 DOI: 10.1111/j.1539-6924.2012.01832.x

Flood Risk Management: US Army Corps of Engineers and Layperson Perceptions

Matthew Wood,[1] Daniel Kovacs,[2] Ann Bostrom,[3] Todd Bridges,[1] and Igor Linkov[1,*]

Recent severe storm experiences in the U.S. Gulf Coast illustrate the importance of an integrated approach to flood preparedness planning that harmonizes stakeholder and agency efforts. Risk management decisions that are informed by and address decision maker and stakeholder risk perceptions and behavior are essential for effective risk management policy. A literature review and two expert models/mental models studies were undertaken to identify areas of importance in the flood risk management process for layperson, non-USACE-expert, and two USACE-expert groups. In characterizing and mapping stakeholder beliefs about risks in the literature onto current risk management practice, recommendations for accommodating and changing stakeholder perceptions of flood risks and their management are identified. Needs of the U.S. Army Corps of Engineers (USACE) flood preparedness and response program are discussed in the context of flood risk mental models.

KEY WORDS: flood; mental models; risk analysis

1. INTRODUCTION

In the fall of 2005, hurricanes Katrina and Rita revealed inadequacies in severe storm and flood protection plans for the U.S. Gulf Coast. Initial criticism centered around engineering design and management issues (e.g., impact and loss projections, flood protection infrastructure) and degradation over time of the region's wetland defenses by various industries (e.g., energy, transportation).[1,2] Recent work has also noted the importance of human factors in disaster prevention planning. For example, Gheytanchi *et al*.[3] stresses the importance of considering psychological factors before engineering and other constraints when designing disaster management plans. The Institution of Civil Engineers panel in the United Kingdom made similar recommendations as part of their assessment of the state of flood management and their proposed improvements in response to severe flooding in 1998 and 2000. Two key recommendations of their report were to "learn to live with rivers" by accommodating waterway expansion from rainfall, and to provide greater weight to human and social factors when assessing flood risk.[4,5]

The U.S. Army Corps of Engineers (USACE) and other agencies are working on increased interagency coordination and stakeholder inclusion in restoration planning for coastal Louisiana and Mississippi.[6–8] This approach includes multiobjective management tailored to the needs of specific communities and the region in general. As the *de facto* leader of U.S. flood risk management (FRM) efforts, USACE is looking to evolve from its historic emphasis on engineering for addressing flood risks to well-informed strategic planning in coordination with state and local management authorities. These state and local agencies typically manage floodplains at a

[1]U.S. Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS
[2]Decision Partners, LLC, Pittsburgh, PA
[3]University of Washington Evans School of Public Affairs, Seattle, WA
[*]Address correspondence to Igor Linkov, US Army Engineer Research and Development Center, US Army Corps of Engineers; tel: 6172339869; Igor.Linkov@usace.army.mil.

micro-level in ways that often do not consider the effects of mitigation plans on upstream or downstream communities.[9,10]

To date the USACE is responsible for 383 lakes and reservoirs, 8,500 miles of dikes and levees, and 240 miles of shoreline protection split across 90 projects in the United States. In addition, the Corps has constructed hundreds of smaller local flood risk reduction projects that have been turned over to non-Federal authorities for operation and maintenance.[11] With such a large stake in the nation's FRM activities, effective policies for designing, coordinating, and implementing FRM plans are particularly essential to USACE's core mission, as well as the work of public safety and risk management professionals generally.

Further complicating matters, many citizens expect government agencies to bear the burden of FRM, even on matters of personal liability or property loss.[3,12,13] USACE design of architecture to reduce flooding probability, along with government certification of levees and National Flood Insurance Program (NFIP) requirements, helps to perpetuate the phenomenon of personal lack of responsibility for flood planning.[9] Though the National Flood Risk Management Program established by USACE is helping to address some personal responsibility issues,[9,10] approaches which incorporate stakeholder perspectives and encourage them to take an active role in disaster planning are critical to future sustainable disaster management in the Gulf Coast. The need for effective FRM is especially pressing given the passive stance that many citizens take toward FRM. Flood risk is often underestimated by individuals, who frequently recall only the most severe (and therefore most infrequent) events and believe the government is the sole provider and responsible party for FRM.[12]

USACE and others are working to increase inter- and intra-agency coordination and stakeholder inclusion in FRM planning. Interagency coordination of FRM is a complex issue, as USACE is conducting FRM planning alongside FEMA, DHS, and a host of other federal, state, and local agencies. The importance of accommodating social and human dimensions in disaster preparedness has been recognized, but specific tools for integrating knowledge, interests, and values of stakeholders[4] require additional development. Mental modeling has been recognized as a useful framework for better understanding and addressing deeply held risk and value beliefs that can enhance stakeholder involvement in strategic planning, and applied to represent layperson perceptions of floods.[12,15,16] While there are comparisons of layperson and expert perceptions of flood risk;[17] addressing the revealed differences between these groups remains a challenge.

This article explores perceptions of FRM from USACE expert and layperson perspectives, with a focus on how experts from a variety of organizational units and disciplines within USACE understand FRM, and identifies opportunities for FRM improvement in general. A key interest here is to examine any differences in FRM perceptions and beliefs between planners and engineers, using formal analysis of qualitative data derived from mental models interviews. These findings should aid USACE in redeveloping its FRM process, and also other agencies with similar risk management responsibilities. Comparisons between diverse FRM stakeholders' perceptions and beliefs can be derived from separate studies of each, or comparative studies. We apply both approaches in this article, triangulating between original investigation of how two stakeholder groups within USACE perceive FRM, and published research on lay perceptions and mental models of flood risks and FRM.

A common approach to identifying discrepancies between expert and lay perceptions or beliefs is to compare the results of studies of each. These research efforts typically focus on a single implementation context. For instance, Bostrom *et al.*[18] conducted a literature review to better understand expert perceptions on the sources of radon in the home and risks of radon exposure. They then surveyed laypersons on the same issues to understand where lay perceptions differed from that of experts. This approach has the advantage of drawing on the accumulated research evidence, but the disadvantage of comparing studies from varying decision and risk contexts, such that the expert and lay views may not be truly analogous. A second systematic approach is to formally model potential FRM decisions with input from experts, then conduct mental models research to elicit the mental models people (with any level of expertise) apply when making such decisions.

This article synthesizes results from both approaches to compare and contrast what is known about lay perceptions of FRM with the views of two groups of experts. First, a literature review was conducted (Section 2) which identified layperson concepts and beliefs related to FRM. These layperson

[4] A stakeholder for the purpose of this report is defined as an individual or organization with a direct or indirect investment in flood preparedness and response.[14]

perceptions are aligned with expert knowledge. Next, an expert modeling effort was undertaken, focusing on USACE FRM experts, as well as the resulting influence diagram (Section 3). Finally, comparative analyses of telephone interviews informed by the expert model (EM) influence diagram are conducted (Section 4).

2. LITERATURE REVIEW OF LAY PERCEPTIONS

2.1. Review Methodology & Structure

A literature review was conducted in order to understand the mental models of laypersons and non-USACE experts on topics related to USACE FRM in order to understand how USACE FRM practice may better accommodate stakeholder knowledge and beliefs. The literature search for this review was conducted from May through July of 2008. It began with a keyword search of the ISI Web of Knowledge database for the term "mental model" along with "flood manage*," "flood respon*," or "flood recov*." Subsequent keyword searches were conducted in both ISI Web of Knowledge and APA PSYCInfo® with terms identified from the initial query, including "concept mapping," "decision support systems," "strategic environmental assessment," "flood risk management," "diagrammatic reasoning," "Logical Argument Mapping," "risk-ranking," "shared mental model," and "team mental model." A limited search was also done on both databases using the terms "schema*" and "folk model*." However, this search returned many results unrelated to risk issues discussed in this article. "Schema*" identified over 8000 entries in Web of Knowledge spanning a large domain of interests (e.g., computational neuroscience, language acquisition), many of which were not relevant to understanding how individuals relate to floods or natural disasters in general. Many discussions of folk models exclusively describe causal attributions of another individual's behavior (theory of mind), and a few authors[19] describe them as a special case of mental models. Social Science Citation Index Expanded was used to identify papers that cited Morgan *et al*.[20] or Doyle and Ford.[21,22] These works provide a context for defining mental models of complex real world phenomena.

