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How media narratives can be used in Decision Making under Deep Uncertainty practice?

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Media narratives employed in contemporary journalism, including data journalism, are critical in shaping public understanding of the complex systems that affect our lives. Depicting a chain of events in a "story" format, narratives are constructed with detailed, precise, and well-researched information based on character identification, human emotions, and real social problems. In many ways, they are indispensable intermediaries of practiced judgment and expertise that guide the public to meaningfully engage with evidence-based understanding of our world and how we can act upon it. DMDU narratives suggest that we can act to shape the future toward our liking even when we cannot predict what that future will be, that we need to simultaneously consider multiple rather than a single future, and that the quest for prediction can interfere with the task of identifying the best actions. DMDU practice relies on substantive stakeholder interaction, and it is supported by vast amounts of empirical evidence. This perspective discusses how media narratives intersect with DMDU to inform and to leverage the complexities of modern contemporary public challenges. We first explore how uncertainty might be actionable, as opposed to fearful. Next, while acknowledging limitations on transference of information during the journalistic process, we address the challenges and best strategies to distill information to the public to maintain and build trust about uncertainty. Next, we discuss how journalistic practices could be useful for disseminating more broadly findings of DMDU analyses.

KEYWORDS

media narratives, deep uncertainty, journalism, complex systems, science communication

Introduction

Media narratives[1] play a significant role in shaping how people perceive and understand the complex issues that influence our lives. These narratives help to convey intricate details and foster comprehension among the public. However, uncertainty complicates these narratives, forcing journalists to balance uncomfortably between accuracy and telling a compelling story. This balancing act often leads to challenges in maintaining the integrity of the information while still engaging the audience. When knowledge is limited and complexity

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1   In this perspective we define narratives as stories with a beginning, middle, and end. Such stories have characters, temporality, and causality, and the details have cause-effect patterns, giving them their persuasive force (Dahlstrom, 2014).

is high, the media may amplify certain narratives and perspectives (Kasperson et al., 2022), influencing public opinion and subsequent decision-making.

Decision Making under Deep Uncertainty (DMDU) traditionally focuses less on narratives, but its methodologies support an account that uncertainty is actionable. DMDU communicates the implications of different scenarios by identifying key decision trade-offs and vulnerabilities, suggesting robust, flexible responses that perform well over a wide range of futures (Lempert et al., 2006; Marchau et al., 2014; Kwakkel et al., 2016). But because DMDU has traditionally emphasized technical details and quantitative analysis, its results can become overly complex and difficult to disseminate broadly.

This perspective explores the extent to which DMDU narratives regarding uncertainty can help journalists mitigate the tradeoff between accuracy and compelling storytelling. By crafting stories that include uncertainty as a fundamental theme, journalists can create engaging narratives that remain faithful to the complexities involved. Furthermore, understanding and informing media narratives can help DMDU practitioners craft more compelling stories about their own work.

We discuss and exemplify how DMDU practice transforms uncertainty into actionable information, motivating individuals and organizations to act despite inherent uncertainties. We then analyze, from the journalism practice perspective, the challenges associated with conveying complex information through narrative journalism and discuss examples of the strategies that journalists use to distill information effectively while maintaining accuracy and trust. Finally, we examine how the intersection between DMDU research and narrative journalism can foster a deeper understanding of complex issues, empowering the public to participate in informed discussions and advocate for effective policies.

The narrative of uncertainty as actionable

Navigating complex systems under deep uncertainty[2] often leads to paralysis and political gridlock. DMDU methods address these challenges with multi-scenario, multi-objective analytic tools and processes of stakeholder engagement using these tools. DMDU analytics use simulation models to scan over large numbers of plausible futures, statistical algorithms to cluster those futures into policy-relevant scenarios, and then help identify actions policy makers can take that make sense over a wide range of futures. DMDU participatory stakeholder engagement helps frame the analyses, generate shared understanding of key tradeoffs, and

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2 Deep uncertainty refers to the lack of knowledge about what the future holds. When decision makers ignore this reality, they can become overly confident, miss out on opportunities, and implement policies that are vulnerable to unexpected events. Deep uncertainty arises when experts or stakeholders do not know or cannot agree on: (1) suitable models to represent the relationships between key factors influencing a system, (2) the probabilities associated with crucial variables and parameters, and (3) the relative importance and desirability of different potential outcomes.

build consensus on near-term actions. DMDU leverages the very ambiguity of these decision-making contexts to activate informed action (Lempert et al., 2006; Marchau et al., 2014).

