energy (transition) I

09:05	Robust policies for unconventional oil and gas development in Argentina in a decarbonizing world	Sara Turner
09:21	Canadian Energy Transition Modelling is Increasingly Political – How Deep Uncertainty Might Help	Jason R. Wang
09:37	Using exploratory modeling and scenario discovery methods to identify drivers of decarbonization vulnerability across nations.	James Syme
09:53	DMDU integration in Energy Planning	Matías Paredes-Vergara

Wednesday | 09:00 to 10:30 | Rhone | back to schedule | to the abstracts

DMDU and Cities

09:05	Navigating Change: The Role of Spatial Planning in Adaptation Pathways	Efrén Feliú
09:21	Lessons Learned in Application of DMDU Methods to Urban Planning Projects in the US	Allison DeJong
09:37	Evaluating climate risk reduction strategies within the U.S. housing sector	Nadia A. Seeteram
09:53	Adaptative planning of drainage and rainwater harvesting systems under deep uncertainty	Gabriela Cristina Ribeiro Pacheco

Wednesday | 09:00 to 10:30 | Yangtze | back to schedule | to the abstracts

Emerging fields in DMDU

09:05	Decision-making under deep uncertainty in cyber disaster preparedness.	Ponnoly, Joseph
09:16	A Viability-Based Optimization to aid adaptive forest management under global change	Clémence Labarre
09:27	Improving risk assessment of storms in a changing climate using storylines	Henrique M. D. Goulart
09:38	Exploring task specialization and interdependent tasks in the adaptation of military organizational structures	Yvonne Lont
09:49	Spatial Decision Making Under Deep Uncertainty (Spatial DMDU): Two Case Studies	Nastaran Tebyanian
10:00	DMDU + LLMs: Synergies in construction schedule management	Vahan Hovhannisyan
10:11	Decision making under deep uncertainty and neuroscience: an experimental approach.	Edmundo Molina

Wednesday | 11:00 to 12:00 | Ganges | back to schedule | to the abstracts

DMDU and energy (transition) II

11:05	A large ensemble analysis of multi-sector impacts of NDC-driven energy transitions	Jacob Wessel
11:21	Energy Policy Analysis Towards Clean Energy Transitions in Mexico	Omar Castrejon-Campos

Wednesday | 11:00 to 12:00 | Rhone | back to schedule | to the abstracts

Equity and Justice

11:05	Exploring Normative Uncertainty in IAMs: Unravelling the Sensitivity of Distributional Outcomes to Modelling Assumptions	Palok Biswas
11:21	DMDU and Normative Futures: Clarifying the Frames of Future-Regarding Governance	Aleksi Neuvonen
11:37	Exploring Equity Challenges into Deeply Uncertain Water Supply Investment Pathways: A Case Study in the Federal District of Brazil	Bruna M. Araújo

Wednesday | 11:00 to 12:00 | Yangtze | back to schedule | to the abstracts

Sea level rise I

11:05	Characterizing socio-environmental tipping points in coastal communities facing sea level rise: a conceptual framework to support transdisciplinary research, exploratory modeling, and practical adaptation decision support	Julie Shortridge
11:21	Order up or abandon ship? Exploring critical thresholds for decision making in barrier island management	Patrick Kane
11:37	Enhancing the practice of scenario analysis of large systems in the context of Decision Making Under Deep Uncertainty (DMDU)	Jayantha Obeysekera

Wednesday | 13:00 to 14:00 | Rhone | back to schedule | to the abstracts

DMDU in health applications

13:05	The need for an adaptive decision model to cope with uncertainties in health care	Anke Aarninkhof-Kamphuis
13:21	Resilience assessment and improvement of coupled societal systems against future pandemics	Sophie, Hadjisotiriou
13:37	Robust Decision Making in Health Policy: Applications to COVID-19 and Colorectal Cancer	Pedro Nascimento de Lima

Wednesday | 13:00 to 14:00 | Yangtze | back to schedule | to the abstracts

Sea level rise II

13:05	Should we stay or should we leave? Beach nourishment versus managed retreat under deep uncertainty	Prabhat Hegde
13:21	Coastal Setback Zones as Adaptive Strategy for Reducing Urban Exposure to Sea-Level Rise: A Country-Specific Evaluation under Uncertain Socio-economic Development in Europe	Claudia Wolff

13:37	Navigating Sea-Level Rise Adaptively in the U.S. Gulf Coast: A Local Perspective	Renee Collini

List of Abstracts

Monday

Monday | 09:00 to 09:15 | Patio | *back to schedule*

Welcome to DMDU 2023 by Jan Kwakkel and Marjolijn Haasnoot

Key Note

Jan Kwakkel, Marjolijn Haasnoot

Welcome word to DMDU Annual Meeting 2023

Monday | 09:15 to 10:30 | Patio | *back to schedule*

Keynote by Debra Roberts

Key Note

Debra Roberts

In a world of changes and challenges, the issue of deep uncertainty is an increasingly important consideration in decisions about important sustainable development priorities. The recent assessments by the IPCC provide an opportunity to better understand the concept of deep uncertainty and its relevance to transformative climate action. But to what extent is the concept being useful in the world of practice?

Monday | 11:00 to 12:30 | Ganges | *back to schedule*

Spatial design and design-based approaches in delta management to address uncertainties in developing a long-term strategy

Thematic

Fransje Hooimeijer; Like Bijlsma; Taneha Bacchin; Ellen Tromp

The current practice of delta management such as being applied in The Netherlands and Bangladesh is largely top-down oriented and based on an adaptive water-centric approach. It assumes that we are in control and well prepared to act when needed and that incremental adjustments of our water system would be sufficient (for the time being) to safeguard the delta from a disaster. However, recent discussions reveal that the current delta management assumptions and methods fall short. Climate change is already happening and the window of opportunity for climate-resilient development in deltas (particularly in the Global South) is rapidly narrowing. Large investments in infrastructure have to take place in the coming decades likely requiring a switch from an adaptive planning (incremental) to a planned adaptation (transformational) approach. This calls for envisioning a desired future which is beyond the transition. This notion has led to a renewed attention for (spatial) design both as a method (process of a problem solving and seeking activity) and a product (e.g. maps). Spatial design in this context aims to complement the current, traditional largely model-based approaches by visualizing these desired futures including the spatial translations and consequences from multiple (incl. bottom-up) perspectives which in turn allows to identify

pathways leading to these futures. Application of this methodology in the spatial context of deltas is still in its infancy. The objectives of this session is to share and discuss the current status of design and design based methodologies and practices in delta management and to explore the future needs. The session will be organized by members of the Redesigning Deltas (RDD) program (https://www.redesigningdeltas.org/) coming from TuDelft, Deltares, Convergence, EUR, PBL, WUR and 15 landscape architecture, planning and consultancy offices from The Netherlands. Four presentations will be given followed by a discussion with the audience. These presentations will be delivered by Fransje Hooimeijer (TuDelft), Like Bijlsma (PBL), Taneha Bacchin (TuDelft) and Ellen Tromp (Deltares)

Monday | 11:00 to 12:30 | Patio | back to session overview

10+ years of adaptation pathways: from theory to practice

Talks

11:05 - 11:18 | in person

Key risks and illustrative adaptation pathways for Europe

Veruska Muccione; Marjolijn Haasnoot; Peter Alexander; Birgit Bednar-Friedl; Robbert Biesboek; Elena Georgopoulou; Gonéri Le Cozannet; Daniela Schmidt.

The key risks assessment developed in the context of the IPCC Working Group II AR6 Europe chapter pulled together multiple line of evidence across the published literature and used expert elicitation to identify those risks with the greatest potential to become severe or that are already severe now. More than 50 discrete options were assessed with the greatest majority showing medium effectiveness to reduce future risks. Alongside the assessment of the key risks, an assessment of the effectiveness of discrete adaptation options was also performed following a protocol which defines adaptation effectiveness as the risk reduction potential of an adaptation option from a given baseline. These two assessments have brought forward some critical aspects in adaptation decision making which have inspired further analysis. These aspects include 1) the need for long term planning, 2) the diversity of contexts within which adaptation takes place, 3) the existence of multiple interacting risks and 4) the limited knowledge on the effectiveness of adaptation as opposed to the knowledge on adaptation limits. We explore here the use of warming sensitive adaptation pathways as a framework to address these critical aspects in adaptation and present reflections on how illustrative adaptation pathways can support effective decision making that also reduces the implementation gap. For example, our pathways framework points at a dichotomous future to reduce coastal flooding in the long term and a future where all options will be needed to reduce the risks of water scarcity. The framework also shows that considering multiple risks together under different levels of warming can inform adaptation decision making about potential constraints, trade-offs, and lock-ins. In general, for the illustrative adaptation pathways to be useful planning tools certain preconditions must be in place such as legitimacy through monitoring and evaluation as well as human and financial capital towards multiple and diverse pathways.

11:18 - 11:31 | in person

Innovations in State-Aware Dynamic and Adaptive Infrastructure Pathways and Multi-Actor Robustness Diagnostics

Lillian Lau; Patrick M. Reed; David F. Gold

Since its conceptualization, dynamic adaptive policy pathways has been applied in a wide range of

applications that include coastal flood risk adaptation, regional water infrastructure planning, as well as financial risk management. It has proven to be an effective decision support framework to structure and visualize the implications of adaptation actions across varying timescales. Moving forward, it is important to improve representations of these systems using state-aware actions that unfold dynamically and are contextually adaptive to the specific world being experienced. Pathway actions also should capture how actors' responses in operationally short-term decisions shape major long-term investments. It is also vital to comprehend how management and investments infrastructure pathways differ across plausible deeply uncertain future states-of-the-world. This work reviews recent innovations and diagnostics that have been developed in support of the Deeply Uncertain Pathways (DU Pathways) framework. The DU Pathways framework introduces closed-loop control methods to improve state-aware, dynamic, and adaptive actions across short-and long-term decisions for cooperative water supply infrastructure management and investments. Thus, we show how DU Pathways is better enabled to capture the state-action dependencies for complex multi-actor-systems. We will also discuss the importance of advancing pathway diagnostics methods to understand the effects of deep uncertainties on pathways, as well as to explore the interdependencies between actors and their actions. We use the WaterPaths water supply portfolio management and infrastructure investment planning platform to demonstrate the innovations discussed above.

11:31 - 11:44 | in person

Decision Making Under Uncertainty using DAPP: Lessons from New Zealand

Judy Lawrence; Andrew Allison; Geoff Williams

Climate change impacts are intensifying globally. New Zealand is no exception. Atmospheric rivers are flowing across this island nation, seas are rising at pace due to warming of the ocean and vertical land movement at the plate margins exacerbating the impacts. At the same time human exposure is intensifying as a result of planning and housing policies that create increased demand on water supply, wastewater and stormwater services at the same time as the climate is worsening. Furthermore, uncertainties for decision makers are compounding as risk appetites change amongst the population while levels of service reduce due to climate stressors affecting yield from coastal aquifer systems. While we can project sea-levels with some certainty to mid-century, projections diverge after that and along with pluvial and fluvial rainfall are highly uncertain. Human coping thresholds are being surpassed with successive pluvial events such as in our largest city, Auckland and rural areas of our east coast of the North Island. Auckland floods were: 0.5% AEP (1-in-220 year event), 265mm in 24-hours, 299.5 in 30 hours, of which 211mm fell in under six hours. And closely followed by Cyclone Gabrielle with 450mm over 3 days, up to 40mm/hour. The risk trigger has resulted in the Government announcing a retreat policy to remove people and livelihoods from harms way in the worst affected areas. Does having a dynamic adaptive plan decrease climate risk? Can such a plan address ongoing progressive climate change impacts at the same time as successive extreme events at the coast and on flood plains? How does land use interact with an adaptive plan? What does this mean for the levels of service water supply, wastewater and flood management agencies to communities? These are questions we are asking after 10 years of DAPP in practice. Lessons learned from DAPP applications are presented to inform the answers to the questions we are now confronted with and where we go from here.

11:44 - 11:57 | in person

The values of adaptation pathways for planning under adaptation limits

Saskia Werners; Edward Sparkes; Edmond Totin; James Butler; Russell Wise; Katharine Vincent; Anna Taylor; Nadine Methner; Hallie Eakin; Lisa Schipper; Chandni Singh

To consider uncertainty and embed flexibility in adaptation planning, practitioners and scholars advanced “adaptation pathways”. Adaptation pathways are forward looking approaches that comprise sequences of possible actions that can be implemented over time, depending on future dynamics. The concept was introduced into adaptation planning a decade ago, which means we can reflect on the lessons learned and look ahead to new challenges for adaptation planning. In particular, with the publication of the IPCC Sixth Assessment Report and recent climatic extreme events around the world, it has become evident that adaptation is constrained by soft and hard limits, which restrict the space in which pathways can be developed and raise questions about the feasibility and scope of transformative adaptation. This presentation discusses how adaptation pathways can be designed and implemented in contexts experiencing severe climate impacts. More specifically, it will explore the conditions and mechanisms for integration of transformational change, adaptation limits and systemic resilience into pathways in different contexts. Learning about the pre-conditions, challenges, and opportunities for developing pathways in the context of large scale change and in the presence of adaptation limits is relevant for policy and practice as we prepare to reduce the risks of future climate change at different scales. The presentation builds on a selection of pathways projects of the authors aims to advance with DMDU members: (i) lessons of pathways approaches for dealing with adaptation limits, and (ii) how co-creation of pathways with stakeholders can build capacity for transformative adaptation under climate constrained conditions.

11:57 - 12:10 | in person

Dynamic Adaptative Pathways for Crisis Management

Tina Comes; Mariken Gaanderse; Karen Meijer; Bouke Ottow; Andrew Warren

Decision- and policy-makers worldwide are grappling with a multitude of crises, ranging from geopolitical conflict and resulting economic crises and inflation to an increasing frequency of climate disasters and the repercussions of the Covid-19 pandemic. Despite the urgency to (re-)act to crises, the consequences of strategic crisis decisions create path-dependencies that reach far into the future. However, currently there is a lack of methods to allow decision-makers to explore the strategic implications of their choices in the volatile and rapidly changing context of crisis response. In this presentation, we explore the application of Dynamic Adaptive Policy Pathways (DAPP) as a method for crisis decision-making. DAPP is designed to support decision-makers in planning for adjusting to different future scenarios. However, DAPP is not designed for the urgent and value-laden context of crises. To explore how DAPP can be applied in crises, we first provide a taxonomy of different crises decisions, and related uncertainties and decision-making constraints and requirements. Then, we map the traditional DAPP approach onto crisis decisions, and explore the application of DAPP by two contrasting case studies representing different levels of decision-making. Simavi is an NGO that focuses on equality for women and girls, and applied DAPP for a water, sanitation and hygiene programme in the response to Covid in Kenya and Uganda. PARTOS is the Dutch membership body for organisations working in international development, bringing together more than 100 organisations. PARTOS used DAPP for strategy development. This exploratory multi-case study set-up allows us to highlight how the specific requirements in each case influenced the methodology and surrounding decision-making process. We then discuss the methodological implications, and implications for practice and research.

12:10 - 12:23 | remote

Climate, COVID, Water and Wine: Pathways for adaptation to multiple stressors

Nick Cradock-Henry; Justin Connolly; Joanna Fountain; Amber Parker

Primary industries must adapt to multiple interacting and compounding pressures. Wine and viticulture is exposed and sensitive to changes in climate, the flow on implications for water resources, emerging pests and disease, as well as the impacts and implications arising from other, unexpected, or unrelated risks, including the recent COVID-19 pandemic. This is particularly significant for New Zealand, where wine and grape growing are among the nation's most rapidly expanding primary industries. As such, the wine industry has urgent adaptation needs that have not yet been addressed. Focussing on the flagship Marlborough Region, we present findings from a multi-disciplinary project exploring the combined effects of climate change and changing water availability, and what's required to secure future sustainability. Working with industry stakeholders, land managers, local government and others, the team is developing a sector-specific pathway to identify emerging risks, realise opportunities and effectively manage for multiple outcomes in light of changing water availability and demand. Workshops, interviews, and group-model building provide the basis for defining, and characterising system boundaries, and the dynamics of water use in a changing climate. Results from the participatory process, reveal the presence of interacting risks associated with changing availability, competing pressure from 'pest' pine trees in upper catchments, constrained labour supply, and increasing urban demand. The resulting adaptation pathway provides a framework to support decision making within the broader context of changing social license, freshwater reform, and recent flood events. Results show the group-based approach helped produce a robust and flexible framework. The presence of multiple stakeholders, diverse values, and emerging rules governing the allocation of freshwater resources, highlight the significance of multiple interactions and feedbacks across domains of interest, and the implications for management.

Monday | 11:00 to 12:30 | Rhone | back to schedule

Climate Risk Informed Decision Analysis - experiences and developments

Thematic

John Kucharski; Umit Taner; Koen Verbist; Sadie McEvoy; Patrick Ray; Ad Jeuken

Climate Risk Informed Decision Analysis (CRIDA) is a methodology for planning under deep uncertainty. It combines earlier work on stress testing and development of adaptation pathways into a comprehensive approach for making implementable plans. It is supported by a growing number of institutions and applications, many of which have been carried out in the global south. Like with many other DMDU approaches, technical complexity and lack of accessibility is, to some extent, hampering use at scale beyond the usual suspects. That is why under lead of UNESCO's international hydrology program, much effort is put into improving access through training programs, webinars and pilot projects and by mainstreaming with existing frequently used software packages. In addition, societal requirements for supporting adaptation decision making are changing. There is an increasing need to pay attention to never seen before extreme events and their, often cascading, impacts. The call for more nature-based solutions forces us to improve the assessments on its effectivity and co-benefits. And existing economic evaluation models more and more restrict us to make long term sustainable choices, so alternative models are needed. In this hybrid yet

interactive session, we will share experiences and new ideas around these common challenges based on recent projects. We invite the audience to reflect and share their experiences and come up with recommendations that could increase relevance and impact at scale. The session follows a simple agenda of a provocative introduction on a topic followed by a moderated discussion with the audience: · A short introduction to the CRIDA methodology and paths for its ongoing development (Koen Verbist, UNESCO-IHP, 10 mins). · Topic: (1) Economic evaluation of climate adaptation plans (John Kucharski, USACE, 10 min) Ø Moderated discussion, 15 min · Topic (2) Planning for extremes: options for stress-testing tools and methods. (Ümit Taner, Deltares, 10 mins). Ø Moderated discussion, 15 min · Topic (3) Assessment of NbS under climate uncertainty (Patrick Ray, Univ. of Cincinnati, 10 min) Ø Moderated discussion, 15 min · Summary and closure (5 min)

Monday | 12:30 to 13:30 | Patio | back to session overview

Poster-Session (and Lunch)

Other

12:30 - 13:30 | in person

Timely adaptive strategies for fugitive interception: a comparative analysis.

Irene S. van Droffelaar; Jan H. Kwakkel; Jelte P. Mense; Alexander Verbraeck

The fugitive interception problem asks, 'What is the optimal set of routes for a fleet of police units to traverse in order to maximize the probability of intercepting a fleeing fugitive?' Models can be used to support the decision as long as the optimal solution is calculated in near-real-time. The unpredictability of the fugitive and not knowing if, where, and when a sensor detects the fugitive introduce deep uncertainty to the problem. Moreover, there is clear path dependency: sending police units in a certain direction constrains their possible rerouting in the future. There is a trade-off between the flexibility to react to new information and the timeliness of decisions. Traditional stochastic optimization methods used for solving the fugitive interception do not account for either the deep uncertainty or the path dependency. On the other hand, there is a longstanding tradition of adaptive decision-making under uncertainty, developed for long-term planning problems, with ample time for analysis and intermediate input from decision makers. Two of these approaches are Policy Tree Optimization and Direct Policy Search. Policy tree optimization applies heuristic methods to find optimal actions based on short-term and long-term information. The method yields a binary tree that delineates under what conditions (i.e., sensor input) what actions should be taken. Direct Policy Search optimizes a policy that maps the state of the system (SOWs) to control actions. In fugitive interception, the system's state is a vector of sensors and whether (and when) they have detected the fugitive. This study evaluates the performance of policy tree optimization and direct policy search on a stylized fugitive interception problem.

12:30 - 13:30 | in person

Robust Strategies for Disaster Risk Financing in a Changing Climate

June Choi; Sarah Fletcher; Noah Diffenbaugh

Evolving disaster risks due to climate change pose a significant challenge for decision-makers who need to establish disaster financing strategies that balance multiple objectives. The most extreme, high-impact disasters and associated damages are characterized by deep uncertainty. Failure to sufficiently cover disaster damages can carry significant financial consequences such as triggering sovereign default, impacting economic growth, poverty, and wellbeing. A range of

financial instruments are available, but guidance on how to effectively combine and structure them under conditions of increasing climate change uncertainty is lacking. This proposal outlines a novel approach for applying Robust Decision-Making to the field of disaster risk finance. An interdisciplinary decision-support tool will be developed to identify robust financing strategies under a changing climate and assess vulnerability scenarios that impact the performance of identified robust strategies. Potential case studies for Caribbean island states will be presented.