Queries identified by Web of Knowledge, PSYCInfo®, and Social Science Citation Index Expanded searches were supplemented with reviews of query reference sections to identify sentinel works, and a Google Scholar search of key authors to locate books or other published works on the topic not available via peer-reviewed journal sources. USACE internal documents were also reviewed. Though by no means exhaustive, this literature search produced over 600 documents, of which the resources cited here make up a fraction. Documents were retained if they elucidated stakeholder perceptions of the FRM process and matched one or more components of the simple EM (Fig. 1 & Section 3). Documents were excluded that detailed existing risk management Decision Support Systems or focused extensively on technical aspects of meteorological, hydrological, or geological processes implicated in flooding. These exclusions were made because these articles, while elucidating the state-of-the-science related to flooding events, did little to elucidate why laypersons hold opinions of flood events and their management that differ from those of experts. Links to the USACE FRM expert model (Section 3) have been made when possible (Table I), though it should be noted that the match between USACE FRM and information uncovered in the literature review is sometimes imprecise. Terms used in the model can be abstract in nature, and any particular piece of reviewed information might fit several different categories.

2.2. Results

While the review is by no means exhaustive, it does capture some of the key issues faced by USACE and other agencies tasked with managing risks from natural hazards like flooding. A summary of review findings and their relationship to the EMs (Section 3) can be found in Table I. In particular, literature review results provide lay perspective information related to *Societal Drivers, Influences on Flood Risks, Quality of FRM Planning,* and *Quality of FRM Implementation*.

2.2.1. Societal Drivers

Societal drivers are factors determined by society at-large that influence the FRM process. Willingness to prepare for an event, and knowing how to prepare, are among the most significant of these factors. These depend, in part, on the availability and accuracy of timely weather forecasts, the decision-making of emergency managers and support staff, and local laypersons who decide when and how to prepare for a storm.[27] Case study reports of disconnects between what laypeople and experts know

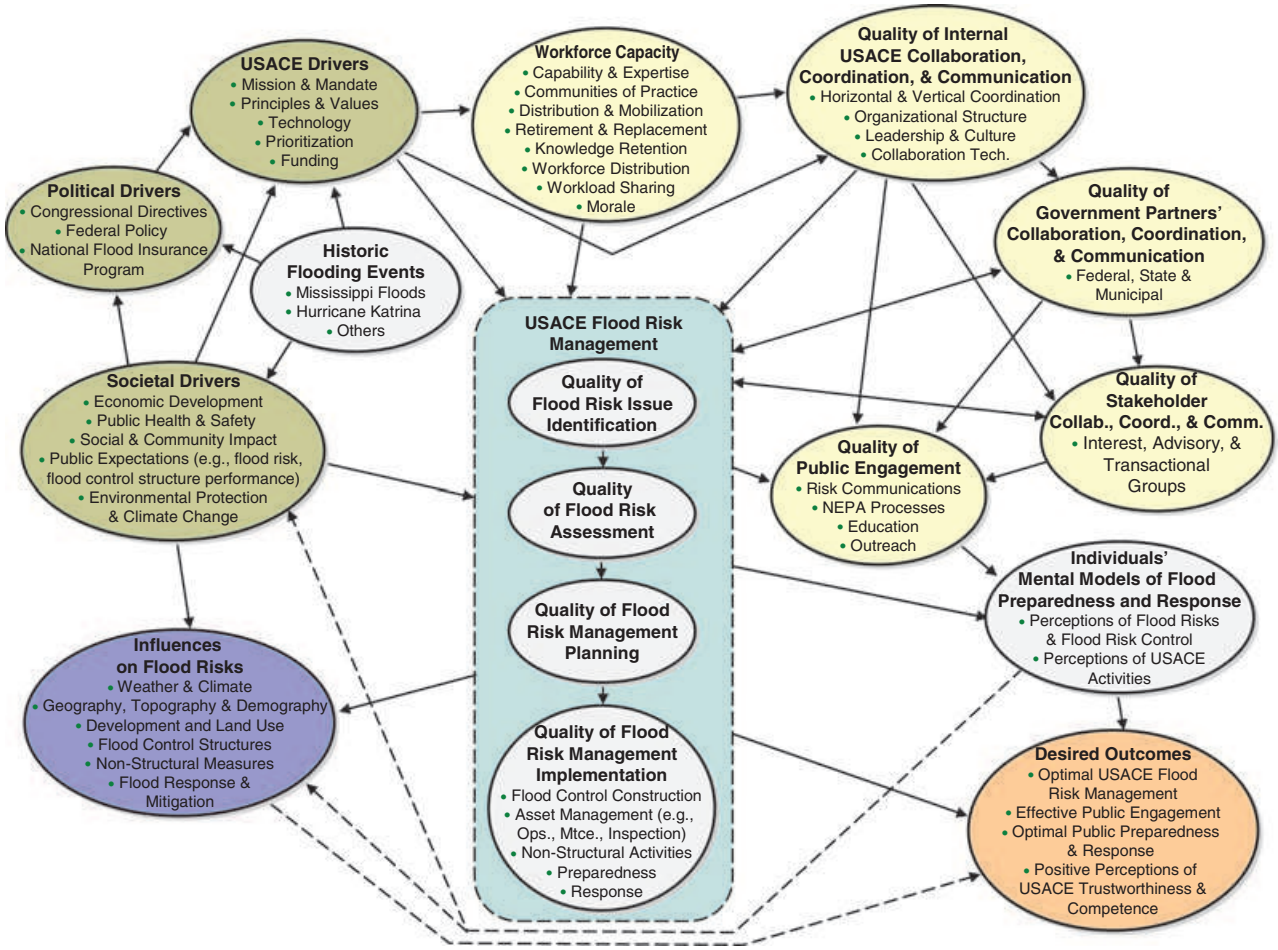

Fig. 1. Simple expert model of influences on USACE flood risk management.

about flooding suggest this discrepancy can inhibit the process of reducing public flood exposure and sensitivity, thereby reducing the effectiveness of proposed adaptations.[28] This is problematic as laypersons generally know little about how to decrease their exposure and sensitivity to floods. This is a case of "... ignorance of what to do, not rejection [of expert plans, which] caused people to ignore advice from flood control experts" (p. 265).[12] Not only do experts need to inform laypeople on what to do for effective execution of disaster plans, but they should also attempt to forecast changes in future compliance if a false alarm is issued,[27] a nontrivial task as disagreement exists about the average net effect of issuing evacuation orders without subsequent storm events occurring.[23] Rasid and Haider[24] also make an argument for properly informing laypersons about the flooding process and clarifying misunderstandings. They state that adequate explanation of flooding risks might help to counter resistance to mandatory evacuation orders that help laypersons avoid adverse consequences. Resistance to evacuation orders may also come from ignoring the possibility of another major flooding event.[12]

In a study on the Red River Valley flood of 1997, Buckland and Rahman[25] found that communities with more physical, human, and social capital were better prepared for flooding. However, social capital somewhat complicated the preparation process. While social capital (quantity and quality of civic organization community involvement) can help to gather people in an effort to prepare, it can also delay important decisions. Other research suggests that those who live in flood-prone areas and downstream portions of urban watersheds are more willing to pay for community-wide measures to decrease exposure and sensitivity.[26] In a study of Milwaukee metropolitan area residents, those who