DMDU computer assisted reasoning leads to the development of dynamic narratives based primarily on empirical findings. Exploratory modeling enables decision-makers and stakeholders to quantitatively assess the implication of vast arrays of different alternative futures. This experimental engagement goes beyond abstract risk assessments, injecting curiosity and a sense of agency into the decision-making process. Unlike unidimensional predictions, DMDU computational experimentation methods encourage exploration, prompting stakeholders to test their assumptions in different situations, despite the absence of certainty in prediction (Groves and Lempert, 2007; Bryant and Lempert, 2010; Kwakkel and Pruyt, 2013).

DMDU methods, like scenario discovery and adaptive pathways, leverage uncertainty to identify key tradeoffs in decision-making. By exploring vast arrays of uncertainties and courses of action, DMDU methods seek to identify key assumptions upon which different decisions are guaranteed. This "stress-testing" exposes unforeseen vulnerabilities and fosters adaptive planning (Bryant and Lempert, 2010; Moallemi et al., 2020). Studies that use DMDU methods often identify potential pitfalls and unintended consequences of status-quo actions. This often empowers stakeholders to refine the design of their policies and plans before committing to real-world implementation (Groves et al., 2019; Molina-Perez et al., 2019; Kalra et al., 2023; Moallemi et al., 2023). Empirical studies support these DMDU methods for making uncertainty actionable. For instance, presentations of climate information that emphasize intersection (e.g., that experts agree on a range of projections) and balance (e.g., avoid unwarranted precision) generate more confidence than presentations that emphasize disagreement over specific projections or seem overly precise (Benjamin and Budescu, 2018). Decision support tools that present uncertainty as a range of scenarios encourage users to seek more resilient strategies than decision support that present uncertainty with best-estimate probability distributions (Gong et al., 2017).

Existent literature in which DMDU methods and processes have been applied show that this analysis framework is conducive to construct actionable narratives that incentivize policy action. Table 1 summarizes four DMDU case studies. These four studies, despite their diverse contexts, collectively exemplify a narrative of uncertainty as actionable, revealing both commonalities and nuances in how they utilize DMDU methods to transform uncertainty into policy debate, re-design, and adaptation.

The four examples explicitly acknowledge and quantify uncertainty. In the pandemic response and Colorado River Basin studies, this involved modeling a wide range of scenarios to understand potential vulnerabilities and stress-test different strategies. The Israeli energy study embraced uncertainty by considering diverse plausible futures, while the decarbonization study quantified the relative importance of actions under varying conditions. This shared emphasis on quantification allows for more systematic decision-making under uncertainty. However, each case study operationalizes uncertainty differently. The pandemic response and Colorado River Basin studies focused on identifying

TABLE 1 Summary of DMDU case studies.