12:30 - 13:30 | in person

Decision-Making Under Deep Uncertainty in Cyber Disaster Preparedness

Ponnoly, Joseph; Puthenveetil, John; D'Urso, Patricia

In a hyper connected world, cyber threat is a global threat now escalating into the realm of cyber warfare. Cyber disasters such as Colonial Pipeline attacks or Solar Winds Hack of 2021 were nation-state attacks that targeted US critical infrastructures and the information technology ecosystem. These attacks were surprise attacks that had a devastating impact. Though they indicated systemic failures, they were mainly caused by decision-making failures. Decision-making under deep uncertainty in a volatile, uncertain, complex, and ambiguous world involved dealing with the unknown unknowns, the black swans, and dragons. Against these unknown unknown threats and risks, decision-making required decision-makers to foresee disaster events and to take measures to reduce the risk and potential adverse impact. Decision-making needed to consider the complexity of the interconnected systems. It involved sensing and sensemaking of the early warning signs of cyber disasters. A qualitative descriptive study of the phenomenon explored a proactive approach to cyber disasters, focusing on the influence of knowledge-based strategies for sensing and sensemaking of the early warning signs of cyber disasters. Decision theory (prospect theory) and complexity theory (complex adaptive systems) underpinned the study. The research questions focused on identifying factors contributing to decision-making failures and systemic failures in detecting the warning signs of cyber disasters. The findings were critical challenges and knowledge enablers to sensing and sensemaking of the warning signs. The conclusions support a new framework for proactive cyber disaster preparedness strategy and cyber early warning systems.

12:30 - 13:30 | in person

Assessing portfolios of Carbon Dioxide Removal options under Deep Uncertainty

Quirina Rodriguez Mendez; Sabine Fuss; Felix Creutzig

In the light of a dwindling carbon budget, meeting Paris climate goals increasingly relies on removing carbon from the atmosphere. So far, CDR technologies and practices have been explored mostly in the form of either technology-specific studies or Integrated Assessment Modelling. It has also been shown, however, that none of these options is a silver bullet and that all of them come with their specific advantages, but also risks, especially when scaled to levels of multiple Gigaton removals per year. It is therefore more likely that removals will be realized through a mix of CDR options, which enable the removal of sufficient amounts of CO2 to keep concentrations in check while minimizing the associated risks, which could also interact. In this work, we present a portfolio approach, as common in finance, to assess the optimality and feasibility of CDR pathways seeking to account for deep uncertainty, deployment dynamics and path dependencies. This allows to unveil further risks and benefits of certain dynamics, e.g. of lock-ins, the consequences of which are not yet well understood, or learning effects, which can reduce costs.

12:30 - 13:30 | in person

Identifying equitable adaptation pathways at scale: the Baltimore Social-Environmental Collaborative

Antonia Hadjimichael; Michael Bader; Benjamin Hobbs; Robert Nicholas; Hong Wu; Benjamin Zaitchik

The Baltimore Social-Environmental Collaborative (BSEC) came together based on the understanding that equitable solutions to the climate crisis are a product of knowledge co-creation. Building on decades of experience within the city of Baltimore, BSEC brings together observation systems and modeling capabilities to inform the design of equitable adaptation pathways across city scales. Central to this design is to define the space of possible actions, uncertainties, and relevant metrics in collaboration with stakeholder communities, as well as to establish mechanisms and processes of iterative framing with said communities. Using these principles, BSEC is: (1) placing environmental justice at the center observation-modeling-design processes; (2) adopting a participatory, multi-objective robust decision making framework to identify just and sustainable pathways under climate change; (3) addressing the complexities of the built environment, including indoor-outdoor environmental interactions, to connect the residents' lived experience; and (4) recognizing that a city is a coupled human-natural system in which human well-being and ecosystem processes are intertwined. In this talk we will be presenting and discussing our efforts in coordinating the application of the multi-objective robust decision-making framework in a large-scale participatory mode: through interactions with stakeholders at different decision-making scales (city level, utilities, neighborhood associations), as well as across different adaptation issues Baltimore is facing (heat stress, flooding and water quality, indoor and outdoor air quality, and greenhouse gas emissions).

12:30 - 13:30 | in person

Modeling northeast Atlantic marine food webs under future global change scenarios.

Amy Shurety; Elena Couce; Murray Thompson; Thomas Cameron; Eoin O'Gorman

Climate driven sea surface warming and commercial fishing are prominent contributors to global change and can cause gradients in numerous biotic and abiotic variables, all of which can alter food web dynamics. The aim of this project is to predict future northeast Atlantic marine food webs based on allometric foraging behaviour and knowledge of how sea surface warming and commercial fishing pressures have historically altered food web dynamics. For example, the prey size range of a consumer is found to significantly increase with sea surface temperature and commercial fishing within the northeast Atlantic. The project makes use of a novel data set spanning from 1950 – 2022 across the northeast Atlantic to empirically parametrise food web models, namely the Allometric Diet Breadth Model, that can forecast food web structure based on future global change scenarios. A suite of ecological metrics were calculated from the food web models, which due to their systemic nature can be used to infer ecological resilience across multiple scales. The results show clear fluctuation in food web properties and consequent ecological resilience, helping to highlight vulnerable systems, communities, and species across the northeast Atlantic. Furthermore, a main goal of the project is to develop a robust modeling framework that has the potential to provide the scientific advice needed for sustainable fisheries and climate change management to be effective despite the uncertainty of global change.

12:30 - 13:30 | in person

Transparency on underlying values is needed for useful equity measurements

Adam Pollack; Casey Helgeson; Carolyn Kousky; Klaus Keller

Decision-makers increasingly invoke equity to motivate, design, implement, and evaluate strategies for managing flood risks. But there is no objective definition of equity. This pluralistic setting calls for transparency about underlying values, but this practice is uncommon. Here, we review how equity is measured by surveying peer-reviewed publications that explicitly state an interest in equity in the context of flood-risk management. We develop a simple taxonomy for how transparent measurements can be defined. We map reviewed measurements to this taxonomy. Finally, we offer guidance on how the pursuit of a clear and consistent quantitative evidence base about equity can become more widespread in flood-risk research and beyond.

12:30 - 13:30 | in person

Law… What is it good for? Uncertainty something

Alexander Stanley

Climate decision-making is heating up, even though climate futures remain as deeply uncertain as ever. Public law decision-making processes, including environmental, infrastructure, urban planning and other administrative approvals, will substantially determine how societies respond to climate change. Yet as such collective climate decision-making proliferates, enabling laws should arguably also reflect new insights from cognitive and behavioural science about how individual decision-makers act under deep uncertainty. In seeking to harmonise these societal and individual responses to climate change, academic attention has focussed increasingly on narratives and scenarios as social coordination devices. These techniques form an essential qualitative part of most decision-making under deep uncertainty (DMDU) approaches. Yet despite the potential of DMDU approaches in climate decision-making (Constantino and Weber 2021), such decision tools remain remarkably underutilised in practice (Siders and Pierce 2021). This suggests a missing link between DMDU and public law theory. Here I seek to bridge that gap and ask: what is a plausible legal basis for the use of DMDU approaches in climate decision-making? Guided by the socially coordinating functions of law (Hoff and Walsh 2021), this paper brings together insights from cognitive science, DMDU and risk management with public law. It aims to lay the groundwork in legal theory for the broader use of DMDU approaches. In this context, what is law good for? Far from absolutely nothing, it argues that law could be a powerful tool for improving climate decision-making in the face of deeply uncertain climate futures.

12:30 - 13:30 | in person

Exploring cooperation and coordination mechanisms in regional coastal adaptation planning under uncertainty using an agent based model

Catherine Knox; Paul Kirshen; Jonathan Lamontagne; Shafiqul Islam

Despite the increase in tidal and storm surge flood occurrences expected in Boston Harbor due to projected sea level rise, there is a lack of governance to coordinate regional adaptations to these conditions. The absence of effective governance mechanisms has led to individualized efforts by cities, towns, developers, and private companies to adapt. This fragmented approach increases

the likelihood of cost-inefficiency, social inequity in adaptation, and environmental damage. To address these challenges, we employ an Agent-Based Model (ABM) to investigate how coastal adaptations may evolve under different scenarios of sea level rise and cooperation levels: no cooperation, voluntary cooperation, and cooperation mandated by a regional flood adaptation authority. ABM allows us to capture details of the complex system and emergent patterns of adaptations, as agents react to a stochastically generated future of sea level rise. By including heterogeneous agents representing key stakeholders with differing adaptation decision-making processes, we will be able to capture adaptation implementation across agent types and geographic area. The use of ABMs enables us to capture the diverse decision-making processes of agents, facilitating the identification of effective and robust recommendations for different types and levels of cooperation. By incorporating scenarios for sea level rise and cooperation processes, our model aims to show how agents navigate uncertainties in sea level rise predictions and the actions of affected stakeholders. Through this process, this model will demonstrate how and why a regional authority for collaborative adaptation may enhance cost efficiency and equity in coastal flood adaptation.

12:30 - 13:30 | in person

Exploring disaster risk management pathways in complex, multi-risk systems using DAPP-MR

Julius Schlumberger; Marjolijn Haasnoot; Jeroen Aerts; Marleen de Ruiter

Climate change and socioeconomic developments are driving complex/compound/multi-risks from natural hazards and thus determine the effectiveness and efficiency for adaptation strategies. With DAPP-MR (Dynamic Adaptive Policy Pathways for Multi-Risk), an approach to apply a decision-focused lens, and a longer-term planning perspective in multi-risk systems has been recently developed (Schlumberger et al., 2022). DAPP-MR guides the exploration of disaster risk management pathways under uncertainty while explicitly accounting for trade-offs and synergies of policy measures across (interconnected) sectors, hazards, and time. As a result, DAPP-MR guides the identification of system-integrated strategies that are not only flexible, robust, and preferable for individual risk owners but also maximize synergies across all its sub-systems. This poster shows results from a study testing DAPP-MR by exploring multi-risk adaptation pathways in a case study (Schlumberger et al., 2023 in prep). We developed and used a stylized multi-risk case study referred to as Waas-MR which is building on an existing one that is loosely related to the river Waal in the Netherlands. The existing version of the Waas case study has been used for testing water management strategies in a riverine area prone to fluvial flooding, and droughts under long term climate scenarios (Jafino et al., 2019; Haasnoot et al., 2013; Kwakkel et al., 2015). The case study is implemented in a model-based approach. A model-based evaluation allows the quantitative development and analysis of trade-offs and synergies of measures and exploration of their effects under a wide range of potential uncertainties. The utility of DAPP-MR was investigated with regards to two main characteristics of the approach: i) the analytical framework and guiding questions provided as part of the DAPP-MR framework to characterize the Waas case study as a multi-risk system by accounting for (a)synergies of measures (de Ruiter et al. 2020), multi-hazard interactions, dynamic vulnerability and impact interactions and ii) the staged approach to gradually increase and manage complexity of the analysis. For the latter, it was investigated (1) how the staged DAPP-MR approach may lead to similar or divergent sets of preferred pathways compared to exploring pathways directly in the full complex system, and (2) to assess what different approaches and metrics are required to evaluate adaptation pathways in an increasingly multi-objective environment. The capacity to capture and account for increasing complexity and dynamics comprehensively is a widely recog-

nized challenge for local, regional, national, and international decision-making processes in public and private governance. Building on methods of adaptation pathways, this research addresses this well-known knowledge gap in system analysis and collaborative policy-analysis approaches.

12:30 - 13:30 | remote

Poverty and land use transitions in Latin America and the Caribbean

Sara Turner; Nancy Lozano Gracia; Alejandro del la Fuente; Peter Hawthorne

The Agriculture, Forestry and Other Land Use (AFOLU) sector is the largest emitter of GHGs in Latin American and Caribbean countries as it accounts for 40 percent of the region's total emissions, almost double the global average. The main contributors to AFOLU emissions are deforestation and land-use change, which, in addition to CO2, release nitrous oxide (N2O) and methane (CH4) emissions. As forested lands act as a natural carbon sink, they create the possibility of removing carbon dioxide emissions generated by other sectors and regions. However, the economies of some countries and regions depend heavily on natural capital and land-use-intensive activities, including agriculture, extensive cattle raising and forestry. Changes to land use patterns to mitigate the impacts of climate change could have a sizeable effect on these countries, as they would need to curb deforestation or regulate the use of their existing forest area. This transition will generate both benefits and costs that will disproportionately affect communities that depend on land-use-intensive subsistence activities, particularly in rural areas. Rural areas have a larger share of the population living in poverty than rural areas in Latin America (46% of the population as compared to 27% in urban areas). This paper analyzes these relationships using exploratory analysis and microsimulation modelling within a robust decision making framework to explore uncertainties and drivers of impacts of land use change in Latin America and the Caribbean. Future scenarios on land use transitions and costs will be combined with subnational poverty data to identify and characterize hotspots where the economic effects of land use transitions overlap with poverty in the region. This analysis will be augmented by a case study that will develop a microsimulation model to explore the impact of transition costs and changing patterns of agricultural income on subnational poverty over time and consider uncertainties in those impacts. Finally, the analysis will assess potential policy measures to mitigate these impacts.

12:30 - 13:30 | in person

Implications of budget policies and other constraints on urban adaptation: The case of extreme heat impacts

Ali Eyni; Benjamin Zaitchik; Rui Shi; Ben Hobbs

The rise in global temperature and the subsequent rise in the number of days with extreme heat conditions can increase the number of heat-related mortalities. The implications of these changes can be even more accentuated in the cities due to the Urban Heat Island (UHI) phenomenon. To alleviate the effects, city planners can present future adaptive actions. These actions can include increasing tree cover, cool roofs, cool pavements and so on. However, presenting an adaptation plan for the future can be a difficult task due to the number of uncertainties and unknowns in the system. These uncertainties can include but are not limited to: impacts of adaptive actions on temperature, the relationship between temperature and mortality in different groups, and future climate conditions. This study evaluates the implications of financial policies and constraints on urban adaptation under these uncertainties. We use the City-Heat Equity Adaptation Tool (City-HEAT) to find the optimized adaptation pathways for different future time scales while focusing on

reasonable city expenditure using different constraints on the pathways. The framework uses the Borg Optimization model and includes more than 3000 scenarios based on the uncertainties that are present in the system. The application of the framework is evaluated for the city of Baltimore in USA.

12:30 - 13:30 | in person

Risk Information Contamination from Levees As An Explanation of the Levee Effect

Parin Bhaduri; Jim Yoon; Heng Wan; Pranab Chowdhury; Brent Daniel; David Judi; Vivek Srikrishnan

Climate change increases the risk of flooding in coastal environments. A standard approach to reducing flood hazards is by building physical infrastructure such as levees. However, questions remain about whether levee protection standards are robust to deep uncertainties. For example, typical planning practices often neglect important human-behavioral responses to built infrastructure, such as the so-called “levee effect,” in which individuals are more likely to move into or invest in a floodplain after the construction of a levee. While the levee effect has been observed in the past, there is no clear consensus about the mechanisms or conditions that would cause such a behavioral response to arise. We demonstrate with a didactic agent-based model that the levee effect can result from the censoring of flood risk information by the levee. The levee filters decision-relevant information by eliminating nuisance flood events and reducing the impact of events which overtop the levee. This information-filtering effect shifts risk from smaller, higher-frequency events to rare, extreme flood events, as residents are unable to learn about underlying risk from less damaging nuisance flooding events, resulting in a reduced efficacy of levees for moderately extreme flood events. Moreover, we identify a range of thresholds where levees can increase exposure to floods. Multiple sources of uncertainty are present under this framework that affect model evolution and output. We conduct a sensitivity analysis of the threshold of this risk-shifting outcome to changes in structural and population dynamics. Finally, we look at the potential for alternative portfolios of flood mitigation approaches, including levees as well as household-scale exposure-reducing measures, to reduce risk-shifting by limiting the information-censoring effect.

12:30 - 13:30 | in person

Using Multidisciplinary Analysis to Develop Adaptation Options against Extreme Coastal Floods

Xinmeng Shan; Jun Wang; Jiahong Wen; Hengzhi Hu; Jie Yin; Mengya Li

Long-term flood risk adaptation and decision making are complex because the future is full of deep uncertainties. Flexibility and robustness can be used to deal with future uncertainty. This study developed an integrated modeling framework that extends previous studies to the spatial domain to assess the future flood risks and the cost and benefit of three adaptation measures for four types of buildings in Shanghai. Cost-benefit analysis (CBA) and dynamic adaptive policy pathways (DAPP) were integrated to develop a dynamic adaptation pathway and identify robust adaptation options. The results show that: (1) Sea level rise and land subsidence will significantly exacerbate the flood risks in Shanghai; (2) Among the three flood control measures, wet-floodproofing has the best economic performance in terms of both the net present value and the benefit/cost ratio, followed by dry-floodproofing, and elevation; (3) Dryfloodproofing can be used at the beginning of the future period (2030–2100), and it can be replaced by wet-flood proofing in 2035–2042; the elevation measure also shows good performance at the beginning of implementation, but its

performance will decline after 2041–2045; (4) The combined strategy of dry- and wet-floodproofing in 2044–2046 and a hybrid strategy combining the three measures should be the optimal solution for reducing the flood risks in 2047–2051. The methodology developed in this study can provide insights for coastal cities to formulate cost-effective and feasible adaptation strategies in a deeply uncertain future.

Monday | 13:30 to 14:15 | Patio | back to schedule

Keynote by Peter Glas

Key Note

Peter Glas

Uncertainties must of course be taken into account in decision-making about climate adaptation, but this comes at a price. That price largely consists of the risk of delays in the implementation of adaptation strategies, with all its possible consequences. This presentation focuses on three emerging sources of uncertainty. They follow from increasing ambitions for the development of adaptation strategies that: (i) Are consistent across spatial scales, (ii) Are integral, (iii) include extra long-term planning horizons The question that Delta Programme Commissioner Peter Glas, as a decision maker, puts on the table for the researchers united in the DMDU network is twofold. The first part reads: “Under what circumstances does the height of that price justify deviating from the ‘ideal approach’ in which all known uncertainties should be regarded as given and should therefore be taken into account in decision-making processes?”. The second part follows logically: “In what rational and responsible way can uncertainties, or the probability that they delay implementation, be reduced?”

Monday | 14:30 to 16:00 | Ganges | back to session overview

Info-Gap Methods for Planning, Design and Decision under Deep Uncertainty

Talks

14:35 - 14:48 | in person

Info-Gap or/and Probabilistic Analysis for Robust Long-Term Flood Management

Maria Mavrova-Guirguinova

Decision making for flood risk management involves comparing options based on their benefits and costs. These choices always involve considerable uncertainties, especially when long-term projections are being developed, taking climate change into account. The aim of the study is to reveal what is the uncertainty robustness of alternative flood defense measures. The treatment of different sources of uncertainty is carried out by using probabilistic analysis of net present value (NPV) as well as using information gap decision theory (IGDT). The case study is a settlement in north Bulgaria with a record of severe flooding in the past, for which divergent climate change projections have been generated under the RCP 4.5 and RCP 8.5 scenarios. The behavior of three civil defense options under these uncertainty conditions is explored over an extended 30-year time horizon up to 2050. A probabilistic analysis of efficiency with NPV performance criterion and then an info-gap decision theory analysis are performed sequentially. After discussing the results, the advantages and disadvantages of the two methods are compared. Some limitations and strengths of info-gap theory are discussed. In conclusion, it is stressed that when making decisions about flood protection in the long term, it is advisable to use multiple methods that differ in data and assumptions, necessarily taking into account hydrological uncertainty arising from climate change

that can dramatically change our choices.

14:48 - 15:01 | in person

Forecasting residential sprawl under uncertainty: An info-gap analysis

Dani Broitman; Yakov Ben-Haim

Spatial planning defines objectives for spatial ordering of a region, together with instruments required to realize them. However, since the future is uncertain, many factors involved in spatial planning are unknown in advance. Scenario-based forecasting is a common way to deal with this fundamental uncertainty. This prospective approach offers guidance to decision makers regarding problems that are likely to appear in the future, and possible ways to manage them in advance. The performance of the forecasting can be assessed in retrospect once the future arrives. However, a method for assessing past management of uncertainty is lacking. This is important because learning from past performance under uncertainty can provide useful insights for the future. These insights can help to design future scenario-based forecasts that are more accurate, and more robust to uncertainty. This presentation develops a methodology to combine retrospective analyses focused on past performance with prospective scenario-based forecasting. We use info-gap decision theory to model and manage uncertainty in scenario-based forecasting assessing efforts to contain residential sprawl in the Netherlands. The suggested approach informs prospective scenario-based forecasting, learning from previous experiences regarding their performance and their management of uncertainty and robustness.