Table I. Summary of Key Research Findings

	Literature Review	
USACE FRM Model Concepts	Expert Knowledge	Layperson Knowledge & Beliefs
Societal Drivers	Experts disagree about effects of issuing evacuation false alarms.[23]	Preference for home flood-proofing versus less risky buy-out option, even after a flood.[24]
	Communities with more physical, human, & social capital are better prepared for floods.[25]	Those in flood-prone areas willing to pay more for community-wide risk reduction.[26]
	Experts need to communicate disaster plan effectiveness & anticipate costs of issuing an evacuation "false alarm".[27]	People know about home protection measures, but not how these measures work.[16]
	Flood risk education may counteract resistance to mandatory evacuation orders.[24]	Resistance to evacuation may come from ignoring the possibility or likelihood of a flooding event.[12]
		Lack of flood exposure and sensitivity knowledge inhibits reductions in exposure & sensitivity.[28]
Influences on Flood Risks: Geography, Tomography, & Demography	Catchment area & precipitation create flash flood risk[16]	Focus on local land/engineering features & precipitation.[16]
		Believe past damages approximate future risk.[28]
		Flood-prone area residents lack flood risk exposure knowledge & motivation to learn.[12]
Influences on Flood Risks: Development and Land Use	Dredging & development can adversely impact natural flood protection systems.[7]	Laypersons blame poorly coordinated activities to increase waterway benefits for creating flood conditions.[12]
Quality of FRM Planning	Fewer structural solutions may reduce public blame of governments or businesses for flooding.[12]	Public and risk management experts have different concepts of acceptable risk.[30]
	Shifting priorities toward land management versus structural solutions to reduce flood risk.[32]	Risk reduction policies can increase risk-taking behavior (lulling effect or risk compensation).[31]
	Control structures can reduce local risk at the expense of increased system-wide risk.[34]	Public misunderstands how flood protection structures work.[33]
	Structural solution advocates recommend dams/levees accommodate Probable Maximum Flood.[35]	Believe (incorrectly) that structures prevent damage.[28]
Quality of FRM Implementation	Emergency managers and scientists lack common FRM language.[36]	Poor infrastructure knowledge promotes activities that increase exposure.[37]
	Forecast accuracy impacts its economic value in FRM.[38]	Postevent compensation policies promote reliance on protective structures.[24]
	Dynamic response approaches can reduce unnecessary preparation & evacuation costs.[27]	Memory of past floods influences willingness to prepare.[39]
	Improving FRM requires changing land regulations and pricing risk into property insurance.[40]	Belief in a just world helps individuals to cope with flood consequences.[41]
	Preparedness depends on forecasting, emergency manager decisions, and lay behavior.[27]	Mandatory flood insurance is unnecessary because government and NGOs provide better aid at lower cost.[12]

lived outside the 100-year floodplain were most willing to pay for flood reduction measures, fearing inclusion in the 100-year plain if flood risk were to increase. Household income was positively correlated with willingness to pay, and belonging to an environmental group also had a small positive effect on willingness to pay for flood mitigation technologies. In addition, laypersons from flood-prone areas sometimes hold suboptimal beliefs even when it concerns their own personal property. For example, respondents to a study in the Red River Basin in Canada after the 1997 flood tended to prefer home floodproofing techniques for flood mitigation, even when fiscal incentives of other strategies (e.g., government buyout) were better.[24] In a different study related to flash flooding, most laypersons knew about floodproofing devices to keep their homes safe. However, they rarely knew how these devices worked to protect their homes.[16]

2.2.2. *Influences on Flood Risks*

Many factors can directly influence flood risk. The most salient factors that arose in materials reviewed include *Weather & Climate*, *Geography, Tomography, & Demography*, and *Development and Land Use*. Lave and Lave[12] find that those who live in flood-prone areas generally know little about their risk of flooding and how floods begin, and are usually unmotivated to learn about either. Those with more education who enjoy reading self-identify as scientifically savvy, or own their own home, tend to know more about the flooding process. Laypersons also have significant misunderstandings related to flood prediction. For example, they believe that flood frequencies are well understood by experts, and that recent flood damages are unprecedented (and therefore unpredictable) because of global warming. Some anecdotal evidence also suggests that many individuals believe flood forecasts are available to everyone.[28] Even if everyone did have access to accurate forecasts of precipitating event likelihoods, current weather forecasting techniques predict extreme weather events with limited temporal and spatial resolution.[29]

Many laypersons believe experts know more about precipitating factors that cause flooding than is actually the case.[28] Concerning flash floods in the Bavarian Alps, Wagner[16] found that laypersons believed weather conditions, debris problems, and local watershed authority engineered structures are important in determining whether a flash flood will occur. In truth, the main factors that influence flash flooding are weather conditions, characteristics of the catchment area, and the processes that occur within mountain torrents in the region of the Bavarian Alps where this work was done. Many laypeople also thought global warming would lead to an increased incidence of flash floods. Though human influence on global warming does not influence flash flooding directly, human impact in terms of land use and torrent control clearly do change flash flood likelihoods. Personal experience and visibility of process are two main influencing factors that explain the accuracy of layperson flash flood knowledge. Laypersons were better informed about floods than landslides, in part because flooding processes are easier for laypersons to observe directly. Those with more experience with flash floods had a more complete understanding of the process. Layperson knowledge about flash flooding changed very little over a two-year period, demonstrating that public perception of flood events can be stable over time.[16]

Many laypeople may be skeptical of government ability to manage water resources effectively. As mentioned earlier (Section 1), waterways are often managed in a piecemeal fashion without considering the interaction of management strategies on adjoining sections of a waterway. Some residents in Lave & Lave's[12] sample of residents near one southwest Pennsylvania river system tended to blame this lack of coordination for flooding events, with their community being sacrificed to save larger urban centers downstream from the consequences of flooding. Dredging operations and development similarly lead to the destruction of wetlands protecting the city of New Orleans from tropical storms. These modifications tended to benefit some groups (e.g., energy companies) at the expense of increasing risk for others (e.g., tourism companies).[7]

2.2.3. *Quality of FRM Planning*

Lack of knowledge about structural defenses may couple with ignorance of flood or precipitating event likelihoods to increase flood damage costs. People have developed property in floodplains under the belief that structural techniques for flood management provide greater protection than they actually do and often disregard the frequency of flood events when developing flood-prone areas. In response to this trend, experts have been moving from structural mitigation strategies to those that rely on land management to make room for some flooding

to occur.[42] These strategies may reduce laypersons' tendency to pass on blame (typically to a government or water management authority) for flood events and damages, since manmade structures have a smaller role in flood management and protecting individuals in the first place.[12]

Some advocates of structural flooding solutions recommend increasing dam heights and modifying spillways so structures can accommodate the probable maximum flood (PMF). However, others have suggested that fixing dams to accommodate the PMF could be ineffective and even wasteful or harmful. As it concerns dam spillways:

> . . . Additional spillway capacity, while preventing dam failure if the PMF occurs, can have very serious negative consequences.[5] Additional spillway capacity is frequently chosen by itself or in combination with a dam raise to bring a dam into compliance with existing policy and law. At some 'unsafe' dams, accepting the status quo (i.e., doing nothing) may be the best course of action.[35]

Though dams and levees are intended to protect individuals from flooding, their construction may actually serve to increase layperson exposure because laypersons tend to believe (incorrectly) that these structures "prevent" damages.[28] Levees can reduce the likelihood of inundation by water, but not eliminate it. Also, while these structures can reduce flood likelihoods in the short-term for the area nearest the levee, they can have ancillary effects on the water table or nearby wetlands that actually lead to a long-term increase in flood likelihood and severity.[34] As Lave and Lave state, "No engineering structure can guarantee protection for people living in a flood plain (p. 257)."[12]

This mindset highlights the discrepancy in risk planning and mitigation between laypersons who demand certainty in risk (e.g., Is X safe or unsafe?) and risk management experts, who take a more nuanced interpretation (e.g., How safe is X?).[30] Advocates of dams who make claims about provided safety may cause people to believe a dam reduces flooding exposure to negligible levels. Laypersons then become more likely to build in the flood plain. Dams lead indirectly to increased sensitivity to floods as measured by property damage rates and loss of life.[12] Though construction within a flood plain appears to lead to a paradox in net levels of flood risk mitigation, the effect seen here is generally consistent with a lulling effect, or risk compensation,[31] whereby individuals engage in counterproductive risky behaviors in response to regulations that require consumer product safety features. People behave less responsibly in the presence of these safety features because individuals believe the features provide a higher degree of protection than is actually the case. Classic cases of this effect can be seen in the transportation safety industry.[43,44]

In general, the protection imparted by infrastructure is poorly understood by the public.[33] People then build within the flood plain, and as time goes by people forget about their exposure and sensitivity to flooding.[37] Furthermore, compensation policies after a flood promote reliance on these structural mitigation methods.[24] These are unfortunate consequences of both a lulling effect and planners suggesting to laypersons that flood control structures can do more than they are designed to in order to reduce concerns arising from misunderstandings of exposure to flood risk.[12] To counteract this trend and reduce flood costs, Lenntorp[40] argues for more effective use of land regulation rules and pricing flood risk into property insurance rates.