Case study	Narrative of uncertainty as actionable
A. Reopening California: Seeking robust, non-dominated COVID-19 exit strategies (Nascimento de Lima et al., 2021)	• **Quantified uncertainty:** The study explicitly modeled a wide range of uncertainties related to COVID-19 transmission dynamics, vaccine effectiveness, and societal behaviors. These uncertainties included uncertainties well-characterized by probabilities as well as deep uncertainties such as future virus variants and the effectiveness of vaccines. • **Tested robustness:** The study stress-tested 78 different reopening strategies comparing their performance under a wide range of future conditions, enabling comparison of standard and more novel approaches. • **Provided actionable insights:** Over the entire range of uncertainty, strategies that observed trends such as hospitalizations and adjusted masking and other guidance based on time-varying thresholds outperformed all other types of strategies for both economic and health outcomes. Embracing uncertainty thus yielded confidence about the best response.
B. The Benefits and Costs of Reaching Net Zero Emissions in Latin America and the Caribbean (Kalra et al., 2023)	• **Quantified importance:** The study assessed thousands of decarbonization strategies to identify the most critical actions for achieving both net-zero emissions and economic benefits. This quantifies the relative importance of different approaches, aiding decision-makers in prioritizing efforts. • **Addressed uncertainty:** The study considered a wide range of uncertain conditions, such as technological advancements and societal changes, to evaluate the robustness of the identified key actions. • **Highlighted co-benefits:** By embracing a wide range of uncertainty, the analysis finds that implementing of key actions not only reduces emissions but also leads to significant net benefits, including economic gains, improved health outcomes, and enhanced ecosystem services over a wide range of future conditions.
C. Adapting to a Changing Colorado River: Making Future Water Deliveries More Reliable Through Robust Management Strategies (Groves et al., 2013)	• **Evaluating targeted solutions:** The study's evaluation of different management portfolios under a wide range of scenarios helped water managers identify which strategies are most effective in mitigating specific vulnerabilities. • **Prioritizing near-term actions:** The study's identification of high-priority, near-term options that should be implemented quickly gives water managers a clear roadmap for taking immediate action to reduce risks in the short term. • **Enabling adaptive management:** The study's recommendations for systematic and recurring system assessments, as well as early planning for long lead-time options, provide a framework for ongoing adaptation to changing conditions. This allows water managers to adjust their strategies over time as new information becomes available, ensuring that the system remains resilient in the face of uncertainty.
D. Natural Gas and Israel's Energy Future: A Strategic Analysis Under Conditions of Deep Uncertainty (Popper et al., 2009)	• **Embracing a wide range of futures:** The study considers a wide range of plausible futures, from favorable to undesirable ones. This allows decision-makers to understand the potential risks and opportunities associated with different energy strategies under various conditions. • **Identifying robust strategies:** By evaluating different natural gas utilization and supply infrastructure strategies across numerous scenarios, the study identifies those that perform well across a broad spectrum of potential futures. • **Revealing key vulnerabilities:** The analysis reveals the factors that could lead to undesirable futures for Israel's energy sector, such as disruptions in natural gas supply or fluctuations in global energy prices. This information enables decision-makers to take proactive steps to mitigate these vulnerabilities and reduce Israel's exposure to risk. • **Informing strategic choices:** The study's identifies a strategy, different from any considered at the start of the analysis, that performs well compared to the alternatives across a wide range of future conditions.

vulnerabilities and evaluating targeted solutions, whereas the Israeli energy study prioritized the identification of robust strategies that perform well across diverse scenarios. The decarbonization study, on the other hand, emphasized the co-benefits of actions, making a compelling case for their implementation even under uncertain conditions. All studies highlight the importance of continuous learning and adaptation in the face of uncertainty. The pandemic response and Colorado River Basin studies explicitly recommend ongoing monitoring and evaluation to inform future decisions. The Israeli energy study emphasizes the need for strategies that are adaptable to changing conditions, while the decarbonization study underscores the importance of co-benefits in maintaining support for actions over time.

These four examples show how DMDU methods can lead to narratives where uncertainty is not a roadblock, but rather a steppingstone toward more informed, robust, and adaptive decision-making. In many respects, DMDU enables a process where it is possible to create a kaleidoscope of possible futures. By identifying "policy-relevant scenarios," DMDU methods showcase

diverse outcomes from multiple perspectives and dimensions of merit (Lempert et al., 2003; Haasnoot et al., 2013). ultimately equipping decision-makers with contingency plans and enabling them to navigate unexpected turns in a world in constant flux.