15:01 - 15:14 | in person

An info-gap approach to explore the robustness of Egypt's water supply from the High Aswan Dam

Anna Murgatroyd; Jim Hall; Yakov Ben Haim

For the session Info-Gap Methods for Planning, Design and Decision under Deep Uncertainty, organized by Dani Broitman and Yakov Ben-Haim. Motivation: With a total storage volume of 162 billion cubic meters (bcm) and regular annual releases of roughly 55.5 bcm/year, the High Aswan Dam (HAD) is a critical water source to Egypt's agricultural, municipal and industrial sectors. The time-varying supply of water from the HAD reservoir depends on climate conditions in the Nile Basin and water use in upstream riparian nations, both of which cannot be predicted with certainty. Whilst we can use empirical estimates to estimate the probability density function (PDF) of HAD supply, we don't know by how much the true PDF of water supply deviates from the estimated PDF, or how it may change into the future. In light of these deep uncertainties, we present an info-gap approach to explore the robustness of HAD water supplies (Ben-Haim, 2006; 2010; 2018). Methodology: Our estimation of water supply from the HAD is contingent on three functions: inflows to the HAD, the volume of water in the HAD, and discharge from the HAD downstream (which itself depends on the HAD volume). These three functions are info-gap uncertain. We define the PDF of HAD inflows, based on a combined CDF of a logistic and extreme value distribution which are fitted to two datasets that sample the bulk and extreme low-flows into the HAD reservoir, respectively. Our info-gap model of uncertainty simulates deviations of the best available estimates of parameters of the bulk and tail distributions of flows, and consequent effect on the HAD reservoir volume, across a dimensionless horizon of uncertainty. We evaluate the performance of various HAD discharge policies with respect to their robustness to the info-gap model of uncertainty. The robustness of a policy is the greatest horizon of uncertainty up to which a probabilistic HAD volume requirement

is satisfied for any realization of the uncertain entities. Results: Results reveal distinct trade-offs between robustness of supply and the probabilistic performance requirement under different discharge policies. For all policies, supply becomes less robust as we demand better outcomes of the system. The system is predicted to be robust to a large horizon of supply uncertainties when the annual water demand is low. For low water demands the cost of robustness is low, meaning that robustness can be improved greatly with little adjustments to the probability of satisfying the probabilistic HAD volume requirement. Higher demands exhibit a higher robustness cost. Importantly, the results quantify by how much we can augment robustness by reducing the probability of satisfying the volume requirement. Conclusion: We demonstrate a method to quantitatively assess the robustness of a dynamic water supply system to deep Knightian uncertainties. The proposed method holds value in both future infrastructure planning and water resource management, whilst also demonstrating a novel use case for DMDU thinking. References Ben-Haim, Yakov, 2006, Info-Gap Decision Theory: Decisions Under Severe Uncertainty, 2nd edition, Academic Press. Ben-Haim, Yakov, 2010, Info-Gap Economics: An Operational Introduction, Palgrave-Macmillan. Ben-Haim, Yakov, 2018, Dilemmas of Wonderland: Decisions in the Age of Innovation, Oxford University Press.

15:14 - 15:27 | in person

Assessing uncertainty in the natural rate of interest: Info-gap as guide for monetary policy in the euro area

Yakov Ben-Haim; Jan Willem van den End

In this paper, we assume that the natural rate of interest is fundamentally uncertain. Based on a small-scale macroeconomic model, info-gap theory is used to rank different monetary policy strategies in terms of their robustness against this uncertainty. Applied to the euro area, we find that an inert or patient monetary strategy is more robust to natural rate uncertainty than a strategy that follows an estimated Taylor rule. An actively responsive monetary strategy is least robust. Our analysis presents a methodology that is applicable in a wide range of policy analyses under deep uncertainty.

15:27 - 15:40 | in person

Cost-effective portfolio allocation across quarantine, surveillance and eradication using info-gap theory

Yang Liu; Melissa L. Thomas; Grey T. Coupland; Penghao Wang; Dan Zheng; Simon J. McKirdy

Invasive species, and the ecological systems they invade, are highly complex and variable. Uncertainties need to be considered in bio-economic modelling to assist in decision making and evaluate the robustness of policy designed. In our research, info-gap decision theory (IGDT) is applied to model and manage such uncertainty. Such robust decision-making methods are often desirable in ecological systems characterized by Knightian uncertainty. This research provides a novel method for applying IGDT to determine the robust population threshold estimate and robust portfolio allocation of limited budget in a biosecurity context, in particular the cost of pre-border prevention versus post-border surveillance and eradication. We use the risk of incursion of the Asian house gecko onto Barrow Island (Western Australia) as a case study. Our work provides guidance for decision makers to balance the robustness against parameter estimate errors and specific total budget limit (the maximum total budget that decision makers may allocate to all three biosecurity activities). We demonstrate that, allocating budget to both quarantine and surveillance results in a more robust option, irrespective of the risk of incursion. Increasing investment in either

quarantine or surveillance increases the annual budget, but also decreases the total budget limit. Budget allocated to quarantine should outweigh that to surveillance. A higher estimated population threshold for post-border surveillance detection could increase robustness against unacceptable total management costs. In addition to managing invasive species, the method outlined here can also be used to better tackle uncertainty in protection of biodiversity and native species in a cost-effective manner.

15:40 - 15:53 | in person

Improving watershed adaptability under large uncertainty of climate change: a case study on the conservation of the Japanese freshwater crab (Geothelphusa dehaani) in the Takasaki river watershed, Japan.

Hiroyuki Yokomizo; Ji Yoon Kim; Jun Nishihiro; Taku Kadoya

To improve watershed management for climate change adaptation, we need to incorporate relationships between extinction risk for species and the frequency and magnitude of environmental disturbances such as drought and flood induced by the global change. Under the adaptation context, we are required to select conservation areas considering future climate change projection scenarios, and thus we must deal with the uncertainty of the climate change projection scenarios for the decision-making. In this study, we developed a model to identify conservation areas based on the information-gap decision theory to improve the adaptive capacity of watersheds, specifically focusing on species conservation. A case study is conducted to conserve the Japanese freshwater crab (Geothelphusa dehaani) in the Takasaki River watershed in Chiba prefecture, Japan. We will further discuss incorporating multiple targets, such as flood control, into the framework in addition to biodiversity conservation.

Monday | 14:30 to 16:00 | Patio | back to schedule

Exploring the institutional contexts for effective DMDU

Panel

Mark Workman; Yena Bassone-Quashie; Robert Lempert

DMDU is generally applied within or for public or private sector organizations. This session aims to explore the intersections among DMDU and organizational decision making. We seek to understand the institutional contexts which are most conducive to making good use of DMDU and what new institutional contexts might DMDU enable. For instance, adaptive management and regulation has been a constant theme in the DMDU literature. The recent IPCC Sixth Assessment report highlights the importance of polycentric governance, in contrast to single decision-making hierarchies, in addressing many climate changes. Recent political science literature argues for the importance of experimentalist governance under conditions of deep uncertainty. To what extent are such processes facilitated by DMDU? To what extent are organizations involved in such processes particularly conducive to DMDU? In particular, our session will focus on exploring what types of governance/institutional context are most conducive to the application of DMDU methods, as well as how DMDU methods can enhance/foster new types of governance. We organize the session around a panel discussion. Panelists will make brief opening comments, a moderator will ask questions, and then questions from the audience. We will use interactive polling to help engage the audience. Panelists include (confirmed and invited): David Victor, Univ of Calif San Diego; Harry Armstrong (Ofwat); Muriel Bonjean-Stanton (University of Leeds); Debora VanNijnatten (Wilfrid Laurier University) or Yena Bassone-Quashie (Toronto Metropolitan University)

Techniques for critical infrastructure assessment: ready for the 21st century in theory in practice?

Talks

14:35 - 14:48 | in person

Keynote: Experiences and lessons learned from working with infrastructure operators

Thomas Bles

-

14:48 - 15:01 | in person

Tipping points in European road networks due to river floods? A robustness assessment using percolation analysis

Kees van Ginkel; Elco Koks; Frederique de Groen; Viet Dung Nguyen; Lorenzo Alfieri

River flooding is a profound climate hazard in Europe and a threat to its road transport infrastructure. However, its impact on road network interruptions is mostly unexplored, while some have suggested that national road networks may experience tipping points. This study assesses the robustness of road networks of European countries and their potential for a tipping point: an abrupt and disproportionally large loss of network functionality, due to unfavourable combinations of floods. Methodologically inspired by percolation analysis, ten-thousands of flood combinations are sampled and their impacts on road network performance are assessed. We examine how realistic it is that catastrophic floods cause tipping points in the performance of national-scale road networks. Additionally, we explore if an adapted form of percolation analysis can deliver useful results for formulating climate adaptation policy. The results show that Albania, Croatia, Serbia and Austria are relatively vulnerable, whereas Belgium, Estonia, Lithuania and Portugal are relatively robust. In small mountainous countries like Slovenia, Macedonia and Albania, the 5% least favourable small-scale 1:100 year floods may disrupt 32 to 41% of the preferred routes between major economic regions, probably causing severe traffic disruptions beyond societal and legal acceptability thresholds, requiring a transformative response from national road operators. Tipping points in the sense of nationwide network fragmentation seem unlikely, but regional-scale tipping points can happen. Flood-proofing the identified weak spots could result in quick wins for national road operators. This talk is based on the paper: van Ginkel, K. C. H., Koks, E. E., de Groen, F., Nguyen, V. D. and Alfieri, L. Will river floods 'tip' European road networks? A robustness assessment. Transp. Res. Part D Transp. Environ. 108, 103332 (2022). https://doi.org/10.1016/j.trd.2022.103332

15:01 - 15:14 | in person

Exploration of the consequences of climate change and possible adaptation strategies in the Rotterdam-hinterland transport corridor

Anoek de Jonge; Thomas Bles; Wiebe de Boer; Jurjen de Jong; Rolien van der Mark; Joris van Ruijven; Mike Woning

We do not know how fast and how much the climate will change and the sea level will rise, but we know it will. This research presents an exploration of the consequences and adaptation strategies for the transport corridor between Rotterdam Harbor to its hinterland under 2-3 meter sea level rise and increased peak rain events and droughts. At first we determined which consequences

of climate change will directly influence the transport system, taking into account the rail, inland water, and road network. We identified tipping points to the transportation system, which could potentially lead to a system change. In the second step we explored four possible solution strategies to sea level rise in the Netherlands and what this means for the transport corridor. The four strategies involve increased protection seawards, a (semi-) closed water system and a retreat option. Per strategy, different measures are identified to keep the transportation system functioning. Using the tipping points and measures, we drew adaptation pathways towards the four strategies. This research gives insight in the choices that need to be made short-term (10-20 years) and what choices are ahead to transform the transport corridor intro a future resilient system taking into account current relevant technological, societal and economical challenges. This is important because due to the long technical lifetime of the infrastructure, the long term perspective needs to be incorporated when making investment decisions.

15:14 - 15:27 | in person

Identifying adaptive pathways by surrogating computationally expensive agent-based models: spatial planning for the technological shift in transportation in Singapore.

Orlando Roman; Canh Do; Pieter Fourie; Tanvi Maheshwari; Qiming Ye; Prateek Bansal; Bryan T. Adey

Planning future cities to embrace new technologies such as automated, connected and electric vehicles is challenging due to complex interactions between mobility, infrastructure and land use. Furthermore, the timing for technologies to be ready, to what extent they are going to be adopted and how people interact with such technologies are highly uncertain. In this regard, the extensive study of current and future mobility changes and their potential impact on people's behaviour and society allows an improved understanding of urban systems. However, despite the increasing recognition that cities face deep uncertainty, traditional spatial planning tools are inadequate to deal with it. Most research efforts have focused on increasing the granularity and complexity of models to gain accuracy, which further impedes a wide exploration of future scenarios. In this work, we explore the potential of using complex models that are capable of capturing the spatial interactions between mobility, infrastructure and land use, such as the agent-based MATSim, under deep uncertainty. We study potential urban measures (network configurations, Pick-Up/Drop-Off points, parking strategies and intersection designs) in response to the technological shift in transportation using the Tanjong Pagar fictive neighbourhood, in Singapore, as the test site. The model was evaluated under three main uncertainties over time: travel demand, automation development and vehicle-sharing preferences and then fit with a surrogate model. The surrogate was then used to search for optimal sequencing, timing and grouping of interventions (i.e. adaptive pathways) to provide guidance on planning urban transitions.

15:27 - 15:40 | in person

Towards a 15-minute city under deep uncertainty

Mikhail Sirenko; Alexander Verbraeck; Tina Comes

The COVID-19 pandemic has intensified the stark disparities prevalent within urban environments, underscoring the crucial role of essential service accessibility in public health outcomes. Populations in socioeconomically disadvantaged areas, disproportionately impacted due to limited access to necessary amenities, have experienced elevated infection rates. With anticipated rises in

pandemics over the ensuing decades, it becomes critical to reimagine urban landscapes through the concept of a 15-minute city - a transformative urban model where all essential needs are within a 15-minute reach. However, resource constraints pose challenges in identifying and implementing effective interventions at an urban scale. This study uncovers the relationship between the spatial rearrangement of a city and its consequent impact on infection rates within vulnerable demographics. We utilize a large-scale agent-based model to simulate the city of The Hague, the Netherlands, allowing us to investigate different scenarios. The strategy involves the strategic relocation of essential services such as supermarkets and pharmacies throughout the city while accounting for uncertainties related to virus transmission and behavioural responses. Our findings underscore the pressing necessity for urban planning policies that promote a more equitable distribution of essential services. It suggests that such adjustments can significantly influence the susceptibility of vulnerable population groups to infectious diseases, thereby helping to bridge the gap in health inequities in cities. This research contributes valuable insights into urban transformation approaches that align public health outcomes with principles of social justice.

15:40 - 15:53 | in person

Use of an arche type approach to implement DMDU in data poor and low capacity situations

Thomas Bles; Andrew Warren; Diana Morales; Mike Woning; Margreet van Marle

The consequences of natural hazards on critical infrastructure networks such as roads are evident. Due to climate change, many of these hazards may intensify and occur more frequently. This has led to an increased interest in studying the effects of natural hazards on the networks for infrastructure operators, as well as regarding the effects for the infrastructure users and society in general. Besides climate change also socio economic developments do pose significant challenges for road planning. Decision makers today face deep uncertainties about future conditions. They need to be confident the decisions they take today will continue to apply in the future. The adaptive strategy building approach that is presented in this paper contextualises and adapts Decision-Making under Deep Uncertainty (DMDU) principles to the specifics of roads planning with limited amount of available data and insight in resilience. We propose a semi-quantitative assessment, whereby available data and expert judgement is combined in a procedure intended to be appropriate for roads planners to implement independently. Every situation and location is unique and should be treated as such. However, to provide a practical approach to analysing long stretches of roads, or even for analysing road networks, a simplification may be made to group situations/ locations together that have comparable characteristics. The description of the characteristics forms a so-called archetype. Archetypes allow for quickly identifying measures that fit the generic description. As such, an archetype needs to be unique (i.e. no overlap with other archetypes), self-explanatory (everyone understands what is meant) and lead to a generic list of measures unique to the archetype. The generic archetype assessments are then contextualized to specific location under consideration. The proposed DMDU approach presents a simplified set of policy analysis activities to support road planners in the development of robust adaptation strategies, taking into account uncertainties surrounding future climate and traffic demands. This includes an assessment of prioritized road sections from a resilience assessment, identification of possible measures, analysis of the effectiveness of the measures, assessment of the future performance of measures including consideration of their robustness under various possible future conditions, prioritisation of the measures and building of adaptation pathways. This methodology has been applied in various countries (i.e. Philippines, Dominican Republic and Kazakhstan) and has proven to provide valuable insights for adaptation planning.

Monday | 16:30 to 18:00 | Ganges | *back to schedule*

Applying DMDU techniques to Global Systemic Risk Assessment

Panel

Ajay Gambhir (Chair); 1; Mark Workman; 2; Janani Vivekananda; 3; Robert Lempert; 4

The world has entered a polycrisis in which several geopolitical, economic, environmental, societal, and technological stressors are synchronously occurring. This has raised profound questions around what the future holds for humanity and other species, whether a more resilient society is possible, and the most robust pathways to achieving a safer future operating space. The new Accelerator for Systemic Risk Assessment (ASRA), hosted within the UN Foundation, has been developed to solidify, grow and galvanise a community of systemic risk professionals throughout the world, including those from the DMDU field. This panel session will discuss and debate a number of urgent questions around systemic risk assessment and response, including key risks on which we should be focused, how they may interact across geographical, thematic and temporal boundaries, and the role that DMDU approaches can play in the context of deeply uncertain societal stressors. The session chair will open the session with a discussion on the polycrisis and interacting systemic risks, before putting specific questions to the panellists, including: 1. What are the range of interacting risks facing society at a regional and global level at this time? 2. How can a DMDU approach help in charting pathways to a safer future in light of these risks? 3. What actions are needed right now, to convince and engage policy and decision-makers to take a truly systems-oriented approach to tackling societal challenges, in the context of deep uncertainty? Following initial responses to these questions from each panellist, the panel will be opened up to the floor for further QandA and discussion.

Monday | 16:30 to 18:00 | Patio | *back to schedule*

Enhancing Decision Making through Effective Visualization Techniques

Thematic

Antonia Hadjimichael; Julius Schlumberger

They say a picture is worth a thousand words, and indeed, a well-designed visualization can greatly support decision-making processes. By visually representing information, data exploration for specific analysis tasks becomes more accessible and insightful. However, it is essential to ensure that these visualizations are comprehensive and align with the cognitive capacities of the end user, while also serving their analytical purposes. As the research topics in the field of DMDU grow increasingly complex, the demand for advanced and meticulously crafted visualization techniques continues to rise. This proposed session aims to provide a comprehensive exploration of visualization techniques within the context of decision-support tools. Through expert insights, collaborative problem-solving, and participant engagement, the session seeks to advance DMDU visualization methods, enabling effective communication and understanding of complex analyses for both experts and non-experts. This session aims to address the following key aspects: • Communicating Uncertainty: Traditional methods of representing distributions often fall short in effectively conveying this information. We will explore innovative approaches to communicate uncertainty, with a particular emphasis on non-expert audiences. We hope to bridge the gap between technical analyses and their interpretation by a broader audience. • Interpretability and Usability: Visualizations often become more intricate and incorporate additional dimensions as the

complexity of the analyzed problems grows. However, it is crucial to consider whether non-experts can comprehend and engage with these visualizations. While certain visualizations can be made interpretable and guided, the question remains: would non-experts readily embrace them? • Visualizing Dependence: The need to depict complex interrelations in data, such as synergies and trade-offs of alternative policies or the path-dependence of policy sequences and interactions, is ever-growing. What existing, comprehensive tools can we use to effectively communicate these complexities? What additional approaches could be useful? The proposed session will be split into two parts. In the first half, we will invite experts from the information visualization research community to share best practices in designing information visualizations within the context of decision-support tools. These experts will provide insights into on vi visualization approaches and offer guidance on how to address the challenges associated with uncertainty, interpretability, and dependence in visualizations. In the second half of the session, we invite participants to join a problem-solving sprint. This interactive segment will provide an opportunity to engage in discussions about the advantages and shortcomings of different visualizations, leveraging the insights shared by the experts. Through collaborative problem-solving, participants will learn from one another's experiences and potentially develop innovative ideas for visualization approaches. Invited speakers are: • Jessica Hullman, Northwestern University, USA • Peter Stempel, Pennsylvania State University, USA

Monday | 16:30 to 18:00 | Rhone | back to schedule

Stumbling Blocks and Stepping Stones: practical challenges and opportunities of using DMDU methods in the transport sector

Panel

Charlene Rohr; Steven W. Popper; Vincent Marchau

DMDU methods are being adopted across a range of sectors that are experiencing deep uncertainty. Yet, take-up in the transport sector has been slower. We propose a panel discussion to explore lessons, challenges, and opportunities for introducing DMDU methods to transport policymakers and their planning staffs. We would specifically explore: - How do DMDU methods align with well-established appraisal guidelines? Are they complements, substitutes or something novel in this setting? - Are current travel demand models a help or a hindrance for DMDU analysis? - Do policymakers and stakeholders accept the results of simpler, more approximate models? - How well do policymakers cope with the complex outputs from DMDU analysis? - What is the further benefit of DMDU methods compared to the more traditional use of scenarios and analyses based on long run-time travel demand models? - What lessons can be learned from real-world examples of DMDU methods being used in the transport and other sectors? - What steps could be taken to encourage take-up of DMDU methods in the transport sector? The aim would be to convene a panel of transport policymakers and DMDU experts working in the transport sector to discuss these questions. We would publish a blog for the DMDU website summarising the key findings and lessons.

Tuesday

Tuesday | 09:00 to 09:45 | Patio | back to schedule

How Society Can Solve Global Problems that are plagued by uncertainty: the case of climate change

Key Note

David Victor

Despite deep uncertainty, progress is being made in addressing the challenges of climate change. Key to that progress are new policy and investment strategies that take uncertainty seriously. Rather than pretending that the right technologies are known and knowable, this new theory emphasizes the need for experimentation and learning. The Paris Agreement of 2015 is, in part, built on this experimentalist logic—creating a framework for governments to make bold pledges for action and adjust them as they learn what they are willing and able to implement. Since Paris, an array of industrial "clubs" has emerged—in steel, aviation, shipping, renewable power, and other industries—that link firms and governments that are highly motivated to pay for and learn from efforts to deploy new technologies that will disrupt their industries and create new, low emission futures. This talk will draw heavily from a book co-authored with Charles Sabel (Fixing the Climate, Princeton University Press) that articulates this new theory of change and offers a more hopeful view of how society will solve the vexing problem of climate change.