2.2.4. Quality of FRM Implementation

One impediment to FRM implementation is the difficulty that expert groups have communicating with each other to take appropriate action in the face of a flood event. These groups can often have different technical terminology for which to refer to FRM processes. For example, professional emergency managers working with the public have difficulty understanding weather forecast uncertainties provided by meteorologists without assistance.[36] Although forecast information must be used on a case-by-case basis when making disaster management decisions, recent work has shown that changes in forecast accuracy impact the economic value of that forecast.[38] If decision-makers have the flexibility to wait for updated forecasts (for hurricanes in this case), they can gain significant value from adopting a dynamic decision model. The gains from adopting a dynamic approach, as opposed to depending on an instantaneous strike probability, can be greater than those from reduced preparation time after an evacuation decision is made.[27]

After a flood, laypersons purchase flood insurance reactively to protect against future financial loss. Large increases in insurance coverage have been

[5]These negative consequences include increased annual downstream flood losses, attenuated benefit–cost ratios, construction accidents from modifying spillways, and high monetary costs for modest safety returns.[35]

shown to occur after flooding, but, consistent with a reactive strategy based on event salience, many new policies are cancelled as time passed and memories of the flood fade.[12] This is an illustration of a general trend in individuals' willingness to plan for the consequences of a flooding event, in that the number of adaptations people are willing to make to protect themselves from flood risk typically decreases with the perceived probability of an event and as past events are forgotten.[24,39] Though few in Lave & Lave's study[12] carried flood insurance, even though it was mandated, several individuals expressed that insurance was unnecessary because social service organizations (e.g., American Red Cross) provided benefits and compensation that were less expensive and better than insurance coverage. Some federal program requirements also help to perpetuate the phenomenon of personal lack of responsibility for flood planning (Section 1).

After a catastrophic flood event, some may feel that their quality of life has suffered permanent negative impact and that their life will never be the same again.[37] The personality trait of belief in a just world (BJW)[6] may help people to protect themselves psychologically when faced with a perceived injustice, like experiences in the aftermath of flooding. When those high in BJW are faced with an apparent injustice, they try to account for it or compensate in some way; this buffering process appears to help such people cope with the event. BJW has been shown to provide psychological protection for victims of floods, and may be important when predicting postevent mental health after other natural disasters.[41]

3. EXPERT MODELING

3.1 Method

Developed initially for facilitating design of risk communication plans, the expert modeling approach used here for identifying beliefs about a risk management topic of interest[20] has been applied in a variety of domains.[45–47] Past successes with mental modeling in understanding environmental management issues include projects on expert and lay knowledge of climate change,[48–50] environmental manager views on climate change and biodiversity,[51] public perceptions of carbon sequestration techniques,[52] lay perceptions of flashfloods and landslides,[16] and numerous unpublished projects with private clients.[53]

An important step in the mental modeling process is the development of an EM, a visual representation in the form of an influence diagram[54] that illustrates the key variables in the decision context, viewed as a system, as well as the direction and strength of their influence on other variables in the system. In this case, a draft EM was first developed with a small number of USACE experts. This draft model was elaborated into an EM and series of submodels illustrating drivers of USACE FRM in a workshop with 11 USACE experts in September 2008, and a series of supplemental interviews with five engineers in October 2008.[55] The EM provided the basis for developing a semistructured mental model interview protocol, with the goal of gaining further insights into specific drivers of the quality of USACE FRM, as well as to understand any differences in perspectives between planners and engineers within USACE stemming from differences in education or roles within USACE.

3.2 Results

The simple EM of *Influences on USACE Flood Risk Management* (Fig. 1) is in the form of an influence diagram,[54] a directed graph in which "influences" (arrows) link related "nodes" (variables) in the system. The direction of the arrow indicates the direction of influence. The following is a narrative description of the simple EM.

3.2.1. Drivers

The model starts in the upper left-hand corner with Political, Societal and USACE Internal Drivers, factors that establish the fundamental conditions that drive USACE activities.

3.2.1.1. Political drivers. Political drivers come from other government entities that influence or control USACE FRM Activities. Political Drivers include: *Congressional Directives* that fund and mandate specific FRM activities; *Federal Policy* that mandates USACE FRM priorities (e.g., economic development); and the NFIP which mandates insurance for areas with specified flood risk levels. NFIP drives much flood control structure construction, aimed at reducing flood risk and removing areas from mandate to purchase flood insurance.

[6]Belief in a just world is the illusory belief that good things happen to good people and bad things to bad people.

3.2.1.2. Societal drivers. Societal drivers come from society at large, including: *Economic Development* priorities that encourage national/regional economic development and damage protection; *Public Health & Safety* priorities to protect public health/welfare; *Social & Community Impact* priorities to protect social networks and community organizations that reflect the collective impact to individuals and the direct impact on social structures and organizations; *Public Expectations* regarding flood risk levels and flood control structure effectiveness; and *Environmental Protection & Climate Change* priorities regarding protection of environmentally sensitive areas (i.e., wetlands) and response to climate change, which is likely to influence flood risks.

3.2.1.3. USACE drivers. USACE Drivers are factors internal to the USACE that influence *Flood Risk Management* activities such as: *Funding* and cost sharing requirements, which limit which projects with positive benefit-to-cost ratios can be enacted; *Mission & Mandate,* covering areas such as public protection, war fighting, protecting water resources and the environment, maintaining waterway infrastructure, and homeland security; *Principles & Values,* focusing on relevance, readiness, responsibility, and reliability; *Technology* and technical innovations such as tools to model floods for risk assessment and planning, enable knowledge sharing/retention, and improve flood control structure performance; *Prioritization* of *Flood Risk Management* activities based on economic development and public health and safety criteria; and *Planning Assumptions,* particularly the appropriate or acceptable level of flood risk.

3.2.2. Historic Flooding Events

The *Drivers* are particularly influenced by *Historical Flooding Events*, including Hurricane Katrina and historic flooding of the Mississippi River Valley. Experts believe the impact of these events has had a significant influence on public perceptions and public expectations (Section 3.2.7.), which in turn strongly influence *Societal*, *Political*, and Internal *USACE Drivers*.

3.2.3. USACE Flood Risk Management

The nodes grouped together in the middle of the model depict *USACE Flood Risk Management* activities, the actual tasks performed by Corps personnel, with the quality of upstream nodes significantly impacting downstream nodes. Specific activities which impact *Quality of Flood Risk Management Implementation* include: *Flood Control Construction,* for example, building dams and levees; *Asset Management,* for example, flood control structure operation and maintenance; *Non-Structural Activities,* such as influencing changes in zoning and development to reduce risk via removal of susceptible structures and people from flood prone areas; *Flood Preparedness,* preparation activities such as warning system design and evacuation planning; and *Flood Response,* response activities such as emergency repair of levees and other flood control structures. These *Flood Risk Management* activities, in turn, influence the node found in the lower left portion of the Simple Model depicting *Influences on Flood Risks.*

3.2.4. Influences on Flood Risks

The node in the lower left corner of the Simple Model represents *Influences on Flood Risks.* These include naturally occurring variables (e.g., weather, geography) and human influences such as flood control structures, policies and individual decision making. It includes the following influences: *Weather & Climate,* such as hurricanes and other extreme weather events and the impact of climate change on the frequency, magnitude and distribution of events; *Geography, Topography & Demography,* the combination of land masses, waterways, and coastal areas potentially impacted by floods and population density that gives rise to flood risk exposure; *Development and Land Use,* the concentration of residential development and other land uses that affect risk exposure magnitude and impact potential; *Flood Control Structures,* such as dams and levees that protect against flood event damage; *Non-Structural Measures,* such as activities that reduce flood risk exposure by limiting development in flood prone areas or improving warning and evacuation procedures to protect public health and safety; and *Flood Response & Mitigation,* activities such as emergency repair of levees and other flood control structures, drainage of flooded areas, and evacuation of people.