Journalistic processes to report deeply uncertain phenomena

The inherent tension in journalism between the pursuit of accuracy and the creation of compelling narratives is amplified when reporting on complex and uncertain phenomena.[3] The dilemma lies in the fact that achieving absolute accuracy can

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3 There are typically two definitions of uncertainty in the media: (1) probabilistic uncertainty, that is, uncertainty about specific events where the statistical distribution is known, and (2) epistemic uncertainty, that is, uncertainty arising from the validity of truth claims (Peters and Dunwoody, 2016).

sometimes lead to stories that are too technical or complex for a broad audience to follow, diminishing their appeal and impact.

Scientific claims are often accompanied by significant uncertainties. Journalists face a critical decision point in how to incorporate this uncertainty into their reporting. Ignoring uncertainty and presenting scientific findings as absolute truths can mislead the public and create a false sense of security. Conversely, abstaining from reporting on uncertain topics can deprive the public of crucial information and hinder informed decision-making.

A balanced approach, incorporating rhetorical techniques or diverse perspectives, can effectively contextualize scientific claims within the broader landscape of uncertainty (Peters and Dunwoody, 2016). Journalists' decisions about how to include uncertainty are influenced by several factors:

- Perceived uncertainty in the field: Journalists' understanding of the level of uncertainty inherent in the research they are reporting on.
- Audience expectations: The perceived needs and knowledge level of the intended audience.
- Competing media: The editorial choices made by other media outlets covering the same topic (Guenther and Ruhrmann, 2016).

Scientific claims in mass-media are often presented as more certain than would been described by the scientific community. This tendency can lead to an underestimation of risks (Peters and Dunwoody, 2016). In contrast, presenting conflicting scientific claims in media stories can lead to exaggerated audience perceptions of uncertainty (Kohl et al., 2016).

The motivations of various stakeholders, including scientists, representatives of companies, public interest groups, and government agencies, influence their willingness to talk about uncertainties. These motivations can be related to concerns about policy, public perception, or the potential consequences of acknowledging uncertainties (Post, 2016). Audience engagement also plays an important role (Besley et al., 2015). Comments and discussions by readers can alter the perceived meaning of stories, impacting the interpretation of uncertainty or certainty in the phenomenon being reported (Peters and Dunwoody, 2016).

Table 2 provides three examples of journalistic efforts to report on deeply uncertain phenomena. The three examples use distinct journalistic approaches to deal with uncertainty. The Greenland ice melt article acknowledges the uncertainty inherent in predicting future ice loss, emphasizing the consensus among scientists regarding the accelerated melting trend while transparently citing recent studies as the basis for its reporting. The COVID-19 death toll article explicitly grapples with the complexities of defining and measuring the pandemic's impact, presenting its own model for estimating excess deaths while openly discussing its limitations and potential biases. The article on polling uncertainty, on the other hand, focuses on the methodological challenges and potential inaccuracies in polling, quoting experts and citing studies to contextualize the issue.

While all three articles acknowledge the inherent uncertainty in their respective topics, the degree of transparency and depth of analysis varies. The Economist's COVID-19 article focusses on the methodological approach and its potential limitations, inviting scrutiny and potential improvement. The Greenland article, while citing scientific studies, does not delve into the methodological details as deeply. The polling article, while informative, focuses more on highlighting the issue of uncertainty rather than providing a comprehensive solution. This diversity reflects the complexity of reporting on uncertain topics and the importance of transparency and critical analysis in journalism.

Journalism on complex public policy issues requires continuous updating and adaptation, as well as meticulous fact-checking and compartmentalization of key facts (Dunwoody, 2020). Journalists play a pivotal role in creating a reporting space for uncertainty, allowing for the emergence of diverse perspectives and challenges to dominant narratives. While compelling narratives are essential for popular journalism, editorial decisions must be made to mediate uncertainty and complexity need to be made. This editorial expertise can be of great value for the dissemination of DMDU research (Duffy, 2021).