Tuesday | 10:00 to 11:30 | Ganges | back to session overview

Climate Resilient Development Pathways I

Talks

10:05 - 10:21 | in person

The state of Climate Resilient Development Pathways In Europe's cities - and pathways forward

Sadie McEvoy; Gaby Langendijk; Marjolijn Haasnoot

Cities are central to achieving climate resilient development (CRD) in Europe. Long recognized as leading contributors of emissions, the density of human life and assets in cities makes them hubs of development and innovation, as well as especially vulnerable to climate change hazards. This research presents the status of CRD in European cities and offers a roadmap for designing CRD pathways. Despite progress on climate action in European cities, mitigation, adaptation and development remain largely siloed and sectoral. As individual policy objectives, decisions regarding mitigation, adaptation and urban development face deep uncertainty. Their interdependence, and different temporal and spatial scales increase uncertainty in designing CRD pathways. Currently, CRD is most documented in nature-based solutions and spatial planning, and to a lesser degree in low-carbon and active mobility and in energy-efficient buildings and construction. Key constraints on CRD adoption in European cities include available funding, clear business cases for investment and quantified information on costs, (co-)benefits, synergies and trade-offs. European cities are still in an early stage of awareness and adoption of CRD. Implementation appears limited to win-win and low-cost actions. Further, CRD is presently mostly static, with limited evidence on CRD pathways, which could help avoid investment regret and lock-in and could identify opportunities for integrating near-term mitigation and development actions with long-term adaptation needs. Operationalizing CRD pathways through climate services and adaptive planning is proposed as a way forward for European cities and will be presented in the case study of Cork, Ireland.

10:21 - 10:37 | in person

Long term decisions under deep uncertainty in the Dutch delta – the search for transformative delta management

Lilian van den Aarsen; Drs Pieter Bloemen

The Netherlands faces effects of climate change: sea level rise, extreme weather, droughts and heat stress. The Dutch Deltaprogramme focuses on long term climate adaptation: safety against flooding, adequate fresh water supply and spatial adaptation. It is a multi-actor programme: all levels of government participate. Climate change moves at a far more quicker pace than we anticipated and the limits of what our natural system of water and soil can accommodate have been reached. Therefore, incremental adaptive deltamanagement will not suffice anymore for some aspects of climate change ánd for specific areas . A transformative approach seems needed: bolder steps, interventions like the Delta works to match the current problems. Our search for transformative deltamanagement started by looking at climate adaptation from a transition management perspective: looking for practices that are not climateproof to be phased out plus looking for emerging climateproof practices that should be supported. On the regional level, climate adaptation meets other transitions. We are looking at ways to speed up the transformation of our rural areas with specific attention to the goals of the Deltaprogramme. Deep uncertainty is an inherent feature of transitions. We would like to exchange experiences on how to cope with the deep uncertainties that arise when constructing and implementing unprecedented interventions. How to complement ór counteract the present way of climate-proofing, often characterized as incrementally strengthening the present system? Which transformative interventions should the Deltaprogramme support or instigate in order to (prepare a) shift to another system? We welcome any thoughts and experiences from other countries.

10:37 - 10:53 | in person

Climate resilient development pathways for farmer producer organisations in semiarid India

Arjuna Srinidhi; Saskia E. Werners; Sandeep Jadhav; Dada Dadas; Nikhil Nikam; Miranda P.M. Meuwissen; Fulco Ludwig

Abstract aimed at session titled: 10+ years of adaptation pathways: from theory to practice led by Dr. Marjolijn Haasnoot et al. Small and marginal farmers in India face vulnerabilities stemming from low agricultural productivity, degraded ecosystems, and market and climate uncertainties. In response, Farmer Producer Organisations (FPOs) have emerged as collectives to address these challenges and are gaining prominence in India's agriculture sector. FPOs incentivize collective action and bring in economies of scale, offering potential to enhance climate resilience while promoting empowerment and inclusive decision-making. However, FPOs encounter challenges in developing business plans, obtaining technical support, and coping with climate change-induced extreme weather events. This research aims to identify climate resilient development pathways (CRDPs) for FPOs in semi-arid India, considering the need to simultaneously address both development and climate change concerns. Collaborating with four FPOs in Maharashtra and eight experts from different backgrounds, we co-created CRDPs for the FPOs. Our findings emphasize that the primary challenge for FPOs lies in establishing viable and long-term business plans. FPOs and their members appear well-positioned to incorporate incremental adaptation measures while not changing their primary agricultural products. However, incentives for transformative changes, whether through

market mechanisms or policy interventions, currently remain inadequate. Our study highlights the necessity of a multi-layered approach to generate differentiated value for FPOs and other informal collectives across the agri-value chain. This approach recognizes varying technology levels, social organization, and financial capacities of collectives, facilitating the transition towards more climate-resilient farming systems in India. Moreover, aligning market and policy incentives is crucial to drive transformative changes and foster climate resilience in FPOs and the broader agricultural sector in India.

10:53 - 11:09 | in person

Climate resilient development pathways in the Hindu Kush Himalayan region

Edward Sparkes; Saskia E. Werners; Neera Shrestha Pradhan; Abu Syed; Sidratun Chowdhury; Suruchi Bhadwal; Hester Biemans; Marijn Gulpen; Shakil Ahmed; Muhammad Khalid Jamil; Bashir Ahmed

Communities throughout the world are facing immense challenges in facing climate change. The Hindu-Kush Himalayan mountain region is a climate change hotspot, where severe climate effects coincide with large numbers of poor and vulnerable people. For development to be sustainable in the region, interventions need to include choices and actions that alleviate poverty, counteract climate change, and are inclusive for the most vulnerable and resilient over time. Climate-resilient development pathways are an emerging practice of decision making that brings together these goals, consolidating adaptation, mitigation and development decisions towards sustainable development. This research aimed to co-create climate-resilient development pathways for communities across Bangladesh, India, Nepal and Pakistan in the Hindu-Kush Himalaya. We followed a general methodology in which we interpret pathways as a set of measures to be implemented progressively that work toward an aspired future, taking into account climate change and development aspirations. The pathways focused on upscaling and outscaling four livelihood innovations, those being springshed restoration, climate and flood-resilient housing, climate-smart agriculture and portable solar water pumping systems. The livelihood innovations were selected from a range of evidence-based options that aimed to enhance climate resilience and strengthen sustainable development processes for communities. To co-create pathways, stakeholders were engaged from a range of different groups, from the community level to national governments, and incorporated qualitative and quantitative methods. From the various cases, numerous specific lessons emerged. In this presentation, we synthesise the lessons, highlighting six critical considerations for advancing the practice of climate-resilient development pathways.

11:09 - 11:25 | in person

Household adaptation to climate hazards: how bounded rationality and behavioral uncertainty produce adaptation deficits

Alessandro Taberna; Tatiana Filatova; Antonia Hadjimichael; Brayton Noll

One of the key priorities of understanding climate change adaptation across scales is the quantification of adaptation at the household level. Modeling to support policy assessment and design has, to date, oversimplified the representation of individual human behavior ignoring bounds on rationality and complex social drivers. At the same time, policy formulation to support household level climate change adaptation is confounded by deep uncertainties, both in how those decision-making processes should be represented, but also in how they interact with key physical drivers. Using original agent-based modeling informed by adaptation survey data, we assess uncertainty in

adaptation diffusion and in damages along a gradient of 'rival framings' about adaptation behavior. We combine this modeling approach with exploratory modeling of physical drivers which assesses their effects on adaptation levels across the gradient of behavioral assumptions. We show that adaptation diffusion is below the economically optimal levels, largely due to diverse adaptation constraints (awareness, self-efficacy, social norms), as opposed to financial constraints. By modeling behavior change shaped by social institutions, we also trace mechanisms affecting inequality dynamics. Through the use of sensitivity analysis, we further demonstrate that behavioral uncertainty mediates the importance of uncertain physical factors which are traditionally thought to be decisive for the uptake of adaptation measures, and draw suggestions for a tailored policy design.

Tuesday | 10:00 to 11:30 | Patio | back to session overview

Recent Advances in Robust Decision Making and Its Applications

Talks

10:05 - 10:21 | in person

Multi-Objective Decision-Making: Understanding the Users' Explainability Needs

Zuzanna Osika; Jazmin Zatarain-Salazar; Pradeep K. Murukannaiah

Most decision-making problems involve multiple stakeholders, who often have competing interests. On top of that, the parties may lack knowledge or consensus on the system model, probability distributions, considered consequences, and their importance. Such problems can be modelled as multi-objective decision-making (MODM) problems by formulating stakeholders' interests as objectives. MODM typically involves multi-objective optimization (MOO) algorithms and (human) decision makers (DMs) interacting with the MOO algorithms. These DMs can be an individual, a stakeholder committee, or a political entity such as a city council responsible for making the final decision to implement. While MODM offers users greater freedom to interact with AI outputs and make decisions, it also presents challenges in understanding both the outputs and the process by which they were generated. To better understand the users' needs for explainability in MODM, we conduct pilot interviews with researchers who interacted with MODM to identify potential questions the users may ask about MODM problems, process, and outputs. Based on the intuitions from the pilot interviews, we develop the initial version of the explainable MODM (XMODM) question bank. That is, we identify questions for which explanations are potential answers. Our work is in the same spirit as the XAI question bank developed by Liao et al. [1]. However, the questions in the XAI question bank are related to machine learning (ML) systems, e.g. questions regarding features, instances, and predictions. In contrast, we identify questions about MODM systems—a class of AI systems that are quite different from the ML ones. The XMODM question bank can be valuable resource for both practitioners, e.g., to assist them in formulating questions about MODM, and researchers, e.g., to assist them in understanding what explanations are necessary and why.
[1] Liao, Q.V., Gruen, D., Miller, S.: Questioning the ai: Informing design practices for explainable ai user experiences. In: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems. p. 1–15. CHI '20, ACM, Honolulu (2020).

10:21 - 10:37 | in person

Value personas-based quantitative decision support: An approach to identifying robust compromise strategies in multi-facetted decision problems

Ingo Schönwandt; Jens Kahlen; Jan H. Kwakkel; Daniel Lichte

The multiplicity of stakeholders in society to any decision on political strategies, such as infrastructure planning among others, presents a challenge for political decision-making due to contested framings of the parties involved. Additionally, the underlying societal values that are the ingrained drivers for preferences, choices and actions of every individual, are bound to change over time. In contrast, this change of societal values may happen at a different pace than the adjustment of political decisions or, for example, the development of an infrastructure. However, quantitative tools for policy and risk analysis are generally designed to compare decision options under a single problem framing. This study aims to expand on recent advances in decision making under deep uncertainty (DMDU) to illustrate an approach for engaging a wide range of stakeholders in multi-facetted decision problems. Therefore, it leverages previous research on applying the concept of worldviews to an economic and ecologic decision problem centered around the lake model, a stylized human-nature coupled system representation, and employing robust decision making. Instead of using coarse-grained „worldviews“ to represent stakeholders, this study employs a set of 49 individually weighted value personas to calculate the parameters and define the relationships of the experimental model, and determine the objective function. Applying robust decision making, this research identifies a collection of robust compromise strategies that minimize the combined regret of all value personas. The study describes how quantitative decision support can apply societal values to consider the multiplicity of changing societal values of stakeholders to decision problems.

10:37 - 10:53 | in person

Conservation planning for climate change amid deep uncertainties

Alexis Rutschmann; and Matthew Moskwik (co-first authors); Neil Berg; Melissa Bukovsky; Abbie Tingstad; Dan Warren; Rob Nicholas; Seth McGinnis; Klaus Keller; Linda Mearns; Robert Lempert; Camille Parmesan (Presenter)

Recent climatic changes have already impacted biodiversity, but estimates of the percent of species threatened with extinction by 2100 range from 1% to 80%. This uncertainty stems partly from differences among algorithms used to estimate species' current and future projected ranges, and from differences among modeled projections of future climate. There is little agreement as to which species' distribution model or which climate model is best, leaving conservation planners often lost in a sea of possible futures from which to choose a management pathway. Here, we used a Robust Decision Making (RDM) approach to look across a wide range of possible futures and identify robust conservation strategies for 20 different species of concern. We estimate where potential habitat for that species is projected to be using multiple Species Distribution Models (SDMs), with multiple sets of modeling parameters and GCM-RCM combinations, resulting in >400 potential futures per species. We then analyse five different conservation strategies for their reliability and potential for regrets, ultimately seeking the most robust decision pathways, given known uncertainties. We found that (i) Climate change considerably affects the future distribution of all the species; (ii) There is considerable variation in the spatial distribution of each species amongst possible futures; (iii) Current state of understanding is not sufficient to estimate which of these futures is most likely; (iv) RDM approaches are helpful in navigating these uncertainties to identify robust management pathways for species conservation. The study offers a innovative conceptual framework that could be adapted to specific circumstances to produce actionable biodiversity conservation plans that are robust to highly uncertain climate futures.

10:53 - 11:09 | in person

Water Governance in the Ganges-Brahmaputra Basin Amid Uncertainty

Nihar Chhatiawala

Utilized by 630 million people in China, India, Bhutan, Nepal, and Bangladesh, the Ganges-Brahmaputra basin system (GB) is unique among major basin systems for its meager multilateral governance. Across all encompassed nations, the long-term utility of the GB for water supply, agriculture, and economic development necessitates governance practices in response to conditions of uncertainty. Such conditions include climate change, water quality, demand patterns, environmental flows, and the compounding externalities faced by downstream nations. IIASA's Global Hydro-economic Model (ECHO), an integrated modeling framework, is uniquely equipped to inform long-term strategies in transboundary basin systems such as the GB subject to such evolving conditions. This ongoing research builds upon efforts at IIASA to develop an ECHO model of the GB in which water users across the system optimize consumption subject to hydrological, economic, and policy conditions. We are developing case studies of water governance amid uncertainties and polycentricity within the GB. The case studies leverage ECHO to explore the fragility of long-term water governance within the system as well as the robustness of policy strategies. We are exploring a variety of decision-making frameworks to highlight the scales and actors within the system and implement mechanisms that reflect domestic policy as well as plausible agreements, conflicts, and actions based on shared objectives between nations.

11:09 - 11:25 | remote

Robust Management of the Lower Most Mississippi River

Patrick Kane; Nastaran Tebyanian; Soupy Daylander

The Lowermost Mississippi River Management Program (LMRMP) is tasked with developing modeling f to support holistic management of the river over the coming decades as a collaboration between Louisiana's Coastal Projection and Restoration Authority, the Water Institute and other partners. The program requires balancing competing goals of keeping the river navigable, engaging in restoration to prevent land loss and mitigating flood risk. While developing management strategies for the river in its current state is important, it is equally vital that these strategies are resilient to climate change. Changing patterns of rainfall, sea level rise, and subsidence all potentially affect the outcomes of river management. In order to develop strategies that can achieve the goals of river management set out by the program, the Institute has adopted a Robust Decision Making (RDM) framework to analyze the uncertainties and choices available to manage the river. Part of our work has been the development of methods to improve the speed of hydraulic modeling to better integrate with hundreds to thousands of simulations required by RDM methods. In this case, we augmented HEC-RAS with surrogate modeling of geomorphology and sediment transit to address multiple key management objectives simultaneously. With these modeling improvements, RDM has been able to provide decision makers with information about what potential climate scenarios cause current management practices to fail to meet their objectives, what levels of objective performance are possible under different management policies, and how different management objectives can tradeoff against each other.

Tuesday | 10:00 to 11:30 | Rhone | back to session overview

Participatory DMDU I

Talks

10:05 - 10:21 | in person

Towards participatory decision-making under deep uncertainty: benefits and research challenges

Karoline Führer; Jan Kwakkel; Floortje d'Hont; Etiënne Rouwette; Els van Daalen

Addressing wicked problems requires dealing with multiple actors with conflicting perceptions, institutional and ethical complexity, and uncertainty about the future as well as the system itself. Decision-making under deep uncertainty (DMDU) provides a set of tools and methods to find resolutions for such complex wicked problems. However, not all characteristics of what makes problems wicked are covered by the DMDU toolkit. Using the ten characteristics of wicked problems as a guiding framework, we identified three key shortcomings of DMDU: its analytical focus, the lack of attention to sense-making and interpretation of analytical artifacts, and the lack of guidance on coming to a decision. This study addresses the need to enable parties to collectively deliberate, and currently a general approach or precise reporting on how the participation was facilitated is lacking. As such, we present a general structure for a participatory DMDU process and lay out for each step the potential benefits of engaging stakeholders. Researchers can benefit from local knowledge as input and validation. Conversely, involved stakeholders gain trust in the process, the model, and the outcomes to create agency to act. We put four research challenges on the agenda for participatory DMDU. First, it needs to be assessed in which cases stakeholder engagement is feasible. Second, there are several design considerations when creating a valuable process. Third, a detailed and transparent operationalization of stakeholder engagement processes would provide guidance on how to facilitate these processes. Fourth, evaluation is needed to establish best practices.

10:21 - 10:37 | in person

Exploring the potential of serious gaming for enhanced DMDU implementation

Ruben Akse; Vincent Marchau; Simone Ritter; Wijnand Veeneman

In recent years, multiple analytical approaches have been developed to support decision-makers who are confronted with (deep) uncertainty. Such tools range from traditional scenario planning methods to Assumption Based Planning (ABP) methods, which include Robust-Decision-Making (RDM) and Dynamic Adaptive Policy Pathways (DAPP). While analytical approaches are strong in supporting the design of adaptive plans, there is still a research gap of implementing such plans into practice. This gap is fairly acknowledged within the DMDU community, but the 'putting into practice' call often remains unanswered. Therefore, the objective of this presentation is to unpack the black box of DMDU decision-making practices, by exploring serious gaming as an instrument for better DMDU implementation. We think these more behavior-focused tools can both enrich and complement existing analytical DMDU methods. Where analytical tools focus on the system-policy interface as object of interest (including scenario discovery and policy pathways), behavioral tools focus on human decision-making competencies and (governance) rules that structure the decision-making process, making behavioral experiments possible. On an individual level, gaming could uncover stakeholder-specific attitudes towards uncertainty. On a collaborative level, gaming could give insight into the complex governance relations between multiple organizations, including the dependencies and trust that is necessary to make decisions under uncertainty. On an institutional level, gaming could be a playful way to find synergies between physical measures and softer measures such as tax policies and standardization. To sum up, serious gaming and DMDU have great potential in being strong companions for better 21st century uncertainty management and governance.

10:37 - 10:53 | in person

DMDU Inception: How to get users to undertake DMDU and Robust Decision Making without realising it

Richard Bendall-Jones; Alan Mosca; Leonie Mueck

This presentation aims to explore strategies for encouraging practitioners to engage in Decision Making under Deep Uncertainty (DMDU) without explicitly labelling it as such, and by using intuitive user experiences. By integrating DMDU / RDM principles into existing decision-making processes, in this case construction project risk management, we can overcome these barriers and leverage the benefits of DMDU without the need for extensive training. By incorporating these concepts into software in an accessible way, we unlock an opportunity to make DMDU approaches scalable and enable mass adoption. These solutions should be capable of capturing and integrating diverse and complex sources of uncertainty, facilitating scenario exploration, and supporting decision-making. This presentation emphasizes the significance of incorporating accessible features and terminology into software and technology solutions that would benefit from DMDU approaches, such as construction planning. User-friendly interfaces and intuitive visualization tools play a crucial role in enhancing practitioners' engagement and facilitating the adoption process. When supplemented by Deep Learning approaches, there is an opportunity to provide a variety of scenarios and options which are far beyond that provided by the most commonly-used Monte-Carlo simulation based approaches. By making DMDU more accessible and seamlessly integrating it into existing decision-making practices through scalable software and technology solutions, we can enable wider uptake of this approach, and potentially supplant existing limited methodologies. By doing so, we can enhance decision-making under deep uncertainty across various domains and sectors. This paper/talk will share some ideas, taking reference from past learnings, as to how this may be implemented.

10:53 - 11:09 | in person

Moving adaptively from models to decision tables

Abel Immaraj; Sam Skinner; Andrew Allison; Shane Tyrrell; Andrew Warren

There is evidence in the Australian and New Zealand water sector that adaptive planning is gaining traction, steered by various state and national government guidelines, executive agencies, and at least six leading water utilities across Australia and New Zealand. We observe an encouraging surge in adaptive planning capability among planners and strategists in these corporations, government agencies and advisory consultants. However, we note constraints in the associated capabilities to socialise adaptive approaches and build intra- and inter-agency legitimacy and authorisation. Limits to existing institutional arrangements, low risk tolerances, and functional delineations are hampering the pace and extent of implementation. In an era of escalating uncertainties, the collaboration among the utilities, Aurecon, Deltares, and NIWA unveils a necessary paradigm shift for water utility management. The paper emphasizes the need to progress from the creation of improved models towards the effective application of existing tools within water utilities. To help strengthen the resolve of water utility Boards and senior executives, this paper advocates for increasing the legitimacy of adaptive approaches, the importance of institutional capabilities that facilitate rather than hinder adaptive implementation, and the vital role of context-setting in water utility decision-making. The interplay between scenario planning and adaptive planning is highlighted, providing a comprehensive framework for tackling multi-faceted challenges. Illustrat-

ing our analysis with case studies including an Australian water utility's Drainage Plan Statement of Obligations and Waterways Strategy Performance Objectives, we explore the requirements for efficient and effective delivery of services where scenario planning is adaptive, having regard to risk and uncertainty and how an adaptation pathways approach is adopted" to understand and manage risks of climate change on waterways. In doing so, this paper aims to suggest practical ways with which to cultivate an environment within water utilities conducive to the robust application of adaptive planning, thereby bolstering agency confidence for informed decisions in times of deep uncertainty.