3.2.5. Collaboration, Coordination, and Communication

The nodes in the upper and right section of the model depict influences on Corps activities related

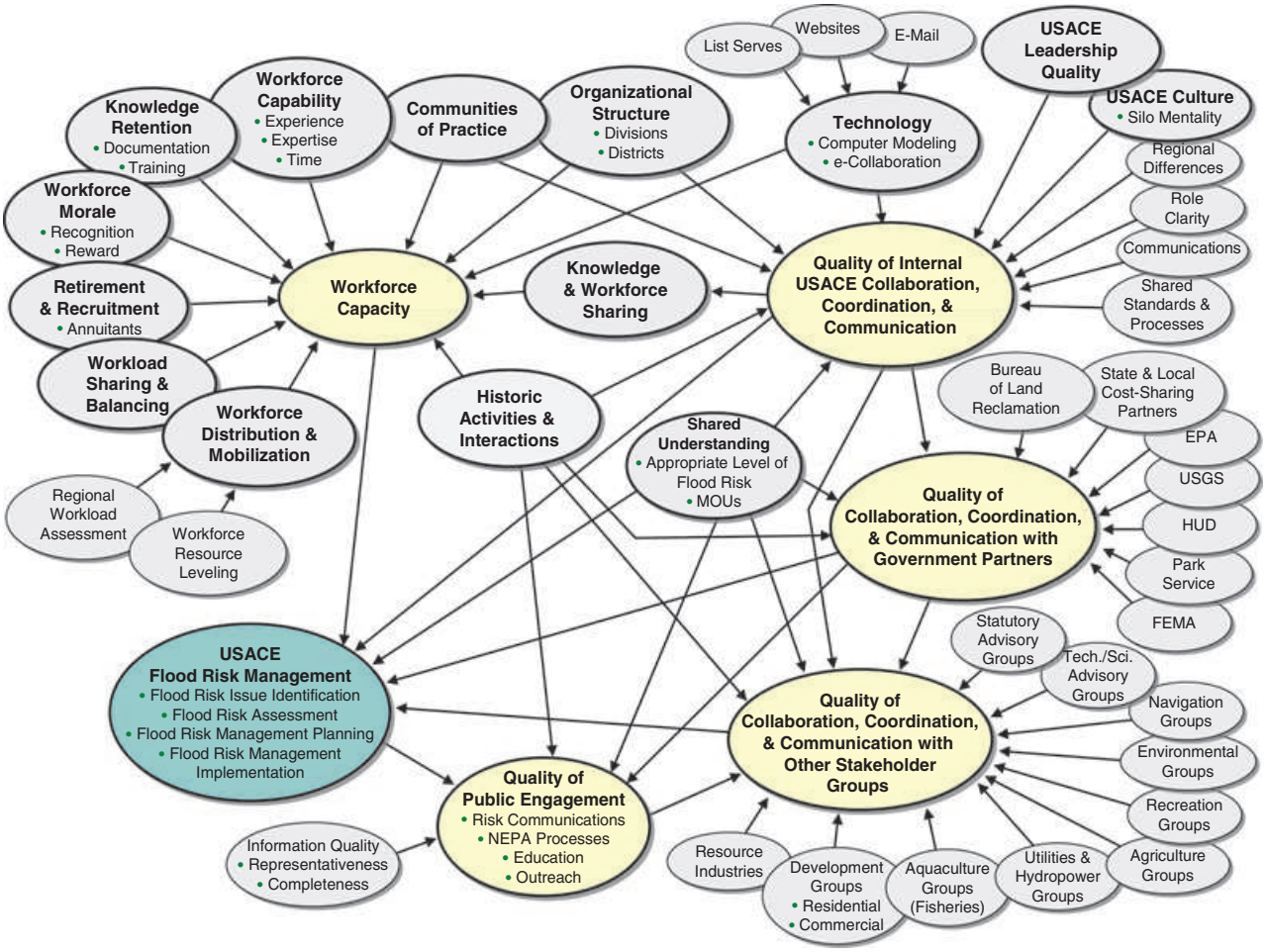

Fig. 2. Detailed submodel of collaboration, communication, and coordination.

to *Workforce Capacity* and to USACE *Collaboration, Coordination, and Communications*, internally and externally as well as the *Quality of USACE Public Engagement*. These nodes are presented in more detail in the *Detailed Sub-Model of Collaboration, Communication, & Coordination* (Fig. 2). *Workforce Capacity* is the effectiveness of USACE workforce based on alignment of workforce resources with workload requirements. *Quality of Internal USACE Collaboration, Coordination, & Communication* represents the effectiveness of internal procedures, policies and activities that affect the quality and effectiveness of working relationships within USACE. *Quality of Collaboration, Coordination, & Communication with Government Partners* represents the effectiveness of internal procedures, policies, and activities that affect the quality of working relationships with other Federal, State and Local agencies and entities, such as *Bureau of Land Reclamation, FEMA, EPA, USGS,* and *HUD,* among others. *Quality of Collaboration, Coordination, & Communication with Other Stakeholders* represents the effectiveness of procedures, policies, and activities that affect the quality of working relationships with other stakeholders. Q*uality of Public Engagement* represents the USACE activities directed at the public with respect to their *Flood Risk Management* activities, including risk and informational communications, educational programs and other outreach activities.

3.2.6. Desired Outcomes

The end point of the model is the *Desired Outcomes* node in the lower right hand corner. This reflects the degree to which USACE FRM activities can achieve desired goals and objectives, such as:

Optimal USACE FRM; Effective Public Engagement; Optimal Public Preparedness & Response; and Positive Perceptions of USACE Trustworthiness & Competence. These outcomes are directly influenced by the Quality of *USACE Flood Risk Management* activities and by *Individuals' Mental Models of Flood Preparedness and Response*.

3.2.7. Individuals' Mental Models of Flood Preparedness and Response

This node represents the perceptions held by individuals that determine their assessment of flood risks of the effectiveness of flood risk controls and of *USACE Flood Risk Management* activities. Section 3 discusses the influence of mental models on public decision making and behavior, which can in turn influence the level of individual flood risk as well as *Societal Drivers* expressed via public expectations regarding flood risk and FRM (Section 3). This node is influenced by the *Quality of Public Engagement*.

4. MENTAL MODEL INTERVIEW COMPARATIVE ANALYSIS

In order to clarify concepts defined in the EMs of USACE FRM (Section 3), follow-up mental model interviews were conducted. These interviews leveraged the EM to develop a semistructured interview protocol with the goal of gaining further insights into specific drivers on the quality of USACE FRM, as well as to understand differences in perspective between planners and engineers within the organization on these topics. We were also interested in investigating differences between planners and engineers in the drivers they emphasize. Past work identified differences in responsibilities and focus between these two groups as they relate to the FRM process. This is in part because of differences in education, and in part due to role differences within USACE. Engineers tend to emphasize specific technical elements of a process they are tasked with creating or optimizing. In contrast, planners tend to focus more on the integration of a technical solution with other systems, as well as the role of stakeholders in system utilization and management.[55]

These differences are consistent with those in other organizations and civil engineering efforts. For example, in the transportation sector, it has been suggested that the U.S. interstate highway system's poor aesthetics are due to engineers who primarily focused on maximizing traffic capacity, and were less concerned about the effects designed structures had on dividing or reorganizing communities.[56] Relating to civil works more broadly, others have referred to the structures that evolve from an engineering focus on utilitarian design as "stupifyingly bleak" in terms of appearance and apparent lack of harmony with the environments and communities where these structures are built.[57] The American Planning Association, one of the major professional organizations for planners, emphasizes the profession's holistic perspective, working " . . . to improve the welfare of people and their communities by creating more convenient, equitable, healthful, efficient, and attractive places for present and future generations.[58]"

4.1. Method

4.1.1. USACE Mental Models Interview Participants

Engineers ($n = 10$), planners ($n = 8$), and program managers ($n = 4$) participated in one-on-one semistructured telephone interviews. Interviews from some participants in the engineer cohort ($n = 5$) were also used in the first part of this effort for EM refinement. Although explicit reference has not been made in past work to similarities or differences between program managers and either engineers or planners, the job functions of program managers in USACE makes their role in the FRM process more similar to that of planners than to that of engineers. Therefore, for purposes of the current analysis, they will be considered part of the planning cohort, yielding engineer and planner cohorts that are roughly equal in size ($n = 10$ & 12, respectively). Interview participants were a convenience sample of senior personnel from a variety of organizational units within USACE.