Lessons DMDU and journalism can offer to one another

The fields of DMDU and journalism have valuable lessons each can offer to the other. For journalists grappling with the challenge of telling a crisp and accurate story amidst contested and inherently uncertain facts, DMDU offers a narrative of managing as opposed to reducing deep uncertainty. Rather than recounting a search for the truth, the narrative focuses on a recognition of inevitable surprise and skillful navigation (or the lack thereof) in the face of this reality. DMDU narratives highlight virtues that include a willingness to embrace uncertainty, humility about one's understanding, adaptability as conditions change, and finding certainty in robust and resilient plans rather than in any conviction that the world will behave as we expect.

DMDU suggests key themes journalists might explore in crafting narratives about uncertainty. The first is due diligence—to what extent do decision makers understand the vulnerabilities of their plans by having stress tested them over a wide range of futures? DMDU suggests that all policies are based in assumptions and many assumptions can potentially fail. Journalists can inquire whether decision makers have identified the conditions under which their plans will meet and miss their goals.

DMDU also encourages journalists to highlight the implications of high confidence information and the areas of agreement among contesting parties. For instance, DMDU uses high confidence information to identify scenarios that all can agree are policy-relevant, even if there exists significant disagreement as to their likelihood. In a typical example, all parties might agree that power plant near the shoreline would become inoperable if sea level rise exceeds one meter. But some might regard the likelihood of such a rise this century as too small to consider while others might see a much larger risk. Journalists can weaver a story around this disagreement while making clear that all would regard a meter of sea level rise as problematic.

TABLE 2 Summary of DMDU case studies.

Case study	Uncertainty as actionable
A. Greenland's Glaciers Are Melting Faster (Erdenesanaa, 2023)	• **Source of uncertainty:** While scientists observe and measure current changes in Greenland's ice melt, predicting the exact future trajectory of ice loss and its consequences remains a challenge due to the complex interplay of various factors, including oceanic and atmospheric temperatures, ice dynamics, and feedback mechanisms. • **Uncertainty narrative:** The article presents recent findings from two separate studies. It acknowledges the uncertainty surrounding future projections while emphasizing the consistent trend of accelerated ice loss observed in recent decades. It challenges dominant narratives by emphasizing the significant contribution of peripheral glaciers to sea level rise, which were previously underestimated. • **Reporting process:** The article relies on the findings of two recently published scientific studies. These studies employed a combination of historical photographs, satellite measurements, and field observations to track changes in glacier extent and ice shelf volume over time. The article also includes interviews with scientists involved in the research, providing insights into their methodologies and interpretations of the findings.
B. The pandemic's true death toll (The Economist, 2024)	• **Source of uncertainty:** It is challenging to determine a precise death toll because many deaths go unreported as individuals may not be tested for the virus, particularly in regions with limited testing capacity. Additionally, attributing a death solely to COVID-19 can be difficult when pre-existing conditions are present. Disruptions to healthcare systems and changes in lifestyle potentially impact death rates from other causes. • **Uncertainty narrative:** The article states the limitations of official COVID-19 death statistics and highlights the importance of excess deaths data for comparing the impact of the pandemic across countries. The article does not present explicitly competing views but acknowledges the inherent uncertainty in the data and the challenges in modeling excess deaths globally. It challenges dominant narratives by highlighting the significant underreporting of COVID-19 deaths in many countries and emphasizing the disproportionate impact on certain regions and demographics. • **Reporting process:** The article describes a multi-faceted approach to estimate excess deaths. It combines official excess mortality data from 84 countries with a machine-learning model that incorporates over 100 statistical indicators to estimate deaths in countries without official data. The article provides transparency by sharing its methodology and making its code, data, and models publicly available. This allows for scrutiny and potential improvement of the model. The article acknowledges the limitations and potential biases in its approach, particularly regarding the accuracy of official data and the applicability of the model to developing nations.
C. Polling isn't broken, but pollsters still face Trump-era challenges (Skelley, 2024)	• **Source of uncertainty:** Polling is deeply uncertain because it attempts to predict human behavior in a complex decision-making context. The article highlights several reasons why this is becoming more volatile: Declining Response Rates, Nonresponse Bias, Likely Voter Identification, Weighting Challenges and what they defined as the "Trump Factor" • **Uncertainty narrative:** The article describes the challenges faced by pollsters and the various approaches they are taking to address them. It includes perspectives from different polling experts, highlighting both successes and failures in their efforts. It challenges the dominant narrative that polling is a simple and straightforward process. It reveals the complexity and uncertainty inherent in accurately measuring public opinion, especially in the context of elections. • **Reporting process:** The article highlights the trade-offs and limitations of different methodologies. It emphasizes that there are no easy solutions or silver bullets to guarantee accurate polling. It references specific examples of polling challenges and experiments conducted by different polling firms, providing concrete evidence to support its claims. The article emphasizes the sensitivity of polling estimates to different assumptions about voter turnout.