11:09 - 11:25 | remote

Towards Democratizing DMDU

Will Mobley; Suzanne Pierce

Software frameworks such as EMA-Workbench and Rhodium have provided an initial generation of support for DMDU approaches. However, DMDU still possesses a steep learning curve. Decision Making under Deep Uncertainty (DMDU) requires not only an understanding of the DMDU process, but also the nuances of the model being used. This presentation will address how we can design a system that reduces the learning curve, both for the models used and DMDU processes. The solution proposed includes developing a web based portal to provide context for DMDU analyses, lead users through the DMDU process, and provide a more interactive analysis. In this presentation, we will use the Shallow Lake Problem as a benchmark model to identify the needs of a DMDU analysis. Further, we will identify the technological needs to create a more user-friendly DMDU system. Our findings suggest a democratized DMDU solution will require integrating current DMDU software, new semantic AI technologies, and custom development. For example, leveraging a platform such as the Model INTegration Platform (MINT) can reduce the required knowledge base of facilitators by improving their ability to discover, and execute preconfigured models, while also providing metadata and context for the best use of the model. The use of MINT can also provide a non-technical entry point into High Performance Computing systems to improve computation time. In addition, a workflow management system can provide context and recommendations to facilitators for the many technical approaches that can be used within DMDU analyses.

Tuesday | 12:00 to 13:00 | Ganges | back to session overview

Climate Resilient Development Pathways II

Talks

12:05 - 12:21 | in person

Societal feasibility of adaptation pathways

Rutger van der Brugge;Marjolijn Haasnoot;Daan Rooze;Stijn Peeters

Under large uncertainties, DAPP-approach provides a systematic approach to design climate adaptation plans based on dynamic adaptive pathways (Haasnoot et al 2013). Dynamic adaptive pathways help to break down adaptation into manageable steps. The approach includes an assessment of so-called adaptation tipping points or thresholds, marking the climatic conditions beyond which measures are not sufficiently effective anymore and additional measures are needed. To date, applications of the approach have focused primarily on the effectiveness of adaptation pathways and less on the feasibility, while both effectiveness and feasibility determine the solution space (Haasnoot et al., 2020). Societal feasibility is especially important to look at for those pathways that imply more fundamental changes, e.g. regional transformations involving multiple thresholds.

Those transition pathways are often so complex, that from a societal perspective the feasibility of such pathways is questionable. Present social conditions may block pathways (Van der Brugge et al, 2015), constrain solution space (Haasnoot et al, 2020) and may lead to maladaptation (IPCC, 2022). The recent IPCC WG2 report assessed both the effectiveness and feasibility of adaptation measures, yet not on pathways. In this paper we therefore propose an approach for the feasibility analysis of adaptation pathways and how to include this in the DAPP-method. The approach supports the formulation of a detailed theory of change of an adaptation pathway. Steps in the approach are: 1) to identify the societal conditions that are prerequisite to implement an adaptation option. We therefore use the STEEPLE-framework (social, technological, economic, ecologic, political, legal and ethical conditions); 2) to develop a theory of change, by identifying the required change processes (to create those conditions) using a typology of change processes used in transition management theory; 3) to analyze feasibility with regard to lead time and steerability of the change processes (i.e. measures to induce or speed up the change process). Our aim is to develop a societal conditions-database for the most occurring climate adaptation options. Using digital tooling we combine the options of a pathway and visualize the lead time of the change processes (in a gantt chart). We then analyze the feasibility of implementing adaptation options before reaching thresholds (tipping points).

12:21 - 12:37 | in person

Transitioning to a resilience approach to managing environmental water under a variable and changing climate

Avril Horne

Climate change is projected to decrease river flows by 20% in the Murray Darling Basin, and under current policy settings the riverine environment will be most impacted by these changes (Prosser et al., 2021). The adverse impacts of climate change on river ecosystems are occurring at a faster rate than previously predicted. Unfortunately, the current generation of management tools are largely based on a stationary view of historic climate, and new approaches are urgently needed to guide river ecosystems management in an uncertain and changing future (Horne et al., 2019, Horne et al., 2017c, Poff, 2018). There is now a wide body of literature exploring decision making under deep uncertainty (Marchau et al., 2019). However, there has been limited application of these approaches to large scale river basins (Fowler et al., 2022a). This presentation will demonstrate methods to apply bottom up decision making in a large river basin to achieve environmental objectives.

12:37 - 12:53 | remote

Leveraging DMDU Tools for Redesigning and Transforming Complex Social Systems

Tim McDonald

Responding to public problems requires efficient problem solving and adapting on the part of public leaders – especially under conditions of deep uncertainty. Sometimes however an effective response requires reshaping social systems to transform their performance over time. The challenge for leaders in democratic societies is to meet near-term needs and expectations while also creating new opportunities – such as promoting health, personalizing learning, or rapidly pursuing renewable energy – that are only available through redesigning and transforming complex social systems. This presentation defines system redesign and transformation, considers when they are

necessary, and discusses how concepts from DMDU can contribute to redesigning complex social systems to achieve policy goals.

Tuesday | 12:00 to 13:00 | Patio | *back to session overview*

Advances and Applications of Scenario Discovery

Talks

12:05 - 12:21 | in person

Identifying Decision-Relevant Future Scenarios for Emergent Societal Phenomena

Patrick Steinmann; Koen van der Zwet; Bas Keijser

Scenarios are a common decision support and planning tool in the national security domain. These scenarios consist of a set of exogenous drivers, and a resulting narrative describing a plausible future. With an ensemble of such scenarios, decision options can be evaluated under a small but diverse range of future conditions. However, this renders the resulting decision outcomes sensitive to the diversity and relevance of the scenarios included in the ensemble. Therefore, the key challenge is to identify meaningfully different future system dynamics and underlying drivers across multiple outcomes of interest. Using a case study of protest dynamics, we develop a simulation-based approach using multivariate time series clustering to identify small sets of scenarios which capture a system's complex dynamics across a range of decision-relevant outcomes. By associating the identified scenarios and their underlying exogenous drivers using multi-class scenario discovery, we also quantify tipping points between the scenarios and their appropriate operational responses, facilitating adaptive planning. Our work demonstrates the usefulness of simulation models for decision support in the national security domain by enabling the systematic identification and exploration of diverse, relevant, and causally grounded alternative scenarios of the future.

12:21 - 12:37 | in person

Multi-actor, multi-impact scenario discovery of consequential narrative storylines in human-natural systems

Antonia Hadjimichael; Patrick M. Reed; Julianne D. Quinn; Chris R. Vernon; Travis Thurber

In understanding and managing complex human-natural systems, scenarios have emerged as valuable tools in assessing and communicating the potential impacts of uncertain conditions or the implications of alternative management. At the same time, it is widely recognized within the deep uncertainty community that the traditional approach of limiting focus on a small number of predetermined scenarios can inadvertently miss consequential dynamics, extremes, and diverse stakeholder impacts. To overcome these limitations, exploratory modeling and scenario discovery approaches have been developed to explore large numbers of plausible futures and investigate alternative system framings. These approaches typically utilize large ensembles of model simulations to draw their conclusions, but often struggle with conveying actionable information to guide planning or further analyses. In addition, traditional scenario discovery methods rely on robustness metrics to classify the acceptability of a system's performance, which faces its own challenges regarding the choice of metric and its relevance to various stakeholders, as well as its ability to identify consequential system dynamics for further planning analyses. This study introduces the FRamework for Narrative Scenarios and Impact Classification (FRNSIC; pronounced "forensic"): a scenario discovery framework that addresses these challenges by organizing and investigating consequential scenarios using hierarchical classification while aiding the selection of storylines drawing on the identification of consequential underlying system dynamics. The framework is

demonstrated on the Upper Colorado River Basin, focusing on drought occurrence and its impacts. Our results show how the FRNSIC can be used to explore combinations of alternative sets of impact metrics and dynamic behaviors to identify narrative drought storylines that can guide future (re-)analysis on adaptation options under consequential dynamic storylines.

12:37 - 12:53 | in person

A clustering and instance selection method for interpretable multi-class scenario discovery

Katerina Tang; Jacob Wessel; Abigail Birnbaum; Jon Lamontagne; Vivek Srikrishnan

Applications of scenario discovery for model-based planning under deep uncertainty traditionally rely on a binary classification of simulation results as either of interest or not and then seek to identify the specific combinations of input parameters—i.e., uncertain factors—that lead to those outcomes of interest. In contrast, multi-class scenario discovery methods first find clusters of similar outcomes and then identify the predictive input subspace for each cluster, allowing for an exploratory analysis of the range of potential outcomes without preliminary judgements about which are of interest. However, identifying meaningful clusters that capture consistent and interpretable narratives can be challenging in a high-dimensional outcome space that encompasses the interests of numerous stakeholders. To address this challenge, we propose a clustering and instance selection scheme that offers scalability to higher dimensions and a principled method for selecting a representative outcome for each cluster. The scalability allows us to incorporate additional relevant information (e.g., metrics describing system dynamics over time) with the goal of identifying clusters corresponding to more coherent scenario narratives; finding a representative member of each cluster then helps to characterize and communicate these narratives more effectively. We apply our proposed method to explore typical pathways by which emissions constraints lead to distinctive shifts in water withdrawals across multiple river basins. With the flexibility of this approach, we also envision future applications in characterizing complex multi-sector network dynamics.

Tuesday | 12:00 to 13:00 | Rhone | back to session overview

Participatory DMDU II

Talks

12:05 - 12:21 | in person

Climate Change and the Nile River Basin: A Cross-cultural Approach to Deep Uncertainty in Environmental Policy Analysis

Arthur Petersen

This presentation provides an initial evaluation of state-of-the-art DMDU methods in the context of environmental policy analysis on climate change and the Nile River Basin. It will be argued that these methods, although some might say that they are 'too Dutch to function', have an important contribution to make to such environmental policy analysis, which needs to tackle cross-cultural dimensions pertaining to water engineering and river-water allocation in situations of international conflict, civil strife and nondemocratic societies. So, an extremely large variety of uncertainties play a role in the case. How can uncertainties pertaining to the future impacts of climate change and the 'equitable and reasonable utilisation' (a principle of international law) of the Nile best be assessed from a large variety of perspectives? Knowledge with respect to geography, engineering, environment, climate change and the interlinkages between water, energy and development

policies in the Nile River Basin all play a role here. Which DMDU methods could best be used and adapted to contribute to analyse the cross-cultural complexities involved – focusing on the past and the present and on both the Blue Nile (from Ethiopia to Sudan and Egypt) and the White Nile (from the Great Lakes to Uganda, South Sudan, Sudan and Egypt)? The presentation will focus on methodological innovation and creation of enriched system-dynamics models, group-model building exercises, simulation games and future scenarios in this case of deep uncertainty.

12:21 - 12:37 | no info

Collaborative modeling for the sustainable management of water resources in the face of an uncertain future – The Guayubin Basin Story

Jennifer Olszewski; Aneliya Nikolova; Rosanna Vasquez; Inmaculada Adames; Raul Perez; Guillermo Mendoza; Patricia Fontanet; Will Logan

This presentation will detail the ongoing Shared Vision Planning (SVP) pilot in the Guayubin subbasin in the Dominican Republic. The Guayubin is a subbasin within the larger Yaque del Norte basin, which is the largest basin in the Dominican Republic and a critical resource for the country. The River Basin Commission of the Yaque del Norte (CRYN) was created to ensure the sustainable management of water resources in the Yaque del Norte. CRYN is currently working with the US Agency for International Development (USAID) and the US Army Corps of Engineers (USACE) to pilot a SVP approach to sustainable basin management in the Guayubin basin. The SVP process is a planning approach that incorporates (1) traditional planning, (2) structured collaboration with stakeholders and, (3) system modeling. As part of this effort, USACE developed a decision support model to allow stakeholders and decision-makers to evaluate performance of their sectors via sector-specific performance metrics under different plans and future scenarios. This model will be used in a series of workshops to support the evaluation, comparison, and selection of water resources investments across all agencies and entities in the subbasin. The CRIDA (Climate Risk Informed Decision Analysis) approach developed by USACE will also be applied to evaluate basin vulnerabilities and plan resiliency to such vulnerabilities.

12:37 - 12:53 | in person

Advancing climate neutrality of the Hague City's transport system by DMDU Framework and Participatory Methods

*Karoline Führer1; Peraphan Jittrapirom*2; Floortje d'Hont1*

The urban transport system is one of the main sources of greenhouse gas emissions. However, the intricate and interconnected nature of the system presents significant challenges in transitioning it to a more sustainable state. Identifying effective sustainable policy levers while avoiding unintended consequences is challenging. Additionally, identified policy levers may be affected by different events or trends, such as an aging society or the availability of new transport technologies that may emerge in the future. In this study, the research team partnered with the municipality of The Hague City to advance the city's ambition to become climate neutrality by 2050. We applied the DMDU framework (Framing, Exploring, and Choosing), using participatory methods with a group of 10 civil servants. The objectives of the study are a) to elucidate the complexity of the system,b) to clarify stakeholders' objectives, c) to explore various options that contribute toward realizing the objectives, and d) to explore how uncertainties and safeguarding actions may improve potential futures. The outcomes illustrate the compatibility of the DMDU framework with participatory methods such as adjusted Generative Robust Visioning and Group Model Building. The workshops

supported participants in understanding the complexity of and uncertainties in their local urban multi-modal transport system, and how these affect decision-making for the municipality of The Hague. The next research steps will further explore added benefits of participatory methods in the context of DMDU. We will be continuing the current process with the municipality of The Hague, in addition to engaging more heterogeneous stakeholder groups.

Tuesday | 14:00 to 15:00 | Ganges | back to session overview

DMDU practice

Talks

14:05 - 14:17 | in person

Gearing up to govern under deep uncertainty - Comparing government's tools to support policymaking of complex issues in Europe

Elias Kock; Andrea Renda

This research paper presents a multi-criteria comparison of two methodologies used in anticipatory governance: foresight-based scenario building and exploratory modelling. Prompted by the growing adoption of anticipatory governance in European policy-making, the study aims to highlight the unique strengths and weaknesses of each methodology. The research questions revolve around understanding the core principles, methodologies, costs, reproducibility of insights, technical difficulties, relevance of insights for decision-makers, coverage of possible futures, and cultural fit within policymaking organisations of both approaches. The research methodology comprises a rapid literature review, case study analysis, expert interviews, and comparative analysis. Foresight-based scenario building is older than exploratory modelling and currently the more prominent approach in anticipatory governance. Despite their shared goal of exploring future uncertainties, there has been little interaction between the foresight and exploratory modelling communities. This lack of interaction, coupled with the longer history of the foresight-based approach, has likely contributed to its current prominence in anticipatory governance. This research aims to impact policy-making by guiding in the choice between the two methods and stimulate further interaction and collaboration between the foresight and exploratory modelling communities.

14:17 - 14:29 | remote

Can We Predict Long-Term Policy Decisions?

Detlef Sprinz; Robert Lempert; Steven Popper

The DMDU research agenda clearly focuses on the depth of time (e.g.Lempert et al., 2003) and advises long-term policies in the context of short-term decisions to be taken (Lempert, 2002; Marchau et al., 2019). Less is known whether we can forecast the actual adoption of long-term policies, i.e. their political feasibility. Multi-party negotiation models lend themselves to explore this challenge. While, e.g., Bruce Bueno de Mesquita made long-term political forecasts for the future of the 1997 Kyoto Protocol (Bueno de Mesquita, 2009) over a one hundred year time horizon, very little is known whether such political forecasts are valid. In this hybrid panel, I suggest to give a 15-20 minutes reflection about long-term policy predictions with the help of the Predictioneer's Game in order to stimulate an expert panel on this topic which will probe the more general feasibility and ramifications of such an approach. Examples will be drawn from published research (Bueno de Mesquita et al., 1996; Sprinz et al., 2016) and the organizer's ongoing research as well as reruns of shorter-term predictions over a much longer time horizon than originally envisioned (Sprinz et al., 2016). In the ensuing panel discussion (40 minutes), we

will probe the usefulness of the approach and make suggestions on how to make more useful long-term policy predictions. Robert Lempert (2007) (t.b.c.) and Steven Popper (2019) would serve as ideal panel members to discuss these issues with the presenter and the general audience. References Bueno de Mesquita, B. (2009). Recipe for Failure - Why Copenhagen Will Be a Bust, and Other Prophecies from the Foreign-Policy World's Leading Predictioneer. Foreign Policy. https://foreignpolicy.com/2009/10/19/recipe-for-failure/ Bueno de Mesquita, B. J., Newman, D., and Rabushka, A. (1996). Red Flag Over Hong Kong. Chatham House Publishers. Lempert, R. J. (2002). A New Decision Sciences for Complex Systems. Proceedings of the National Academy of Sciences, 99(90003), 7309-7313. https://doi.org/10.1073/pnas.082081699 Lempert, R. J. (2007). Creating Constituencies for Long-Term, Radical Change. John Brademas Center for the Study of Congress, New York University, Research Brief, Lempert, R. J., Bankes, S. C., and Popper, S. W. (2003). Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis. Rand Corporation. https://www.rand.org/pubs/monograph_reports/MR1626/index.html Marchau, V. A. W. J., Walker, W. E., Bloemen, P. J. T. M., and Popper, S. W. (Eds.). (2019). Decision Making under Deep Uncertainty: From Theory to Practice. Springer International Publishing. https://doi.org/10.1007/978-3-030-05252-2_16. Popper, S. W. (2019). Reflections: DMDU and Public Policy for Uncertain Times. In V. A. W. J. Marchau, W. E. Walker, P. J. T. M. Bloemen, and S. W. Popper (Eds.), Decision Making under Deep Uncertainty: From Theory to Practice (pp. 375-392). Springer International Publishing. https://doi.org/10.1007/978-3-030-05252-2_16 Sprinz, D. F., Bueno de Mesquita, B., Kallbekken, S., Stokman, F., Sælen, H., and Thomson, R. (2016). Predicting Paris: Multi-Method Approaches to Forecast the Outcomes of Global Climate Negotiations. Politics and Governance, 4(3), 172-187. https://doi.org/https://doi.org/10.17645/pag.v4i3.654

14:29 - 14:41 | remote

DMDU Thinking in Practice: Lessons Learned From a Decade of Louisiana's Comprehensive Master Planning Process

Jordan R. Fischbach; David G. Groves; David R. Johnson; Michael T. Wilson

The State of Louisiana faces a substantial challenge in addressing the joint problems of rapid coastal wetlands loss and flooding from coastal storm events. This challenge is exacerbated by rising sea levels, land subsidence, and other uncertain drivers. After the devastating 2005 hurricane season, Louisiana established a new state agency, the Coastal Protection and Restoration Authority (CPRA), to address these existential challenges to Louisiana's coastal communities and ecosystems. CPRA was tasked with developing a 50-year master plan, Louisiana's Comprehensive Master Plan for a Sustainable Coast, and updating this plan every 5-6 years based on the latest available science. The most recent 2023 Coastal Master Plan was approved unanimously in May by the state legislature. Researchers and practitioners from a range of private, nonprofit, and academic institutions helped develop an integrated modeling system and transparent, objective planning process to evaluate proposed coastal restoration and risk reduction projects across uncertain future scenarios, weigh tradeoffs between key goals, and assemble a consensus $50 billion portfolio of projects for the master plan. Although DMDU methods were not formally applied to develop prior plan iterations, DMDU concepts, including exploratory uncertainty analysis and participatory tradeoffs analysis, have been central to plan development since 2010. This presentation will reflect on how DMDU ideas helped to inform and improve Louisiana's planning process. We will also describe current efforts to formally apply DMDU methods for future plan updates, including an ongoing exploration of Dynamic Adaptive Policy Pathways (DAPP) to develop adaptive pathways for the state's future restoration decision making.

14:41 - 14:53 | in person

Practitioner perspectives on accommodation and retreat in response to climate change in the Netherlands

Caroline M. Kraan; Marjolijn Haasnoot; Katherine J. Mach

The Netherlands considers itself the safest delta in the world due to its excellent flood risk management system. However, unless extremely ambitious reductions in global greenhouse gas emissions are implemented, the country will face significant climate change impacts over the coming centuries that will impact its water management system. Dynamic Adaptive Policy Pathways have been developed for future adaptation options for the country as a whole. This study explores perspectives from practitioners, professionals working on climate adaptation, on the accommodation-retreat pathway under continuing climate change in the Netherlands. This pathway depends less on the strengthening and improving of flood protection infrastructure, and more on adaptation through accommodation—reducing the impact of flooding—or retreat—relocating people and assets away from flood-prone areas. We use an expert assessment process, in which closed-form quantitative judgments are enriched through open-ended follow-up questions. In-depth, semi-structured interviews with >40 experts explore how accommodation and retreat as adaptation options can play a societally beneficial role in climate change adaptation. Experts have a variety of backgrounds, including academia, government, NGOs, and the private sector. A conceptual model organizes the diverse set of perspectives in four quadrants, based on the perceived desirability of land use change and likely scale of implementation. An improved understanding of the barriers to and opportunities for accommodation and retreat as adaptation options facilitates policy decision-making by helping to identify low-regret options under a range of uncertain climate scenarios and adaptation strategies.