4.1.2. Interview Process

An interview protocol was adapted from that used in previous research on USACE personnel's beliefs and knowledge related to the Corps current FRM process[59] to identify important areas that required further clarification or where additional information was otherwise valuable. As these changes to the interview protocol were modest, and the information provided by earlier engineer participants was consistent with that from new engineer participants, data from the October 2008 sample of five engineers is included in the following analysis. Of particular interests was information related to:

(1) The most important drivers of USACE FRM.
(2) The scope and quality of USACE FRM activities.
(3) Drivers of the quality of collaboration, coordination, and communication.

   (i) Internally (within USACE).
   (ii) Externally (with other government, NGO, and layperson stakeholders).

Questions were asked to assess key features, beliefs, and perceptions of the above as they exist in current FRM practice, as well as how these drivers are forecasted to change in the future. In general, interview questions were structured to address a topic broadly (e.g., "Thinking at the most general level, what would you say tends to drive, or significantly influence the Army Corps' flood risk management activities?") and then focus on a series of different aspects of the topic (e.g., "Has the significance of any of these drivers changed over time?"; "How would you describe the quality of Army Corps personnel working together *internally*?"). This structure is consistent with past interviews developed from EM diagrams.[20,47] Interviews were an hour long on average (mean = 66 minutes; range = 45–82 minutes) and were collected from October 2008 through June 2010. All telephone interviews were recorded.

4.1.3 Transcript Analysis.

Recordings of interviews were transcribed, and investigated via content analysis. An analyst with a Ph.D. in Engineering and Public Policy with over 14 years experience using mental model methodology viewed responses for questions one-at-a-time, and identified common themes that these responses exemplified using a two-pass process. In the first pass, each interviewee's responses are read and associated with particular elements of the EM to allow for subsequent comparison of EM topics across interviews and across questions. In the second pass, once interviewee responses are entered into a database; responses are examined by question, across interviews, to identify more specific fundamental themes within topic areas (and elements of the EM). Frequencies of the number of participants mentioning a theme are recorded for each question, converted to a percentage of total participants overall and by cohort (engineers or planners) and rounded to the nearest 5%. Differences between cohorts are reported only if they are greater than 20%. Results will be reported for a select subset of questions, based on their utility in clarifying concepts and processes in the EM related to FRM, and in providing insights concerning differences between cohorts. Unless otherwise indicated, percentages reported in-text refer to the entire sample.

4.2. Results

4.2.1. Drivers of USACE FRM Activities

Participants provided a variety of factors consistent with the EM when asked about drivers of FRM activities. They placed particular emphasis on drivers related to public safety and reducing risk to the public (55% [$n = 12$]). These items constitute a key element of USACE's mission. Respondents also frequently mentioned Congressional mandate, funding, and politics (45% [$n = 10$]); as well as historical events, and a propensity for reactivity rather than proactive protection (45% [$n = 10$]). Respondents suggest Congressional mandate and politics are related to funding in that project funding depends on approval from Congress, especially for large projects, and projects that Congress feels are more closely related to USACE's Congressional mandate are more likely to be funded. Sometimes it is difficult to demonstrate the need for a project unless a catastrophe has occurred, even though Corps personnel may feel problems are imminent. Political will (and therefore funding) for FRM projects is often closely tied to public outcry over these events, which is often strong at its onset but lacks persistence.

Responses related to local interest, support, sponsorship, and cost sharing are consistent with this story (30% [$n = 7$]). A sizable proportion of participants mentioned public interest in their responses. Economics, National Economic Development (NED), and economic efficiency (25% [$n = 5$]) rounded out the field of drivers participants felt drove the USACE FRM process. Although interest and support for a project often occurs on a local or state basis, the benefit/cost ratio used to determine which projects are suitable for funding only takes National Economic Development into account. Some respondents perceived this as unfair, since localities often bear a significant portion of the costs, but the benefits to localities are underrepresented in cost–benefit analyses.

Across the dominant five themes related to FRM drivers, engineers tended to mention more of these than planners in their responses. Engineers who were

interviewed for EM refinement were allowed to discuss earlier questions more freely, thereby mentioning more topics and perhaps driving this. In particular, engineers focused on Congressional mandates and political drivers (60% [$n = 6$] vs. 35% [$n = 4$] of planners), and on National Economic Development (NED)[59] assessment requirements (40% [$n = 4$] vs. 10% [$n = 1$]). Several engineers explained that Congressional mandates tend to drives the Corps current objectives, especially when it comes to big projects. Concerning NED, engineers tended to focus on the fact that the assessment emphasizes national (versus regional or local) benefits, and efficient risk reduction rather than optimal risk reduction.

4.2.1.1. Most Significant Drivers.

4.2.1.1.1. Currently most significant. Overall, respondents cited politics and congressional mandates (especially related to funding; 40% [$n = 9$]), economic development (30% [$n = 7$]), and response to weather and significant effects (25% [$n = 6$]), Corps' mission and mandate (15% [$n = 3$]), and guiding principles were also identified (15% [$n = 3$]) as the most significant drivers behind FRM activity. A small number of participants also mentioned local interests, environmental protection and impact, and technological drivers. Between cohorts, planners were much more likely to emphasize politics and congressional mandates. In contrast, engineers tended to focus on economic development and responding to weather and significant events. This contrast makes sense in terms of organizational roles, as planners are more likely to seek project financing. In contrast, engineers are more likely to conduct site visits in areas currently or recently impacted by weather and other natural hazard events. Engineers' tendency to focus on NED figures is consistent with responses on drivers of FRM activities, and indicates frustration with a system that appears to emphasize national economic development over local safety.

4.2.1.1.2. Ideally most significant. Respondents varied in their judgments regarding which drivers are most significant. Two on which there was some agreement were public safety (20% [$n = 4$]) and responding to storm events, including historical events (15% [$n = 3$]). Other topics that respondents thought should be most significant included USACE guiding principles, environmental protection and climate change, politics, and a systematic approach. A few other participants indicated that something other than economics (especially NED), or funding constraints that limit ability to conduct proper initial studies and complete projects correctly the first time, should be driving the FRM process.

4.2.1.2. Changes in Driver(s) Significance. Concerning the question of whether any of the drivers in the EM have changed significance over time, respondents noted changes in five key areas: planning criteria, primarily based on past events (55% [$n = 12$]); political and legislative changes, especially funding (40% [$n = 9$]); technology (25% [$n = 5$]); and environmental protection and climate change (25% [$n = 5$]). A few participants also mentioned resources as a driver that has changed in significance in recent years. Between cohorts, engineers overwhelmingly emphasized changes in the importance of public priorities based on past events (80% [$n = 8$] vs. 35% [$n = 4$] for planners). Changes in public priorities have a resulting influence on planning criteria, and the frequency of changes recently in planning criteria has lead to "...an almost schizophrenic kind of behavior..." as described by one planner. Several respondents reflected on the impact of Hurricane Katrina. One engineer noted:

> Hurricane Katrina has forced us to enforce policies that we already had in place that we had became inconsistent in applying and still struggle with. From a corporate perspective it has elevated public safety to the high level. We're shifting how we go about planning these projects away from economics only to where we have a more balanced approach, where we try to balance economics, environmental, and societal impact.