Finally, DMDU encourages journalists to examine the extent to which decision makers have made uncertainty actionable—crafting policies that are robust and resilient. To what extent are policies designed to achieve their goals when things, as they often do, go wrong? Do decision makers exercise the necessary adaptiveness and flexibility? Assuming decision makers understand the futures in which their plans meet and miss their goals, can they describe how they are monitoring for such conditions? Have decision makers articulated what they will do if such conditions arise? Can decision makers explain why the balance of risks and opportunities in the plan they propose outweigh those of the alternatives?

DMDU practitioners seeking policy impact from their analyses can gain guidance from journalists' need to balance accuracy with compelling narratives. DMDU practitioners can emphasize the certainties that emerge from their analyses alongside the uncertainties. Practitioners can tell stories about making uncertainty actionable, using the embrace of uncertainty to motivate robust and resilient responses. They can tell stories about the process of going from uncertainty about what will happen to

certainty about vulnerabilities and the best responses to them. Practitioners can describe how the analysis addresses the concerns and interests of various contesting parties to the policy debate. As will any good policy analysis, DMDU practitioners can also emphasize the concrete policy implications of their work.

Future directions

DMDU practitioners and journalists, despite operating in different fields, share a crucial common challenge: making complex information understandable, engaging, and useful for decision-making. Borrowing practices from journalists, DMDU practitioners can improve their delivery of DMDU analyses. To enable this, we identify three key areas for future research and work:

• Editorial role in DMDU practice: ultimately deciding how to handle uncertainty in a DMDU application is

a collaborative effort between researchers, sponsors and government counterparts. However, the processes editors use and their experience in dealing with uncertainty in journalism can benefit DMDU practices. This includes rigorous quality assurance to guarantee scientific integrity, replicability and transparency of findings, but also editorial decisions that can help the team focus on the most relevant aspects of the analysis, ensuring budget and time constraints are met. A DMDU editor can help the team identify the core findings of their research and present them upfront, with supporting details following in a clear hierarchy.

- Framing DMDU findings as narratives: journalists excel at crafting compelling narratives that engage the public and guide them through the complexities and uncertainties of a topic. DMDU practitioners can adopt this approach by framing their findings as stories with a clear beginning, middle, and end. Highlight the decision tradeoffs contained in the data, its significance for the decision context under consideration and the potential implications for the stakeholders participating in the study. Being aware of the potential cognitive biases and framing effects of media narratives that readers may hold that influence their evaluation of different options and trade-offs with respect to an issue.

- Meaningful engagement with DMDU findings: journalists utilize diverse and creative ways to present data, such as infographics, interactive maps and visualizations, and animations. DMDU practitioners can explore these options to make their findings visually appealing, interactive, and easier to understand for their audiences. In fact, wider dissemination of DMDU work in this form, can enable bigger audiences to engage with DMDU analyses. This can enable learning from audience engagement through strategies used by journalists, like interactive forums, comments, and social media outreach, to tailor DMDU analysis delivery and foster meaningful dialogue with the public.