Tuesday | 14:00 to 15:00 | Rhone | *back to session overview*

Exploratory Modelling

Talks

14:05 - 14:21 | in person

Exploratory modelling of stochastic land use cover change (LUCC) future scenarios for spatial planning

Orlando Roman; Benjamin Black; Emma Zeindl; Bryan Adey

Land Use Cover Change (LUCC) models simulate future geospatial projections of urban and rural areas by including physical, regulatory and transportation-related factors as important drivers of change. Different sources of uncertainty in LUCC modelling such as data inputs, model parameters, model structure and future scenarios have been widely researched in the past by evaluating output variability (i.e. uncertainty analysis) and quantifying the importance of specific uncertain factors (i.e. sensitivity analysis). These efforts focused mainly on reducing uncertainty and improving model accuracy and predictions, even though LUCC models are mainly stochastic (e.g. cellular automata models) and used for highly uncertain long-term projections. With a different perspective, Exploratory Modelling embraces uncertainty and does not try to predict the future, instead, takes a model as a device for simulating potential future scenarios. This presentation shows how advances in uncertainty research can be used in LUCC models within an exploratory approach to better understand spatial planning options. Specifically, the main novelties of this piece of research are 1) the extension of Sobol indices, as a sensitivity analysis technique, to evaluate the influence of

several uncertain factors including model parameters, planning decisions and the stochasticity of the model; 2) the use of scenario discovery techniques to develop sensitivity-informed uncertainty maps; and 3) the investigation of the potential of such model-based techniques for spatial planning. As a case study, we project future urban development scenarios in the Lausanne-Morges agglomeration, in Switzerland, in connection with major infrastructure development plans. We then generate a large ensemble of future scenarios and identify the most influential factors on urban development (i.e. Sobol indices) and the combination of factors that produce salient scenarios for the planning of the agglomeration (i.e. scenario discovery). This paper showcases the value of conducting spatially explicit exploratory modelling as the decision-relevant factors show important spatial variations.

14:21 - 14:37 | remote

Exploratory modelling to identify patterns of urban vulnerability in Mexico City

Yosune Miquelajauregui; Erick A. Hernández Medrano; Luis A. Bojórquez Tapia

Addressing urban vulnerability requires the adoption of robust decision-making approaches. Exploratory modeling represents a powerful approach that explicitly follows a learning process called deliberation with analysis that supports adaptive decision-making under contexts of high uncertainty. In this study we used exploratory modelling and data mining techniques to identify socio-hydrological vulnerability patterns associated to water scarcity in Mexico City. We hypothesized that urban vulnerability emerges through the interactions between environmental conditions and socio-political factors meaning that stakeholders' actions and responses can also act as main determinants of vulnerability. To test this hypothesis we used the spatially-explicit model MEGADAPT to evaluate water scarcity patterns projected to 2060 under six water management scenarios. We found differentiated vulnerability patterns across the water management scenarios. These patterns were the result of feedbacks between biophysical, socioeconomic and decision-making elements. We found that vulnerability to water scarcity increases under scenarios characterized by increased number of days without water, whereas lower vulnerability patterns were observed under scenarios that account for improvements of the city's physical infrastructure. Our results shed light into the mechanisms conducive to water scarcity vulnerability in Mexico. We argue that these results could inform urban planning decision-making towards more sustainable futures.

14:37 - 14:53 | remote

Automatic Identification of Outlier Ensembles in the Exploration of Uncertain Futures

Amal Sarfraz; Charles Rougé; Lyudmila Mihaylova; Jonathan Lamontagne; Abigail Birnbaum; Flannery Dolan

The escalating complexity of models, paired with the necessity to perform sensitivity and exploratory evaluations, gives rise to increasingly large datasets. The analysis of these large datasets may present substantial difficulties when utilizing traditional scenario discovery approaches. Our research focuses on identifying clustered outliers that could represent critical climate and socioeconomic scenarios in datasets comprising future human-environmental systems and their interactions. Our methodology integrates probabilistic clustering and a Mahalanobis distance-based statistical test to identify scenarios that cluster together as outlier ensembles. Probabilistic clustering aids in highlighting candidate outlier ensembles within complex datasets and Mahalanobis distance follows a chi-square distribution that enables us to verify which of these candidate ensembles can

be labelled as outliers. We call the resulting methodology MOED (Mahalanobis distance-based outlier ensemble detection). We offer a robust validation with thousands of synthetically generated datasets with associated outlier clusters, exploring several degrees of freedom in data configuration and outlier ensemble size, position, and spread. This validation highlights the adaptability and robustness of MOED. We also apply MOED to data from a large ensemble of Global Change Analysis Model simulations, with a focus on Indus River Basin agricultural outcomes. Preliminary results show MOED is a promising tool to extract scenarios of interest and can be applied to identify critical scenarios in large datasets such as those generated from Integrated Assessment Models or other complex forecasting tools. These findings contribute to a comprehensive understanding of the complexities of socio-ecological systems under conditions of deep uncertainty.

Tuesday | 14:00 to 15:00 | Yangtze | back to schedule

Developing pathways in complex multi-sector multi-hazard systems – Lessons from European pilot regions

Forum

Andrew Warren; Julius Schlumberger; Sharon Tatman; David Geurts; Noemi Padron Fumero; Anne Sophie Daloz; Lin Ma

Co-developing methods and frameworks for decision-support is fundamental for impactful science. MYRIAD-EU, a European Horizon2020 project has the objective of codeveloping such approaches to enable policy-makers, decision-makers, and practitioners will be able to develop forward-looking disaster risk management pathways that assess trade-offs and synergies of various strategies across sectors, hazards, and scales. Testing of these methods in various European regions leads to refinement of the methods and lessons learned about the co-development process. In this session, we will showcase three work-in-progress examples of testing and co-development. An approach to develop systemic pathways in complex multi-sector systems is being applied in the diverse case studies of the off-shore strategic spatial planning managing the needs of energy, ecosystem and shipping in the North Sea, the highly interconnected and co-dependent system of the tourism destination Canary Islands and the regionally interconnected energy and water supply system and demand in Scandinavia. We propose a panel discussion with the focus on: a) Sharing experiences from three different cases to develop pathways for multi-sector and multi-hazard challenges. b) Creating a platform for dialogue between scientists, practitioners and other stakeholders to discuss challenges of such co-production processes and means to overcome these.

Tuesday | 15:30 to 16:30 | Ganges | back to schedule

Prospects and Challenges in Advancing Adaptation Pathways: A Discussion Forum

Forum

Marjolijn Haasnoot; Judy Lawrence; Jan Kwakkel; Valeria Di Fant; Julius Schlumberger

Adaptation pathways approaches have gained significant traction since the formation of the DMDU community, being extensively researched and applied in various domains such as natural resource management and spatial planning. Over the past decade, pathways approaches have become established in various policy domains and regions fields, and has even been taken up into decision-making processes and norms. Simultaneously, emerging domains like climate resilient development and disaster risk management are recognizing the value of pathways thinking and seeking to apply it in their specific decision contexts. As researchers and practitioners explore the limits and opportunities of emerging methods and tools, including Machine Learning, a vital discussion emerges.

This discussion forum aims to share collective experiences gained in the past 10 years of adaptation pathways research and practice. Together, researchers and practitioners will reflect on the current state of the approach and engage in meaningful discussions about potential future developments. Participants will have the opportunity to engage in lively discussions and collaborative reflections on the future directions for the pathways research community. The world café will focus on harnessing emerging methods and tools, exploring synergies with other societal goals such as climate mitigation and sustainable development, and streamlining pathways thinking into practical implementation. Additionally, participants will contribute to the creation of a global map showcasing past and ongoing adaptation pathways projects and topics. We foresee the following topics that will be pitched by the table facilitators: 1) emerging tools to generate pathways (hosted by Jan Kwakkel), 2) transformative adaptation and CRDP (hosted by Valeria Di Fant), and 3) supporting uptake and implementation of pathways approaches (hosted by Judy Lawrence).

Tuesday | 15:30 to 16:30 | Rhone | back to schedule

The Future of Integrated Assessment Models and their Role in Decision Making under Deep Uncertainty

Forum

Jazmin Zatarain Salazar; Palok Biswas; Giacomo Marangoni; Jan Kwakkel

Integrated Assessment Models (IAMs) have emerged as a key tool to allow long-term, holistic view of climate mitigation strategies by coupling climate sciences, economics and policy considerations into a unified framework. However, they face growing relevance and scrutiny in real-world contexts. Our proposed session aims to facilitate a multidisciplinary dialogue surrounding the evolution, application, and significance of IAMs in decision-making under deep uncertainty. Key topics will include current challenges associated with IAMs, strategies for enhancing their robustness and validity, the potential role of AI and machine learning in improving IAMs, and ensuring ethical use of IAMs. The discussion will convene a diverse group of experts, at different career stages, encompassing IAM researchers, policy-makers experienced in IAM usage, ethicists focusing on AI and decision models, and experts in participatory processes to address stakeholder engagement and plurality of views. The session will start with a brief introduction of the panelists and an overview of the topic, followed by each panelist presenting their insights on the future of IAMs. A moderated discussion will follow, leading to an interactive QandA session with the audience. We anticipate that this proposed discussion will offer a variety of perspectives of future directions for IAM development, and will reaffirm their role in decision-making under deep uncertainty.

Tuesday | 15:30 to 16:30 | Yangtze | back to schedule

DMDU and the Humanities

Panel

Henry Graumlich; Steven W. Popper; Ian Prichard

How might insights from the humanities benefit DMDU methods and practice? DMDU has developed a set of technical means designed to support complex and controversial aspects of human decisionmaking. The humanities also seek to explore choices, tradeoffs, and consequences of fraught and morally loaded decisions. The humanities also offer tools for exploring shifts in perceptions, paradigms, and contexts over time that both inform and result from such decisions as well as means for investigating how the ways in which we frame decisions, and discussions about decisions, reflect social values. The DMDU practitioner might profit from drawing upon this storehouse of knowledge. Defining where such wisdom is to be found and possibly utilized

is also in keeping with DMDU approaches that seek, among other things, to integrate insights from a range of disciplines into an analytical synthesis. There may also be value in bringing DMDU concepts to bear on persistent questions in the humanities, such as improved analysis of historical processes as well as 21st Century questions, while also conveying the values of contextualization and perspective from the humanities into the scientific, philosophical, and practical issues faced by DMDU practitioners. Hard sciences tend to exist in an eternal present; a dialogue between DMDU and the humanities could provide practitioners and decisionmakers with a bridge to understanding how policies act and interact over time. This panel will continue discussions begun at the DMDU Society's 2023 Summer School and will seek to broaden engagement within the Society.

Tuesday | 16:30 to 18:00 | Patio | *back to schedule*

Tools and Software Market

Key Note

Ümit Taner, Gundula Winter, Jan Kwakkel, David Gold, Julius Schlumberger

At the DMDU 2023 Annual Meeting brings together various experts and researchers developing cutting-edge tools and software for decision-making in the face of deep uncertainty. The purpose of this market is to show the diversity of available tools, offer an entry point for the participants to learn more about the use purpose and available support, and spark discussions about new fields in which these (software) tools could be applied. The market will include engaging live demonstrations highlighting the latest tools and software to support robust decision-making, scenario analysis, adaptive management, policy design, and risk assessment. The showcased tools encompass state-of-the-art techniques, modeling frameworks, visualization methods, and simulation platforms used for scientific and practical applications in the context of DMDU.

Tuesday | 16:30 to 17:30 | Rhone | *back to schedule*

DMDU Regional and Interest Groups Workshop (16:30-17:30)

Forum

Pedro Nascimento de Lima

DMDU Regional and Special Interest groups can advance the goals of the DMDU society by providing a nexus for greater collaboration and engagement with DMDU methods and tools. DMDU Regional Groups will enhance the geographic representation of the society, helping us to reach a broader audience in all continents. DMDU Special Interest Groups will provide a point of contact for specific disciplines (i.e., DMDU in Health) or specific domains of the DMDU methodology and practice (i.e., DMDU stakeholder engagement methods) that would benefit from greater structured collaboration amongst members. This workshop will gather member feedback about this initiative, identify an initial set of regional and special interest groups, the audiences they would reach, activities they may conduct and group leads.

Tuesday | 16:30 to 18:00 | Yangtze | *back to schedule*

Informal session organized by Pieter Bloemen (17:00-18:00)

-

-

Wednesday

Wednesday | 09:00 to 10:30 | Ganges | back to session overview

DMDU and energy (transition) I

Talks

09:05 - 09:21 | remote

Robust policies for unconventional oil and gas development in Argentina in a decarbonizing world

Sara Turner; Mariana Conte Grand; Julie Rozenberg

We use a robust decision making approach to explore the feasibility of developing the unconventional oil and gas sector in Argentina given uncertainty around the pace of global decarbonization. The performance of policy portfolios for oil and gas development and domestic energy transition support, under different future domestic and global demand and prices for oil and gas, investment costs, and fiscal incentives, are analyzed according to three objectives: positive NPV for the private sector (a necessary condition for investments), positive impact on fiscal accounts (Federal and Provincial) and positive impact on the trade balance (netting out imports). Results suggest that less than 30% of analyzed scenarios have positive impacts across all three goals and that trade balance and fiscal impacts are the primary constraint on meeting all three policy goals. Furthermore, positive outcomes for fiscal and trade balance are strongly corelated. Assessment of vulnerabilities finds that policy portfolios that prepare for a domestic energy transition by investing in energy efficiency, reducing price distortions between domestic and international markets, and actively beginning to increase electrification, perform better under futures in which the world moves away from oil and gas. By contrast, policy packages that continue current domestic energy policies and push harder for oil and gas development, are more vulnerable to negative fiscal and trade balance impacts in oil and gas under net zero scenarios.

09:21 - 09:37 | in person

Canadian Energy Transition Modelling is Increasingly Political – How Deep Uncertainty Might Help

Jason R. Wang

The Canadian economy and national political discussions are dominated by the energy sector, especially surrounding the oil and gas industry. In the province of Alberta, oil and gas extraction has contributed 25% to provincial GDP since 2000. Despite climate policy progress (e.g., national net-zero legislation and economy-wide carbon pricing), contemporary energy transition discourse has been politicized, and there is skepticism about policy durability. Energy regulator forecasts have, at times, been politically directed, and modelling outcomes used as political arguments (e.g., using policy cost estimates to justify inaction). Even within the modelling practitioner community, there is limited understanding of limitations to model-based analysis beyond their sensitivity to input assumptions. This talk summarizes three cases of net-zero energy and electricity production outlooks and their politicization: the Canadian Energy Regulator biannual Energy Future reports, a provincial electricity system operator net-zero electricity pathways study (that only studied one pathway), and the convergence of three modelling efforts that may have shaped the 2023 Alberta

election. I compare these studies to other Canadian modelling efforts where nascent Deep Uncertainty (DU) techniques – or ones similar to DU – have been used to inform policymaking and further reflect on the potential of DU, open-source modelling, and modelling literacy to depoliticize energy transition deliberations.

09:37 - 09:53 | in person

Using exploratory modeling and scenario discovery methods to identify drivers of decarbonization vulnerability across nations.

James Syme; Nidhi Kalra; Edmundo Molina

This study identifies drivers of decarbonization vulnerability in 26 nations using exploratory modeling and scenario discovery methods. The SISEPUEDE modeling framework is used as scenario generator in this study. SISEPUEDE is a rapidly deployable and scalable modeling framework for multisector dynamic exploratory emissions and cost-benefit modeling. It considers four emission sector models: AFOLU (agriculture and livestock, forestry, and land use), Circular Economy (solid waste and wastewater), IPPU (industrial processes and product use), and Energy (electricity, industrial energy, transportation, stationary emissions and carbon capture and sequestration). Individual nations' modeling profile is generated through the integration of over a dozen public databases, the review of scientific literature, and calibration. A maximum effort decarbonization policy, comprised of thirty different sectorial transformations, is defined for each nation. This maximum effort policy is then stress-test against an ensemble of 1,000 cases that combine different socio-economic, technological, and environmental conditions. The resulting database is then analyzed using scenario discovery methods to identity to identify nations' drivers of decarbonization vulnerability. We discuss resulting patterns of vulnerability drivers across regions and their implications for developing more robust decarbonization strategies in the region.

09:53 - 10:09 | in person

DMDU integration in Energy Planning

Matías Paredes-Vergara;José Luis Cerda-Arias;Rodrigo Palma-Behnke;Jannik Haas

Sustainable Energy Transitions (SET) develop under conditions of deep uncertainty in several dimensions, such as techno-economic, political, and sociotechnical. To support model-based decision-making under uncertainty in complex systems, such as SET, a body of literature known as Decision Making under Deep Uncertainty (DMDU) proposes several methodologies, each with strengths and limitations for SET application. Although these methods offer promising tools for long-term energy planning, their diffusion in decision-making instances is still scarce. Moreover, the DMDU approach has been catalogued to overlook some contexts for policymaking, particularly relevant in SET, such as the organizational and individual contexts. This work contributes to the DMDU literature by providing considerations to integrate the DMDU approach in long-term energy planning adequately. To do so, we reviewed the main sources of deep uncertainty and the prominent DMDU methods to cope with SET. Considering this characterization of sources and methods, we proposed a methodology for integrating DMDU methods in energy planning. Thus, using this methodology, we introduced a DMDU approach in an institution involved in energy planning in Chile, the National Electricity Coordinator (CEN). Following our methodology, Robust Decision Making (RDM) emerged as the adequate DMDU approach and diverse options for integration of RDM in the CEN were proposed. These considerations were developed based on an illustrative case for the transmission and generation expansion planning for the Chilean power system.

DMDU and Cities

Talks

09:05 - 09:21 | remote

Navigating Change: The Role of Spatial Planning in Adaptation Pathways

Efrén Feliú; Gemma García; Saioa Zorita

As cities and regions face the increasingly complex and uncertain challenges of climate change, long-term flexible adaptation pathways have emerged as a promising approach. These pathways offer a framework for anticipating and responding to future climate impacts, but their successful implementation relies heavily on effective translation into local and regional regulations, particularly in the domains of urban, spatial, and land use planning. This talk explores the challenges associated with integrating adaptation pathways into these planning processes. It highlights the need for cohesive strategies that balance the dynamic nature of adaptation pathways with the rigidity of regulatory frameworks. During the talk it will be discuss the importance of knowledge sharing and awareness raising between stakeholders, interdisciplinary collaboration, and the utilisation of innovative planning tools to bridge the gap between long-term adaptation goals and local planning practices.

09:21 - 09:37 | in person

Lessons Learned in Application of DMDU Methods to Urban Planning Projects in the US

Allison DeJong; Nastaran Tebyanian; Patrick Kane; Jordan Fischbach; Renee Collini; Colleen McHugh; Soupy Dalyander; Jessica Henkel

Challenges facing urban planners in the United States include contentious and polarized governance, deference to market-oriented solutions, and siloed treatment of critical systems. Methodologies intended to bring structure and transparency to complex multi-objective and multi-party decisions, including Structured Decision Making (SDM), Robust Decision Making (RDM), and related DMDU methods, hold promise for overcoming difficult governance challenges, expanding the universe of alternatives to consider, and integrating multiple uncertainties and systems. Over the past five years, a multidisciplinary team composed of urban planners, decision analysts, and physical scientists has applied a variety of decision support methods into planning at multiple scales, with successes and lessons learned. These projects include a state-level climate action planning process that used SDM to drive consensus toward a first-ever climate action plan in a fossil energy dominant state; a municipal resilience plan for a city larger than 2200 sq. km that incorporated a detailed analysis of spatial alternatives to inform place-appropriate adaptation strategies; a project modeling urban stormwater flood risk under uncertain climate conditions; and more. This presentation will detail from a practitioner lens how decision science and DMDU methods were originally scoped into these planning projects, how their application worked and evolved in the project context, and how those methods impacted the project's goals and implementation. This practitioner retrospective will engage researchers and practitioners, providing lessons learned about the conditions for successful application of DMDU methods, and opening the discussion for how decision scientists can develop relevant methods for practical application in complex urban planning processes.

09:37 - 09:53 | in person

Evaluating climate risk reduction strategies within the U.S. housing sector

Nadia A. Seeteram; Alizé Carrère; Reagan E. Cerci; Trinish Chatterjee; Anna Garner; Radley M. Horton; Katharine J. Mach; and Linda Shi.