4.2.2. Current Strengths in FRM Process & Capability

When asked what USACE does well in the area of FRM, many participants cited the quality of structural activities and projects (50% [$n = 11$]) and risk analysis and flood risk modeling techniques (50% [$n = 11$]). Engineers (70% [$n = 7$]) were more likely than planners (35% [$n = 4$]) to mention quality of structural work, focusing specifically on innovations and efficiencies in materials and design, as well as high maintenance standards for legacy structures. Engineers also emphasized USACE's exemplary response to flood emergencies (40% [$n = 4$]) relative to planners (10% [$n = 1$]; 25% [$n = 5$] overall). Emergency efforts were hailed for short lags in response time and a high degree of technical expertise and flexibility. Other strengths referenced were the

quality of the overall planning process (25% [$n = 5$]), the expertise and commitment of Corps employees (25% [$n = 5$]), nonstructural activities (<10% [$n = 1$]), and environmental protection (<10% [$n = 1$]).

4.2.3. Opportunities for Improvement in FRM

When it comes to opportunities for USACE to improve the current FRM process, engineers were especially sensitive to the difference between public expectations and reality (90% [$n = 9$] vs. 40% [$n = 5$] planners; 65% [$n = 14$] overall), especially as it concerns the amount of protection a structure is designed to provide and the longevity of that protection. The public is often unaware that the planning and protection horizon on a structural project is often finite, that "[a] structure is going to be good for 50 years and then, that it is going to give after that," or that an area protected by a structure is one of the riskiest places to be if the structure is compromised in any way. Planners and engineers both expressed a need for public education, citing misunderstandings of the meaning of probabilistic terms like "the hundred-year flood," and lack of awareness of probabilistic terms.

Engineers were also quite critical of current project evaluation criteria (70% [$n = 7$]) relative to planners (35% [$n = 4$]; 50% [$n = 11$] overall). Many participants reported a perceived mutual exclusivity in NED and ecosystem restoration metrics for deciding which projects to fund. Some also found NED to be an unfair metric, calculating costs for both federal and regional/local groups, but only concerning itself with benefit at the national (and not local) level. Others focused on a lack of certainty on how best to use the growing variety of alternative metrics for project planning. One planner noted how more metrics may not necessarily indicate better planning:

> . . . you could have as many as three criteria besides NED and NER [National Environmental Restoration] and other social effects and you're supposed to somehow add up both the monetary and the nonmonetary benefits so that means you go from a one-variable decision rule to as many as a six-variable decision rule. A one-sided game, I can understand. A six sided game, now we're pressing the edges of my comprehension.

In contrast, planners tended to focus more on improving collaboration internally and with partner organizations (40% [$n = 5$] vs. 0% engineers; 25% [$n = 5$] overall), as well as on shortening often exorbitantly long project timelines (35% [$n = 4$] vs. 10% [$n = 1$] engineers; 25% [$n = 5$] overall). Some planners recognized that improvements in collaboration, especially with external partners, might help to hurry things along, but they also recognized that "our policies and processes are not for the faint of heart . . . . . there are cities and towns out there who are not engaging with us because of the time and funding it takes us to get through our process." The planning cohort (which includes project managers; see Methods) was also more sensitive than the engineering cohort (35% [$n = 4$] vs. 0%, respectively; 20% [$n = 4$] overall) to inefficiencies in the project management process. Specifically, planners commented that the process does not allow for nonlinearity. More critically, project management is currently yoked by a very cumbersome peer review process. One planner identified as many as seven layers of review in the current process. This planner added "There are times when I think we've spent more on review than on the biggest possible mistake you could make. In one project I've worked on, we've spent more on study than we will on implementation. This is a baleful influence on our effectiveness." Notably, several engineers in the sample cited peer-review processes as one of the strengths of the Corps FRM process. Other areas for improvement identified by the sample included proper funding levels and mechanisms to improve design quality and limit inefficiencies with the current process (30% [$n = 7$] overall), slowing degradations to the Corps technical expertise base (25% overall [$n = 6$]; 40% [$n = 4$] engineers, 15% [$n = 2$] planners), accounting for watershed impacts (20% [$n = 4$]), follow-up on Corps structures handed off to other organizations for maintenance (15% [$n = 3$]), incorporating more nonstructural and nonproject-based solutions (15% [$n = 3$]), and translating technical capabilities into practical methods (15% [$n = 3$]).

4.2.4. Organizational Structure and Alignment with FRM Activities

Participant sentiment was mixed on the extent to which USACE's current organizational structure was aligned with FRM activities. While most participants (65% [$n = 14$]) commented positively, many also had negative comments on organizational and functional alignment (45% [$n = 10$]), with a few individuals providing both positive and negative comments. The extent of positive and negative comments was comparable across cohorts. Positives included improving alignment between planning and engineering functions/groups concerning FRM planning,

improved communication between the Corps key business lines (e.g., navigation, recreation, FRM), and tactically sensible district and regional management frameworks organized at the basin and watershed level. One key negative cited in the organization's structure was that the heavy emphasis on project-based funding makes it very difficult to implement changes to FRM (or other processes) at a programmatic level. In addition, since flood risk is determined by the activities across the Corps other business lines, expertise in FRM is dilute across those lines, making it difficult to improve current FRM process.

While the organization's hierarchical structure was hailed by some participants for the consistency in procedure it creates, it was criticized by others as discouraging interdistrict, and especially interregion, collaboration. Many participants reported being encouraged to search their districts and regions exhaustively for necessary expertise before reaching out to other organizational units. The peer-review process was also hailed as a mixed blessing as it relates to the Corps' historically hierarchically dominant structure. While the shift from a supervisor-approval model of project critique was appealing to several participants because of its increased transparency and the diversity of viewpoints it can bring to a project, it was cited by others as leading to unnecessary study-phase costs and eroding accountability for later design flaws.

4.2.5. Quality of Internal USACE Collaboration

Opinions concerning the quality of collaboration, coordination, and communication within USACE were quite mixed, with some participants responding positively (35% [$n = 8$]), while others expressed a negative viewpoint (30% [$n = 7$]). A third group (25% [$n = 5$]) noted that the quality of collaboration is heavily dependent on the individuals and districts composing the project team or working group. A planner summarized this view as it concerned collaboration between districts:

> It varies across the organization . . . . . Some Districts are very good at working with each other with no 'turf jealousy' or anything like that. There are other Districts across the Corps where . . . . . they won't even talk to each other, even on issues, which may have relevance to both of them.

When asked to reflect on strengths of Corps collaboration, participants cited the effectiveness of multidisciplinary project teams (30% [$n = 7$]), and the willingness of Corps personnel to interact with each other (20% [$n = 4$]). In terms of opportunity gaps, participants frequently mentioned changes in management and organization to promote cultural change (60% [$n = 13$]), and a requirement for more appropriate levels of resources, especially funding and manpower (55% [$n = 12$]). A few also mentioned a need for technical expertise and oversight (15% [$n = 3$]). Specific suggestions for improvement included creating structures that encouraged a balance of power between project managers and engineers, an increase in the number and diversity of engineering personnel, and a shift from project-based Congressional funding to more "continuing authority-type" funding.

4.2.6. Factors Impacting USACE Collaboration, Coordination, & Communication Quality

Participants were asked about the ways in which several factors influenced how well Corps personnel work together. These factors were identified from the EM in an earlier investigation,[55] and included workplace quality, resources (especially funding and personnel), organizational culture, and role clarity. On matters of workplace quality, participants noted that the organization has made good investments in leadership and leader development that are paying off in improving the quality of the workforce, collaboration, and the Corps capacity to complete projects. While sentiment on leadership training was good, that on training in general was more nuanced. Some participants noted "great improvements" in the past ten years, while several others stated that the ability to conduct training is limited because of the project-based nature of most Corps funding.