Progress in these areas can help the DMDU community apply systematically journalist-inspired approaches to deal with uncertainty. This can effectively help improve how DMDU findings are communicated, fostering trust and transparency, encouraging critical thinking, and enabling wider public engagement with DMDU findings.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

EM-P: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. RL: Writing – original draft, Writing – review & editing. JW: Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Benjamin, D. M., and Budescu, D. V. (2018). The role of type and source of uncertainty on the processing of climate models projections. *Front. Psychol.* 9:403. doi: 10.3389/fpsyg.2018.00403

Besley, J. C., Dudo, A., and Storksdieck, M. (2015). Scientists' views about communication training. *J. Res. Sci. Teach.* 52, 199–220. doi: 10.1002/tea.21186

Bryant, B. P., and Lempert, R. J. (2010). Thinking inside the box: a participatory, computer-assisted approach to scenario discovery. *Technol. Forecast. Soc. Change* 77, 34–49. doi: 10.1016/j.techfore.2009.08.002

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *PANAS.* 111, 13614–20. doi: 10.1073/pnas.1320645111

Duffy, A. (2021). Out of the shadows: the editor as a defining characteristic of journalism. *Journalism* 22, 634–649. doi: 10.1177/1464884919826818

Dunwoody, S. (2020). Science journalism and pandemic uncertainty. *Media Commun.* 8, 471–474. doi: 10.17645/mac.v8i2.3224

Erdenesanaa, D. (2023). *Two Studies on Greenland Reveal Ominous Signs for Sea Level Rise.* Available at: https://www.nytimes.com/2023/11/09/climate/greenland-glaciers-ice-melt.html (accessed November 9, 2023).

Gong, M., Lempert, R., Parker, A., Mayer, L., Fischbach, J., Sisco, M., et al. (2017). Testing the scenario hypothesis: an experimental comparison of scenarios and forecasts for decision support in a complex decision

environment. *Environm. Model. Softw.* 91, 135–155. doi: 10.1016/j.envsoft.2017.02.002

Groves, D. G., Fischbach, J. R., Bloom, E., Knopman, D., and Keefe, R. (2013). *Adapting to a Changing Colorado River: Making Future Water Deliveries More Reliable Through Robust Management Strategies.* Santa Monica, CA: RAND Corporation. Available at: https://www.rand.org/pubs/research_reports/RR242.html2

Groves, D. G., and Lempert, R. J. (2007). A new analytic method for finding policy-relevant scenarios. *Global Environ. Change* 17, 73–85. doi: 10.1016/j.gloenvcha.2006.11.006

Groves, D. G., Molina-Perez, E., Bloom, E., and Fischbach, J. R. (2019). "Robust Decision Making (RDM): application to water planning and climate policy," in *Decision Making under Deep Uncertainty: From Theory to Practice* (Cham: Springer), 135–163.

Guenther, L., and Ruhrmann, G. (2016). Scientific evidence and mass media: Investigating the journalistic intention to represent scientific uncertainty. *Public Understand. Sci.* 25, 927–943. doi: 10.1177/0963662515625479

Haasnoot, M., Kwakkel, J. H., Walker, W. E., and Maat, J. T. (2013). Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. *Global Environm. Change* 23, 485–498. doi: 10.1016/j.gloenvcha.2012.12.006

Kalra, N., Molina-Perez, E., Syme, J., Esteves, F., Cortés, H., Rodríguez-Cervantes, M. T., et al. (2023). *The Benefits and Costs of Reaching Net Zero Emissions in Latin America and the Caribbean.* New York: Inter-American Development Bank.