Climate risks are increasing across the United States, motivating long-term planning for more resilient housing. Large-scale climate-related disasters have reduced available housing and "new normal" climate conditions are shifting resident preferences for safer housing, yet climate adaptation plans rarely include a housing-specific focus. Alignment across private- and public-sector actors within the U.S. housing sector is needed to build more resilient housing and reduce climate impacts, while simultaneously addressing ongoing housing-supply challenges. Path dependencies and maladaptation associated with current housing stock vulnerabilities may be limiting flexibility across possible decision options, enhancing societal goals, alternative futures, and adaptive pathways. This study evaluates risk-reduction strategies for addressing climate impacts on housing across coastal communities within the U.S., where intensifying climate-related disasters, sea-level rise impacts, and affordability concerns further pressurize tight housing markets. Based on ~60 in-depth semi-structured interviews with experts across government, financial institutions, commercial interests, urban planners, design firms, and community-based organizations, we investigate current and proposed risk-reduction solutions–and opportunities and barriers for implementing them within each sector across the climate risk-housing policy nexus. This presentation will highlight the experts' range of perspectives on climate risk-reduction strategies within their respective fields, including differences in approaches across rural, suburban, and urban gradients and interdependencies across sectors. Integrating a multi-sectoral approach with expert elicitation can provide critical information for the development of dynamic and adaptive policies that address long-term climate adaptation within housing.

09:53 - 10:09 | remote

Adaptative planning of drainage and rainwater harvesting systems under deep uncertainty

Gabriela Cristina Ribeiro Pacheco; Camila Yarla Fernandes; Conceição de Maria Albuquerque Alves

Urban Water Systems (UWS) have been treated as complex systems increasingly facing climate, social and economic uncertainties. In societies under unequal distribution of income and political instability, the planning and management of these systems pose additional challenges to decision makers. This study proposes and applies a decision making under deep uncertainty framework to evaluate the performance of two categories of UWS in Brazil, an Urban Drainage System (UDS) and an Urban Rainwater Harvesting System (URHS). The framework defined system configuration, objectives, deep uncertainty factors and performance metrics to evaluate selected policies in an ensemble of States of the World (SOW). The framework was applied to urban areas in the State of Goiás and in the Federal District of Brazil. Results for the URHS indicated selected categories of housing and levels of water consumption that could benefit the water security in the city in a large range of scenarios while visualizing the economic impacts for the water utility. In the case of the UDS, selected alternatives of stormwater management as Low Impact Development (LID) solutions for public areas and households can be evaluated indicating the uncertainties that influence the pathway towards more sustainable solutions. This strategy allows for defining the most robust solutions to generate better performance of the UWS for different urban areas under the challenges

promoted due to global changes.

Emerging fields in DMDU

Talks

09:05 - 09:16 | in person

Decision-making under deep uncertainty in cyber disaster preparedness.

Ponnoly, Joseph; Puthenveetil; John; D'Urso; Patricia;

In a hyper connected world, cyber threat is a global threat now escalating into the realm of cyber warfare. Cyber disasters such as Colonial Pipeline attacks or Solar Winds Hack of 2021 were nation-state attacks that targeted US critical infrastructures and the information technology ecosystem. These attacks were surprise attacks that had a devastating impact. Though they indicated systemic failures, they were mainly caused by decision-making failures. Decision-making under deep uncertainty in a volatile, uncertain, complex, and ambiguous world involved dealing with the unknown unknowns, the black swans, and dragons. Against these unknown unknown threats and risks, decision-making required decision-makers to foresee disaster events and to take measures to reduce the risk and potential adverse impact. Decision-making needed to consider the complexity of the interconnected systems. It involved sensing and sensemaking of the early warning signs of cyber disasters. A qualitative descriptive study of the phenomenon explored a proactive approach to cyber disasters, focusing on the influence of knowledge-based strategies for sensing and sensemaking of the early warning signs of cyber disasters. Decision theory (prospect theory) and complexity theory (complex adaptive systems) underpinned the study. The research questions focused on identifying factors contributing to decision-making failures and systemic failures in detecting the warning signs of cyber disasters. The findings were critical challenges and knowledge enablers to sensing and sensemaking of the warning signs. The conclusions support a new framework for proactive cyber disaster preparedness strategy and cyber early warning systems. (Dr. Ponnoly, Joseph, the researcher will be the main presenter. Dr. Patricia D'Urso was the dissertation committee chair and Dr. John Puthenveetil was the content expert. During the presentation, they will intervene as and when required).

09:16 - 09:27 | in person

A Viability-Based Optimization to aid adaptive forest management under global change

Clémence Labarre; Denis Loustau; Jean-Christophe Domec

Traditionally, optimization methods applied to the management of forest ecosystems have often focused on maximizing goods and revenues. However, managing such long-lived ecosystems admist deep climate uncertainties requires a paradigm shift in decision-making strategies. Challenges remain in predicting the occurrence and severity of extreme events such as droughts, fires or windstorms, their impact over the forest-wood supply-chain and in accounting for the future society's needs. However, decision-making in forestry is commonly overlooking the importance of tree resilience and forest adaptability that both are difficult to model and predict. Our study acknowledges management flexibility as preserving the maximal adaptability. By optimizing the flexibility of management alternatives over time, we postulate that forest ecosystems can better adapt and thrive in the face of extreme events. We aimed for a modular optimization program to maximize management flexibility at the regional scale and over the long run. Further, we estab-

lished a decision-making tool that dynamically evaluates the management degrees of freedom over the landscape to prioritize actions fostering the longevity of forest ecosystems. Our framework drew inspiration from viability theory to enhance the resilience, adaptability, and vitality capacities of forest ecosystems [1]. The decision-making tool was built upon the predictions of the process-based model GO+ [2] and identified critical bifurcations and treatment actions to be taken during a planning horizon. Our analyses uncovered the range of management possibilities that satisfy long-term forest objectives while preventing computational overload. Additionally, customizable options empower users to incorporate their own constraints and could be suitably used in a decision support system. Researchers and practitioners are invited to explore viability-based optimization, embracing deep uncertainty and flexibility for a sustainable future. [1] De Lara, M., and Doyen, L. Sustainable Management of Natural Resources: Mathematical Models and Methods. Environmental Science and Engineering Subseries Environmental Science. Berlin Heidelberg: Springer, 2008. [2] Moreaux, V., S. Martel, A. Bosc, D. Picart, D. Achat, C. Moisy, R. Aussenac, C. Chipeaux, J.M. Bonnefond, S. Figuères, P. Trichet, R. Vezy, V. Badeau, B. Longdoz, A. Granier, O. Roupsard, M. Nicolas, K. Pilegaard, G. Matteucci, C. Jolivet, A.T. Black, O. Picard, and D. Loustau, Energy, water and carbon exchanges in managed forest ecosystems: description, sensitivity analysis and evaluation of the INRAE GO+ model, version 3.0. Geosci. Model Dev., 2020. 13(12): p. 5973-6009 DOI: 10.5194/gmd-13-5973-2020.

09:27 - 09:38 | in person

Improving risk assessment of storms in a changing climate using storylines

Henrique M. D. Goulart; Karin van der Wiel; Linda van Garderen; Bart van den Hurk

High-impact climate events, such as storms, trigger actions and responses aimed at minimizing the impacts of similar events from happening again. However, the unfolding of an extreme event represents only one possible outcome within a range of potential scenarios, each carrying distinct impacts and requiring different responses. In addition, global warming introduces uncertainties regarding the nature and extent of changes in extreme climate events, potentially making measures based solely on a single historical event outdated. We aim to explore the benefits of generating alternative realizations of historical events to enhance our understanding of extreme event risks, particularly in the context of a changing climate. For that, we use physical climate storylines, which account for the deep uncertainties in future projections by relying on physically plausible alternative scenarios that are relevant for society. More specifically, we build alternative realizations of a historical storm, which consist of a combination of pre-determined levels of global warming, different sea level rise scenarios, and storm track manipulation. This way, we account for both internal variability and climate change effects. Results show sea level rise increases significantly the total coastal flooding. However, internal variability also plays an important role in the total coastal flooding, highlighting the importance of accounting for it when assessing the risk of high-impact climate events.

09:38 - 09:49 | in person

Exploring task specialization and interdependent tasks in the adaptation of military organizational structures

Yvonne Lont ; Tina Comes; Jan Kwakkel

The success of military operations depends on the timely availability of military units and essential supplies. The timeliness creates interdependencies in resources, which requires the coordina-

tion of operational decisions. The structures used to coordinate these decisions effectively are context-specific. Military organisations face deeply uncertain environmental contexts, which creates additional dynamics at the operational level. Adapting the coordinating structures within a continuously changing context is complicated because military organizations tend to be massive institutions organized in a vertical hierarchy, with a high level of task specialisation. Any coordination of decisions in such organizations is rigid and inherently involves various inertia. What is the effect of task specialisation on the emergence of a coordinating structure that can timely deliver the required essential supplies given the deeply uncertain contexts? Therefore, we explore the emergence of a vertical hierarchy in the presence of task specialisation and interdependent tasks and assess how deeply uncertain changing contexts affect organisational effectiveness: We extend Epstein's model (Epstein, 2006) of adaptive organizations with task specialisation and interdependent tasks. In this model, agents endogenously generate organizational structures and share information to make decisions. Next, we experiment with dynamically changing contexts and assess how this affects the performance of the organization and how this leads to organisational change and additional inertia.

09:49 - 10:00 | in person

Spatial Decision Making Under Deep Uncertainty (Spatial DMDU): Two Case Studies

Nastaran Tebyanian; Patrick Kane; Hong Wu; Lisa Iulo; Robert Lempert; Jordan Fischbach; Klaus Keller

Spatial planning decisions are often characterized by their wicked and complex nature (Batty and Marshall, 2012; Rittel and Webber, 1973). For one, spatial planning decisions modify complex human-natural systems. Moreover, these decisions are typically made under deep and dynamic uncertainties (Hillier, 2016; Rauws, 2017). In response, scholars have long questioned the relevance of predict-then-act frameworks for spatial planning problems (Batty and Marshall, 2012; Rittel and Webber, 1973). Despite these observations, methods for decision-making under deep uncertainty remain the exception in spatial planning. The emergent research in spatial DMDU tackles important and practical questions in climate risk management: "Where" to prioritize future mitigation and adaptation strategies under deep climate and socioeconomic uncertainties? This presentation reviews two case studies of spatial DMDU in the context of urban stormwater management in Pittsburgh and New Orleans. One study conducted in Pittsburgh's Negley Run watershed illustrates how factoring in deep rainfall uncertainty alters Green Infrastructure (GI) spatial allocation recommendations. These GI investments aim to satisfy multiple objectives, such as minimizing stormwater, reducing costs, and maximizing investment in vacant lands. A New Orleans study reveals that the main drivers of vulnerability can be either climate or infrastructure uncertainties, depending on the specific spatial area of focus. The presentation concludes with a brief discussion on the opportunities and challenges in advancing spatial DMDU research frontier.

10:00 - 10:11 | no info

DMDU + LLMs: Synergies in construction schedule management

Vahan Hovhannisyan; Alan Mosca; Yael Grushka-Cockayne

In construction, schedule uncertainties from various sources often lead to unanticipated challenges. In this talk, I will present our innovative work integrating Large Language Model (LLM) agents to automate not only the creation of scenarios but also the iterative steps involved in the

robust decision-making process, as part of nPlan's schedule risk forecasting and management platform. Our forecasting platform can create a comprehensive array of scenarios that capture uncertainties from an outcome-first point of view, leveraging machine learning on a large dataset of past schedules, and a large number of simlulations. This capacity to generate scenarios forms the basis of the automated DMDU process on top of which the LLMs are applied. On top of just scenario generation, our LLM agents have been actively participating in the various stages of DMDU. They facilitate the framing of decision problems, identifying vulnerabilities in current plans, and suggesting a range of policy alternatives. The agents then execute scenario discovery to assess the impact of uncertainties on policy options. They guide decision-makers through trade-off analysis, highlighting the consequences of different strategies. Moreover, the LLM agents are instrumental in the adaptive planning phase, recommending when and how to take actions, based on the evolving nature of uncertainties and project status. This is possible because the project's progress, and updated forecast, are re-generated regularly as soon as new information is available. I will present the technical architecture of our LLM agents, elaborating on how they actively contribute to each step of the DMDU process. Through real-world examples, I will demonstrate the efficiency and adaptability that these agents bring to construction project management, and how they can help in achieving robust decision-making. In conclusion, this talk will give an example of the paradigm shift brought about by the potential combination of LLM agents and DMDU. Through automating scenario generation and guiding the various steps of the DMDU process, these agents act as invaluable tools for achieving resilient, efficient, and informed decision-making in the face of deep uncertainties.

10:11 - 10:22 | in person

Decision making under deep uncertainty and neuroscience: an experimental approach.

Edmundo Molina

Decision-making in complex and uncertain environments is a high-level individual or group process that depends on various cognitive, psychological, and social mechanisms, such as perception, attention, memory, abstract thinking, and debate. Deeply uncertain environments require a series of decisions to be made, with each decision depending on rapidly changing information, complex computational intelligence tools (CITs), detailed data analysis tasks and multiple agents' perspectives. This talk discusses the results of a series of experiments that combine behavioral experimentation and neuroscientific methods to study decision making under deep uncertainty. We report results of an online experiment in which more than 500 respondents participated. The results of this experiment are used to develop decision-makers taxonomies. We used these taxonomies in a neuroscience laboratory to assess how experimental conditions, and participants psychological and neurological characteristics determine their decisions under conditions of deep uncertainty.

Wednesday | 11:00 to 12:00 | Ganges | back to session overview

DMDU and energy (transition) II

Talks

11:05 - 11:21 | remote

A large ensemble analysis of multi-sector impacts of NDC-driven energy transitions

Jacob Wessel; Jonathan Lamontagne (1); Gokul Iyer (2;4); Thomas Wild (2;3); Yang Ou (2;4); Haewon

McJeon (2;4)

The global transition to a deeply decarbonized energy system to meet goals set forth by the Paris Agreement and countries' Nationally Determined Contributions represents a complex problem with deeply uncertain and poorly understood multi-sector consequences. Mapping out a wide range of outcomes to identify important drivers and characterize uncertainties could enable policy-makers to mitigate tradeoffs and identify robust strategies for navigating this transition. This study contributes an exploratory scenario discovery analysis applied to a large ensemble of model realizations generated under a wide range of parametric uncertainties using a global-scale integrated assessment model to identify policy-relevant scenarios. Here, eleven energy-related sensitivities are systematically varied in the model configuration, representing national mitigation pledges, region-specific institutional factors, and global techno-economic parameters, among others. The resulting ensemble characterizes the impacts of a combinatorial time-evolving uncertainty space on energy-economic metrics (e.g., stranded assets, electricity burden) as well as socio-environmental metrics (e.g., water scarcity, crop production) to determine how future energy uncertainties drive national and global pathways toward deep decarbonization. Results show that the costs of the energy transition, as measured by multiple metrics, can be unevenly distributed across a wide range of future states of the world, while institutional factors are likely to strain developing countries' mitigation pathways. Previous studies characterizing parametric uncertainty typically vary only a few factors, and other large-ensemble work has not (to our knowledge) combined such a framework with climate mitigation pledges. Our results underscore the advantages of large-scale robust scenario ensembles in informing climate mitigation policy.

11:21 - 11:37 | no info

Energy Policy Analysis Towards Clean Energy Transitions in Mexico

Omar Castrejon-Campos

This talk presents the findings of an exploration into the effects of robust energy policy mixes on clean energy transitions in Mexico. We have developed and implemented a new integrated method to support policymakers in designing robust energy policy alternatives. Our method combines quantitative and qualitative approaches and integrates sustainability and energy transition concepts with analytical tools used by robustness-based approaches, quantitative simulation modelling techniques, and exploratory modelling and analysis. We discuss the relevance of applying model-based policy analysis with a robust approach to help policymakers improve the policy exploration process by identifying the consequences of implementing different policy alternatives towards energy transitions under deep uncertainty conditions. Our research findings suggest that policymakers in Mexico could focus on economic signals and performance standards to meet medium and long-term policy objectives on greenhouse gas emissions reduction strategies. Join us to learn more about our groundbreaking research and how it can help drive the clean energy transition in Mexico.

Wednesday | 11:00 to 12:00 | Rhone | back to session overview

Equity and Justice

Talks

11:05 - 11:21 | in person

Exploring Normative Uncertainty in IAMs: Unravelling the Sensitivity of Distributional Outcomes to Modelling Assumptions

Palok Biswas; Jazmin Zatarain Salazar; Jan Kwakkel

ntegrated Assessment Models (IAMs) are central to shaping climate policies. However, these models face a significant challenge: In long-term forecasts, normative uncertainty outweighs socioeconomic and climatic uncertainties. This predicament stems from the fundamental assumptions ingrained in the economic submodel, climate impact functions, and social welfare functions; these model components are fraught with deep uncertainties that inevitably magnify over extended time horizons. Normative uncertainty often goes unnoticed in the literature. Recent endeavours to enhance IAMs' complexity to capture detailed socioeconomic and environmental outcomes have, paradoxically, only amplified this normative uncertainty. If the normative uncertainty is not addressed, IAMs can exacerbate existing social injustices, resulting in significant distributional impacts. To delve into the normative uncertainty in IAMs, we employed the RICE 2023 model as a surrogate for the complex IAM currently in use. We transformed the RICE IAM from an optimization model to a simulation optimization model to enable a comprehensive exploration of uncertainty. Additionally, we modularized the components of RICE, facilitating a more detailed study of how different assumptions accross submodels affect the distributional outcomes associated with climate mitigation policies. In addition to the neoclassical submodel within RICE, we supplemented a post-Keynesian economic submodel, the DEFINE model formulated by Dafermos et al. (2018). We employed FAIR v2.0 as the climate model to investigate uncertainty in the equilibrium climate sensitivity and transient climate response. Different climate impact functions are also examined to estimate varying levels of regional damage, acknowledging that climate economic impact is deeply uncertain and highly contested. We also restructured the Social Welfare Function (SWF) in light of four distributive justice principles - Utilitarian, Sufficientarian, Egalitarian, and Prioritarian - to evaluate different mitigation policies' effects on societal well-being. Finally, we utilized the Multiobjective Robust Decision Making (MORDM) framework to identify optimal strategies amidst multiple, often conflicting objectives. This framework facilitates a comprehensive analysis of decision-making problems under deep uncertainties, aiding our investigation of uncertainty across different model components. We find that alternative assumptions in climate impact functions and SWFs result in strikingly different optimal abatement pathways. However, different economic assumptions fundamentally transform the effects of mitigation policies on economic growth. The neoclassical model presents a trade-off between mitigation and economic growth, while the post-Keynesian model proposes mitigation policies that facilitate economic growth. Our study offers critical insights into how different modelling assumptions influence the outcomes of IAMs, emphasizing the frequently overlooked normative uncertainty in these models. We argue for a thorough understanding of normative uncertainties and highlight the need for broader engagement of diverse stakeholders for deliberations and finding common grounds. Our research paves the way toward improving the fairness of IAM-generated climate policies by explicating implicit assumptions and systematically addressing normative uncertainty.

11:21 - 11:37 | no info

DMDU and Normative Futures: Clarifying the Frames of Future-Regarding Governance

Aleksi Neuvonen

The emergence of DMDU, coupled with a growing interest in various forms of foresight, highlights the demand for practices that support future-regarding governance. These practices aim to overcome the dominance of short-termism in planning and decision-making by providing tools to govern longer time horizons. However, the adoption of these practices is driven by different

factors in various contexts and organizations. In addition to coping with uncertainties, there is a parallel field of governance practices focused on normative futures. Science-based, normative long-term goals addressing climate change and biodiversity loss now serve as strategic horizons for contemporary societies. This phenomenon is poised to shape the field of future-regarding governance and planning practices across diverse sectors. While some attempts have been made in the DMDU literature to link it with transitions guided by long-term normative, society-wide goals (e.g. Malekpour et al., 2020), the topic has been relatively limited in scope and depiction. Normative goals introduce an additional layer of uncertainty, forming a new modality of governance that warrants exploration. This paper highlights the imperative to develop a robust and practical taxonomy of different frames for envisioning the future. Such a taxonomy would enhance future-regarding governance by enabling decision-makers to comprehend and effectively apply steadily available approaches like DMDU and various backcasting scenario methods. The integration of these approaches is particularly relevant in contexts such as the formulation of carbon neutrality policies, where their synergy can significantly facilitate effective decision-making. Keywords: Normative futures; Future frames; transitions; backcasting; Future-regarding governance Malekpour, S., Walker, W., de Haan, F.J., Frantzeskaki, N., Marchau, V. 2020. "Bridging Decision Making under Deep Uncertainty (DMDU) and Transition Management (TM) to improve strategic planning for sustainable development", Environmental Science and Policy 107, 158-167.