Kasperson, R. E., Webler, T., Ram, B., and Sutton, J. (2022). The social amplification of risk framework: new perspective. *Risk Analysis* 42, 1367–1380. doi: 10.1111/risa.13926

Kohl, P. A., Kim, S. Y., Peng, Y., Akin, H., Koh, E. J., Howell, A., et al. (2016). The influence of weight-of-evidence strategies on audience perceptions of (un)certainty when media cover contested science. *Public Understand. Sci.* 25, 976–991. doi: 10.1177/0963662515615087

Kwakkel, J. H., Haasnoot, M., and Walker, W. E. (2016). Developing dynamic adaptive policy pathways: a computer-assisted approach for developing adaptive strategies for a deeply uncertain world. *Clim. Change* 136, 495–518. doi: 10.1007/s10584-014-1210-4

Kwakkel, J. H., and Pruyt, E. (2013). Exploratory Modeling and Analysis, an approach for model-based foresight under deep uncertainty. *Technol. Forecast. Soc. Change* 80, 419–431. doi: 10.1016/j.techfore.2012.10.005

Lempert, R. J., Groves, D. G., Popper, S. W., and Bankes, S. C. (2006). A general, analytic method for generating robust strategies and narrative scenarios. *Manage. Sci.* 52, 514–528. doi: 10.1287/mnsc.1050.0472

Lempert, R. J., Popper, S. W., and Bankes, S. C. (2003). *Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis.* Santa Monica, CA: RAND Corporation. Available at: https://www.rand.org/pubs/monograph_reports/MR1626.html

Marchau, V. A., Walker, W. E., Bloemen, P. J., and Popper, S. W. (2014). Structured decision making as a proactive approach to dealing with deep uncertainty. *J. Environ. Manage.* 146, 304–313.

Moallemi, E. A., Kwakkel, J., de Haan, F. J., , and Bryan, B. A. (2020). Exploratory modeling for analyzing coupled human-natural systems under uncertainty. *Global Environm. Change* 65:102186. doi: 10.1016/j.gloenvcha.2020.102186

Moallemi, E. A., Zare, F., Hebinck, A., Szetey, A., Molina-Perez, E., Zyngier, R. L., et al. (2023). Knowledge co-production for decision-making in human-natural systems under uncertainty. *Global Environm. Change* 82:102727. doi: 10.1016/j.gloenvcha.2023.102727

Molina-Perez, E., Groves, D. G., Popper, S. W., Ramirez, A. I., and Crespo-Elizondo, R. (2019). *Developing a Robust Water Strategy for Monterrey, Mexico: Diversification and Adaptation for Coping with Climate, Economic, and Technological Uncertainties.* Santa Monica, CA: RAND Corporation. Available at: https://www.rand.org/pubs/research_reports/RR3017.html

Nascimento de Lima, P., Lempert, R., Vardavas, R., Baker, L., Ringel, J., Rutter, C. M., et al. (2021). Reopening California: seeking robust, non-dominated COVID-19 exit strategies. *PLoS ONE* 16:e0259166. doi: 10.1371/journal.pone.0259166

Peters, H. P., and Dunwoody, S. (2016). Scientific uncertainty in media content: Introduction to this special issue. *Public Understand. Sci.* 25, 893–908. doi: 10.1177/0963662516670765

Popper, S. W., Griffin, J., Berrebi, C., Light, T., and Daehner, E. M. (2009). *Natural Gas and Israel's Energy Future: A Strategic Analysis Under Conditions of Deep Uncertainty.* Santa Monica, CA: RAND Corporation. Available at: https://www.rand.org/pubs/technical_reports/TR747.html

Post, S. (2016). Communicating science in public controversies: Strategic considerations of the German climate scientists. *Public Understand. Sci.* 25, 61–70. doi: 10.1177/0963662514521542

Skelley, G. (2024). *Polling Isn't Broken, but Pollsters Still Face Trump-era Challenges.* Available at: https://abcnews.go.com/538/polling-broken-pollsters-face-trump-era-challenges/story?id=110677969 (accessed May 30, 2024).

The Economist (2024). *The Pandemic's True Death Toll.* Available at: https://www.economist.com/graphic-detail/coronavirus-excess-deaths-estimates?fsrc=core-app-economist (accessed June 22, 2024).