11:37 - 11:53 | in person

Exploring Equity Challenges into Deeply Uncertain Water Supply Investment Pathways: A Case Study in the Federal District of Brazil

Bruna M. Araújo; David F. Gold; Lillian B. J. Lau; Conceição M. A. Alves; Patrick M. Reed

Urban water managers worldwide are challenged by uncertainties driven by climate extremes, changes in land use, and sustained population growth. In recent years, adaptive water supply infrastructure pathways and exploratory modeling have proved to be important tools for identifying robust infrastructure investment and management policies. However, in regions containing high levels of social and economic disparities, decision-makers must carefully consider how adaptive actions shape conditions for the most vulnerable populations. In this work, we evaluate adaptive water supply investment pathways to support long-term water supply planning in the Federal District of Brazil (FDB). The FDB is home to Brazil's capital city, Brasilia, and nearly 3 million people. The historical development of the FDB has been marked by unregulated urban occupation, a rapidly growing population, and strong inequalities in income and water consumption patterns. This study applies the Deeply Uncertain Pathways (DU Pathways) framework to discover robust and adaptive infrastructure investment and management policies for the FDB, identify uncertainties that drive regional vulnerability, and examines the equity of policy outcomes. Our analysis clarifies regional inequity by disaggregating system performance according to the supply network's distinctly different regional supply areas that have significant differences in their underlying socioeconomic characteristics. Our results reveal that low-income regions in the FDB struggle to maintain acceptable performance and robustness levels, while high-income regions remain robust even in the most challenging, deeply uncertain scenarios. We further illustrate the importance of new infrastructure investment for maintaining acceptable system performance and show how regionally cooperative measures such as water transfers can help mitigate vulnerable areas' risks of water supply failure. Overall, our findings are relevant to decision-makers looking to unravel complex system dependencies between socioeconomically disparate regions and reveal the effects of systemic inequity on the performance and robustness of water utilities.

Sea level rise I

Talks

11:05 - 11:21 | in person

Characterizing socio-environmental tipping points in coastal communities facing sea level rise: a conceptual framework to support transdisciplinary research, exploratory modeling, and practical adaptation decision support

Julie Shortridge; Anamaria Bukvic; Jesse Goldstein; Molly Mitchell; Tom Allen

The concept of climate tipping points is receiving significant attention as researchers identify potential risks stemming from nonlinear changes in the earth's biophysical systems. In recent years, there have been efforts to translate this concept to socio-environmental systems to characterize non-linear climate change impacts and encourage rapid social transformations in response to increasing climatic hazards. However, the processes that lead to these tipping points, as well as their impacts, are highly complex and deeply uncertain. This stems not only from uncertainty in the rate and nature of climatic and non-climatic drivers, but also the environmental and human responses to these drivers. In the face of this complexity and uncertainty, this research presents a conceptual framework that describes potential systemic processes that could lead to socio-environmental tipping points in coastal communities facing sea level rise. Within this context, we propose a conceptual framework consisting of elements, state variables, links, internal processes, and exogenous influences. This conceptual framework is then used to describe three mechanisms by which socio-environmental tipping could occur. We also present results from an expert panel review, in which resilience professionals, planners, and stakeholders assessed the framework and found that it had particular potential in characterizing the effects of secondary climatic impacts that are rarely the focus of coastal risk analysis activities. Finally, we identify salient areas for further research that can use the proposed conceptual framework to provide planning and decision support for building community resilience in the face of sea level rise.

11:21 - 11:37 | in person

Order up or abandon ship? Exploring critical thresholds for decision making in barrier island management

Patrick Kane; Nastaran Tebyanian; Soupy Daylander; Travis Swanson; Diana Di Leonardo; Maricel Beltran Burgos

Barrier island chains provide a vital form of protection against the effects of tropical storms for communities all along the Louisiana coastline as well as providing valuable habitat for many species. While barrier islands may recover land area lost to storms in some cases, the effects of sea level rise and increased storm intensity due to climate change have left the barrier islands of Louisiana's coast in need of regular restoration to prevent island loss. The management of this sediment nourishment presents its own set of challenges in determining how best to source sediment and which islands to prioritize. We present a reduced complexity model of the Louisiana barrier island system that incorporates the interconnections between islands and the effects of sea level rise and populated with data drawn from newly developed statewide databases, all at a level of resolution suitable for decision making on the order of years to decades. We pair this reduced complexity model with a simplified policy design drawn from analogy to the literature on supply chain management . We use this model and policy space to search for robust strategies for long

term sediment management, including decisions for when to search for new sediment sources and how to prioritize restoration operations in the immediate aftermath of a storm. The framework is being co-developed and applied in close coordination with decision makers at Louisiana's Coastal Protection and Restoration Authority.

11:37 - 11:53 | in person

Enhancing the practice of scenario analysis of large systems in the context of Decision Making Under Deep Uncertainty (DMDU)

Jayantha Obeysekera

Rapidly evolving current conditions and increasing uncertainty of future projections present formidable challenges to the sustainability and resilience of large-scale water resource systems subject to human influence and environmental drivers that are nonstationary. The California Bay Delta System, our case study example, consisting of a complex network of waterways, islands, and marshes is a critical hub for the State of California's ecosystems and its water supply. The Bay Delta region faces pressing challenges including water scarcity and ecosystem decline which will be exacerbated by numerous environmental drivers including sea level rise, altered precipitation patterns, rising temperatures, increasing wildfires, and changing social, policy, and economic dynamics. The region is poised to make substantial investments aimed at the sustainability and resilience of both human and environmental systems in the face of deeply uncertain futures. The California Delta Independent Science Board (ISB) is conducting a review to build scientific tools that can increase the capacity to anticipate and adapt to growing uncertainties of future conditions in the region. This review encompasses the exploration and analysis of plausible and possible future scenarios, the assessment of the utility of Decision Making Under Deep Uncertainty (DMDU) tools, and the examination of the role played by cognitive biases in scenario development. This presentation will provide an overview of the summary of expert elicitation from a group of practitioners well-versed in these subject areas and the proposed strategies for addressing uncertainties associated with the alternative futures of the Bay Delta system.

Wednesday | 13:00 to 14:00 | Ganges | back to schedule

Policy Relevant Uncertainty Analysis in Energy System Modeling: An Expert Panel Debate

Panel

Leslie Abrahams; Mikenna Montgomery; Rolando Almada; Michael O. Dioha

Uncertainty analysis plays a crucial role in energy system modeling, providing insights into the robustness and reliability of modeling results and supporting informed decision-making. However, the process of uncertainty analysis is often complex, specialized, and limited to a select group of experts, which can silo the important information gained by such an analysis within a theoretical realm rather than informing policy analysis and legislative decisions. Despite advances within the literature of new methods and applications of uncertainty analysis to this field, most policy decisions remain informed by deterministic models that run under a limited set of scenarios. While there is a need to continue the academic pursuit of new methods for deepening understanding of uncertainty, we simultaneously need to strive to identify transparent, impactful, and time-relevant means of infusing decision-relevant uncertainty into the policy realm and encourage a more effective, equitable, and sustainable energy transition. This panel seeks to convene experts at the intersection of technical analysis and policy to discuss the challenges and barriers of translating

uncertainty to inform policy decisions and how these may be addressed. The discussion will delve into key themes, including: -Policy and Decision-Making Challenges: Limitations preventing uncertainty analysis from being consistently applied within a policy context. -Simplifying Uncertainty Analysis: Development of user-friendly tools, guidelines, and frameworks that enable non-experts to perform meaningful uncertainty assessments. -Collaborative Uncertainty Assessment: Collaborative approaches in uncertainty analysis, involving diverse stakeholders such as researchers, policymakers, industry representatives, and local communities. -Communication of Uncertainty: Effective communication strategies for uncertainty analysis results, ensuring clear and concise messaging that is understandable to policymakers, stakeholders, and the general public. -Education and Capacity Building: Empower a wider range of individuals and organizations in conducting uncertainty analysis.

Wednesday | 13:00 to 14:00 | Rhone | back to session overview

DMDU in health applications

Talks

13:05 - 13:21 | in person

The need for an adaptive decision model to cope with uncertainties in health care

Anke Aarninkhof-Kamphuis; Hans Voordijk; Geert Dewulf

A longitudinal study will be presented to develop a dynamic adaptive decision support model for healthcare organizations. Many of the studies so far on adaptive models focused on policy studies and not on decision-making within organizations that have to deal with a rapidly changing context and hence 'deep' uncertainties. The case study allows the researcher to understand the complex social and technical realities of strategic decision-making by a healthcare organization. For this purpose we take the complex decision-making of real estate decisions in health care as case since they can be characterized as deep uncertainties with high stakes for the organization. The research results in the design of an adaptive decision support model. The model and implementation lessons will be discussed at the conference. Participants at the conference will be invite to share their comments to further improve the model.

13:21 - 13:37 | in person

Resilience assessment and improvement of coupled societal systems against future pandemics

Sophie, Hadjisotiriou; Coenen; Jannie; Marchau; Vincent; Korzilius; Hubert; Olde Rikkert; Marcel

The need for making systems more resilient against future pandemics has been argued by various researchers and governmental institutions. Particularly, pandemics carry many deeply uncertain effects on the functioning of coupled systems caused by their ill-predictable interactions. Furthermore, the dynamics of these systems may impact resilience on the short and long term due to a change in the functioning of one system and how it interacts and impacts the other systems. In this paper, we show how exploratory scenario development and group model building can be combined to identify domain-specific resilience assessment and improvement indicators of coupled societal systems against future pandemics in a participatory manner. Exploratory scenarios enable to understand how uncertainties regarding pandemics interact to give way to different futures. Causal loop diagrams help us to identify and visualise experts' views on resilience in relation to the target variables of coupled complex systems. The assessment indicators are slow and fast variables,

thresholds, critical feedback loops, and cross-scale interactions, while improvement indicators constitute the elaboration of leverage points. Confronting the causal loop diagrams with exploratory scenarios, provides insight into how different futures may affect or change resilience of coupled systems. Through exploratory scenario development and group model building as a preparatory approach, future research can focus on quantitative resilience assessment and improvement of coupled complex systems under deep uncertainty to inform policymaking towards more resilient systems. We illustrate a preparatory approach through the target variable 'accessibility' of the healthcare and education system in the Netherlands during future pandemics.

13:37 - 13:53 | in person

Robust Decision Making in Health Policy: Applications to COVID-19 and Colorectal Cancer

Pedro Nascimento de Lima; Robert Lempert

The COVID-19 pandemic demonstrated the value of modeling to inform health policy. Models were used to provide situational awareness and inform mitigation policies. However, uncertainty surrounding the longevity of vaccine and infection-induced immunity, the emergence and characteristics of SARS-CoV-2 variant strains, and behavioral responses to policy interventions prevent modelers from providing more than a few weeks of model-based foresight. Under those conditions, policymakers have options to control the pandemic, but deep uncertainties deny the prediction of their long-term effects. This talk presents a series of projects that demonstrated the utility of RDM for supporting health policy decisions. We present RDM applications to COVID-19 disease (COVID-19) and cancer prevention, and discuss opportunities and challenges in using DMDU methods to inform decision-making in the life sciences.

Wednesday | 13:00 to 14:00 | Yangtze | back to session overview

Sea level rise II

Talks

13:05 - 13:21 | in person

Should we stay or should we leave? Beach nourishment versus managed retreat under deep uncertainty

Prabhat Hegde; Vikrant Vaze; Klaus Keller

Sea-level rise poses considerable risks to coastal communities, ecosystems and infrastructure. Levers to manage these risks fall into three categories: (i) protect (ii) accommodate or (iii) retreat. Designing a sound risk strategy can be challenging, for example due to trade-offs and synergies between multiple objectives and/or the deeply uncertainty surrounding model structures and parameters. Past studies addressing this question have provided valuable insights. However, they are typically silent on deep uncertainties and/or the trade-offs between objectives. Moreover, most studies considering retreat typically assume that retreat takes place instantaneously and with perfect foresight. In contrast, real retreat is often slow and incomplete. We hypothesize that accounting for slow and imperfect retreat would increase the costs of the economically efficient strategy and therefore would mandate earlier retreat. The current nexus provided by newly available system models, efficient multi-objective optimization algorithms, and uncertainty characterization methods enables important new insights on how realistic representations of retreat impacts the decision of when to retreat and to offer reliable flood-protection while staying in place. The scientific community still lacks a sound quantitative understanding of how retreat may impact

the spatio-temporal dynamics of the coast. Our study provides an avenue towards an improved understanding of these dynamics. Current funding programs for buyouts struggle to meet existing demand, with years-long wait times. The methodology we propose aims to alleviate these concerns by enabling the planning and initiation of early retreat.

13:21 - 13:37 | in person

Coastal Setback Zones as Adaptive Strategy for Reducing Urban Exposure to Sea-Level Rise: A Country-Specific Evaluation under Uncertain Socio-economic Development in Europe

Claudia Wolff; Hedda Bonatz; Athanasios T. Vafeidis

Reducing future coastal urban exposure is a critical aspect in addressing the risks posed by sea-level rise, associated hazards, and human settlement patterns. While studies have acknowledged the effectiveness of constraining urban expansion within coastal floodplains as an adaptation measure, there is a knowledge gap regarding the potential of landuse planning interventions to reduce coastal exposure in Europe. This study aims to address this gap by comprehensively evaluating various coastal setback zones as adaptive strategies for minimizing urban exposure in the face of sea-level rise and uncertain socio-economic development. To assess the efficacy of these strategies under uncertain socio-economic conditions, we developed country-specific urban change models that use input variables such as elevation, population density, or road network and an artificial neural network to project urban development on a regional scale. These models encompass coastal EU Member States, along with BIH, GBR, and NOR, where relevant data and Shared Socioeconomic Pathways projections were available. Our analysis focuses on quantifying the extent of urban land located within coastal lowlands under different types of setback zones and socio-economic projections. Our findings highlight the location-specific nature of optimal setback zone designations, influenced by factors such as coastal profile/floodplain morphology. Notably, nations with large coastlines, such as Italy, Norway, France, Sweden, and Great Britain, can derive substantial benefits from implementing setback zones due to the inherent challenges and costs associated with protecting long coastal stretches. Implementing the most effective setback zones tailored to each country could potentially reduce coastal urban exposure in the EU by 47% under a high urban growth scenario. Furthermore, the study highlights the effectiveness of establishing setback zones based on specific elevation criteria, prohibiting construction above a certain height relative to sea level. This approach emerges as one of the most efficient strategies for reducing urban exposure in coastal lowlands across the majority of EU countries. Thus, the design, construction, and development of urban spaces in Europe's coastal lowlands will play a pivotal role in determining future exposure to sea-level rise. In summary, this study emphasizes the importance of considering diverse adaptation strategies, including coastal setback zones and retreat, while stressing the necessity of country-specific approaches that account for coastal characteristics. By providing insights into effective measures for limiting urban exposure, this research contributes valuable knowledge towards shaping resilient and sustainable urban futures in the face of uncertain future coastal conditions in Europe.

13:37 - 13:53 | in person

Navigating Sea-Level Rise Adaptively in the U.S. Gulf Coast: A Local Perspective

Renee Collini; Alison Rellinger; Jordan Fischbach; Allison DeJong; Nastaran Tebyanian; Ioannis Georgiou; David Rounce; Mathew Weathers; Stephanie Patch

Adaptation pathways that enable responding to sea-level rise based on observed trigger points provide an appealing, common-sense approach to planning under deep uncertainty, allowing stewards of fiscal and physical resources to avoid unnecessary expenditures, while still being prepared for changes. This is particularly true in communities that have less funding or very dynamic landscapes (e.g., barrier islands). However, practical applications of dynamic adaptive policy pathways or related approaches are difficult in some cases. For example, developing pathways frequently requires additional detailed modeling, and there is often a mismatch of timing between information and expected action. As this approach reaches a greater awareness among users with a variety of technical and fiscal capacities, the needs around successfully pursuing and implementing adaptive pathways are diversifying. This presentation will share preliminary results from focus groups of different stakeholders addressing sea-level rise across the U.S. Gulf Coast. The focus groups assessed current perspectives on uncertainty and timing of SLR and how that translates to potentially applying adaptive planning and pathways to their work. A key aspect of those conversations was discussing the potential benefit of a screening-level tool that assembles basic adaptation pathway options to allow users to explore adaptation options within the context of probabilistic sea-level rise projections. This presentation will also include an application case study in a small (<1,500 people), barrier island community and explore additional lessons learned on the practical applications at the local level including how stakeholder engagement shaped the process and the outcome.

Wednesday | 14:15 to 15:15 | Patio | back to schedule

Panel on the DMDU future

Key Note

DMDU

-

Wednesday | 15:15 to 15:30 | Patio | back to schedule

Closing by Marjolijn Haasnoot and Jan Kwakkel

Key Note

Jan Kwakkel, Marjolijn Haasnoot

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Useful Information

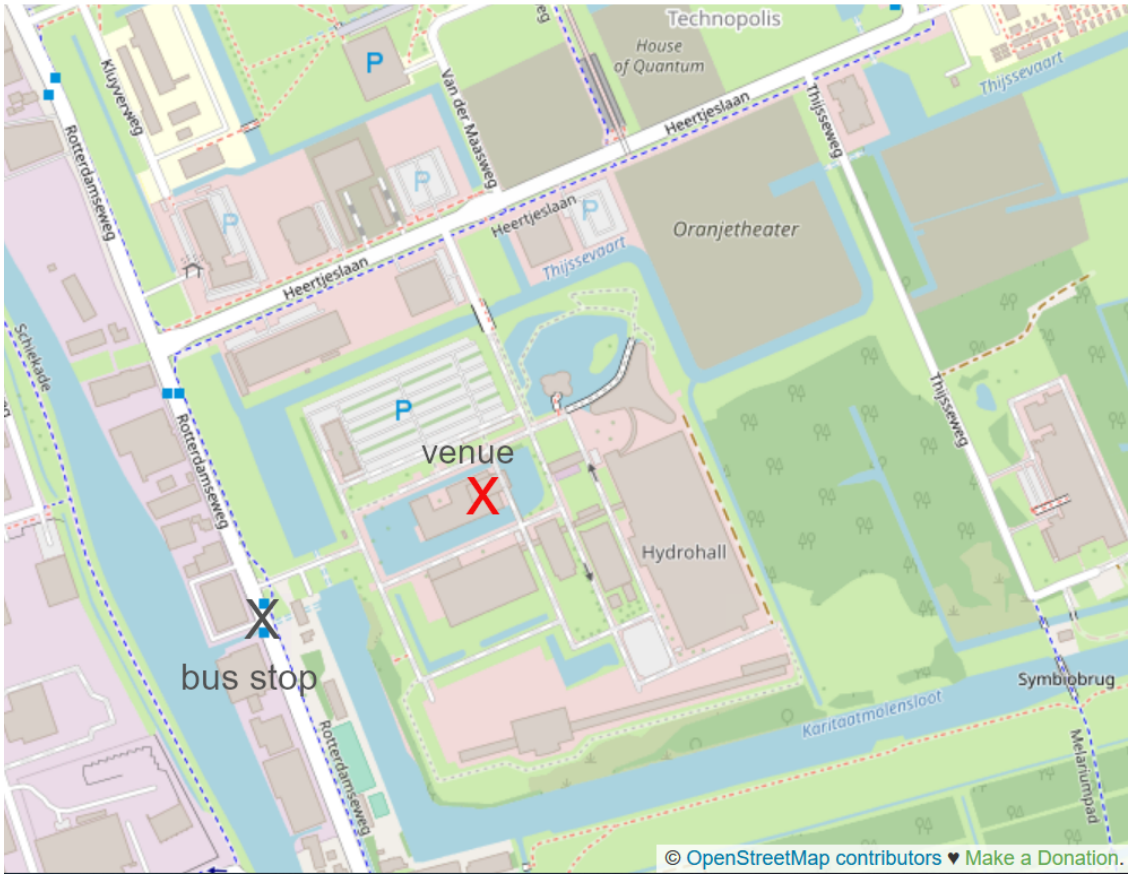
Accommodation options

There are plenty of accommodation options in Delft and around. We recommend: Hotel Royal Bridges, Grand Museum Hotel, Hotel Johannes Vermeer, or Hampshire Hotel.

The Venue and how to get there

The conference will take place at Deltares, Boussinesqweg 1, 2629 HV Delft, located outside the city center of Delft.
From the city center of Delft, it is a 3,5 km (flat) walk to the conference venue. Alternatively, bus 40 goes from Delft station to bus stop 'Delft, Vrijenban' which is a 4-minute walk away from Deltares.

At Deltares, the conference takes place in the main building (with the large tower). Registration and rooms are set up on the ground floor.



Conference Dinner

On Monday evening, the conference dinner will take place. The costs for food are covered by the registration fee. You have to pay yourself for the drinks.
The conference dinner on Monday is at Lijm & Cultuur. It is a 22-minute walk, or a 7-minute bus ride (the same bus 40) from Deltares.

WiFi

There are two general purpose wireless networks available: the eduroam network and the wireless network which is visible from a device with wifi as "DELTARES". If you have an eduroam account your device should automatically connect.
If you want to use the "DELTARES" wireless network, you can request access by scanning the QR code below, using the column at Delta Plaza, or entering the weblink eduroam.deltares.nl within the browser of your device. You will be sent to a registration form where you are obliged to fill in a number of details. This data will be stored for a period of 3 months so that you can be traced in the event of undesirable activities. After filling in the registration form, you will receive a text message with the Eduroam login details. This login data can be used by the visitor for Wifi connection with the laptop, tablet or mobile phone. The account is valid for one day. After this day the procedure has to be repeated.