On the impact of resources, particularly funding and personnel capacity and availability, most engineers and some planners noted that the Corps workforce is stretched thinly across many projects, and that coordination is one of the first items to be compromised when everyone is trying to meet a schedule. Some participants believed constrained workforce issues were related to constraints in funding. In particular, respondents noted that many functional units (e.g., Communities of Practice, Major Subordinate Commands) have difficulty regularly meeting mission objectives because of limited funding availability, let alone communicate progress on those objectives to others. Increased workforce turnover from retirement and shorter employee tenure was

also cited as a negative impact on collaboration, communication, and coordination. This secession means that established relationships between employees in different units need to be recreated as new talent enters the organization to replace the veteran workforce.

On matters of organizational culture, many participants noted that the culture of the Corps encourages districts and regions to work autonomously, decreasing the likelihood and willingness of districts to cooperate. That said, many also indicated that this cultural feature was slowly starting to change toward increased collaboration. The addition of younger, more flexible staff members and the introduction of virtual teaming and other collaboration tools were cited as some of the reason for this culture shift.

Most engineers and some planners noted that role clarity was an area of concern as it relates to internal collaboration, coordination, and communication. Some comments suggested that recent reorganizations in workflow and responsibilities have blurred what team members are specifically responsible for what tasks. Some cross-functional responsibilities, like decision documentation and other tasks that do not clearly fall within one discipline, are sometimes neglected because no team member wants the additional responsibility. One respondent noted cases like these as a result of the communication lag that often follows a swift organizational change. Some other respondents noted that role clarity was good, but only in some situations, providing credence to the reorganization-in-progress view of recent role clarity issues.

4.2.7. *Quality of Collaboration, Coordination, and Communication with Partner Organizations*

Most participants stated that relationships and partnering efforts with other government organizations are typically good (55% [$n = 12$]). Particular cited successes included the Advisory Committee on Water Information, recent work in dam safety programs with the Bureau of Reclamation and the Federal Energy Regulatory Commission, and the Silver Jackets program done in cooperation with FEMA. Of the individuals that reported mixed results in working with other agency partners (30% [$n = 7$]), complaints included some of the barriers that were reported to limit internal collaboration. These included limits to resources of the other agency and USACE's available resources to partner with that agency, role ambiguity that arises from overlapping jurisdiction, and a history of poor interaction with some partners (particularly FEMA).

Concerning work with nongovernment organizations (NGOs; community, industrial, commercial, environmental, and other interests), nearly all engineers (80% [$n = 8$]) and some planners (35% [$n = 4$]) regarded interactions with these groups as usually positive. These respondents typically regarded NGOs as partners with whom shared goals could be established. Nature Conservancy was cited by several participants as a specific partner who shared particularly good relations with the Corps, though other agencies were also mentioned. Interestingly, of individuals who reported problems working with NGOs, some were planners (40% [$n = 5$]), but only one was an engineer (10%). Most individuals who reported problems with NGOs noted that those groups that share a formal partnering agreement (like Nature Conservancy) share a good relationship with the Corps. NGOs that do not have a financial stake in a project were noted by several planners as being tolerated, but not considered or included when it ultimately comes to project decisions.

4.2.8. *Quality of Public Interaction and Partnering*

When asked about interaction with the public, some participants (40% [$n = 9$]) reported that interaction does happen with the public writ large through regulated public notices and hearings, but that specific individuals were rarely consulted and that the public was rarely considered a formal partner on projects. Many participants noted that relations could be improved with public stakeholders (50% [$n = 11$]). Specific suggestions included better communicating risk mitigation plans and current risk exposure to the public, being more responsive to public concerns and needs, and being more consistent as an organization in the degree to which project progress and risks are communicated. Several who reported that public interactions could be better also noted that work was in progress to improve public communication, but that these initiatives are still under development or otherwise have yet to bear fruit.

4.2.8.1. Accomplishing Synergy with External Partners. When asked whether working relationships with external stakeholders were synergistic,

many participants reported that they were (45% [$n = 10$]), though just as many others (45% [$n = 10$]) reported that they could be more synergistic than they are currently. There were no meaningful differences between planners and engineers on this issue. Those who reported synergy with external stakeholders noted that these partners often share information with USACE that the Corps does not have itself, and that the purpose of many of the processes in place is to bring groups together. Of those reporting opportunities for improvement, several reported that USACE was trying to improve and expand cooperative relationships with other groups, and a few others reported that these relationships were improving already.

4.2.9. Engineers and Planners: An Essential Tension and Potential for Agreement

Engineers and planners did show some meaningful differences in terms of their opinions regarding current FRM process and collaboration with internal and external partners. Many areas in which engineers were more vocal than planners are consistent with a need for certainty on the part of engineers. For example, engineers tended to believe that more programmatic (versus project-based) funding was necessary to make sure technical capacity is maintained and kept up-to-date with current technologies. They also noted that the layered peer review approach was effective in ensuring that structural solutions to FRM effectively achieved plan parameters. Engineers also tended to emphasize public safety more than planners, with a desire to make safety a more prominent concern in designing risk management plans. Even with regard to communicating with the public, engineers expressed a desire to align expectations closer with reality, which they thought would increase the certainty of appropriate public utilization of FRM plans.

In contrast, planners were much more interested in making the FRM process more efficient, and tended to take more of a systems view of FRM and other risk management processes. Planners were slightly more likely than engineers to express frustration over Congressional mandates and the way that large projects are funded. If Congress asks for higher levees in Region X, the Corps must build them, even though they may know that more effective and less expensive ways exist to reduce flood risk in that region. While agreeing with engineers that a need exists for better public communication about flood risks, it appears that this interest in communication is targeted toward getting the public to better understand what tools are reasonable to reduce flood risk. Engineers in this sample appeared more focused on communicating what a tool or structure does given that it has already been put in place.

While planners and engineers tended to agree that more funding and manpower was required to ensure the Corps could do its work effectively, planners were much more likely to point out inefficiencies in the existing planning process. Engineers hailed the peer-review process as key for quality assurance, but planners noted that the many layers of review meant increased costs in terms of money and manpower. Engineers tended to focus on maintaining technical capacity so it could be used to fully understand a risk management problem in the event such expertise may be needed; planners, in contrast, noted that some information is not worth generating, in that it will be unlikely to change a current course of action even after that information is known. Although planners agree that multicriteria assessments that include criteria other than NED can be helpful for more effective planning, generating additional data can become very costly, and the additional factors to consider can make it more difficult to identify the best course of action.

These differences between engineers and planners might signal an essential tension: engineers tend to focus on doing the most good with each project they are tasked with, while planners are more focused on maximizing the public good across projects. As is manifest in USACE's FRM process, engineers tend toward more project study than may be practically useful because they discount costs involved in acquiring that information, and how those increased costs impact ability to conduct other projects. So, contrary to the sentiment expressed by many engineers, staffing levels may be sufficient but more staff time is used during study phase for each project than may be useful. This leads to a net shortfall in available staffing. Planners and program managers, interested in making the most out of available resources across the portfolio of current projects, use NED (and perhaps a few other metrics) to formulate a quick decision rule about the best projects to fund. This rule may discount the importance of public safety and other noneconomic indicators. In addition, to the engineer, a planning heuristic like the one described here may lend itself to the appearance that the planner or program manager is not doing all that he or she can for any given project.

5. DISCUSSION

The preceding review makes it clear that, despite high profile cases of catastrophic flooding in recent history (e.g. 2004 Indian Ocean Earthquake, Hurricane Katrina in 2005), lay stakeholders remain largely unaware of the processes that create flood risk and the measures that may be taken to mitigate this risk. Several recommendations are available in the literature to improve this knowledge, and taking advantage of these recommendations may facilitate improvement in the FRM process not only from USACE's perspective, but potentially also from the perspective of other government agencies and stakeholder groups.

The Expert Model of Influences on USACE FRM (Fig. 1) shows that stakeholder perceptions (Individuals' Mental Models of Flood Preparedness and Response) have a significant and direct influence on Desired Outcomes concerned with improving the USACE FRM process. The model also suggests that these individual mental models can be influenced in two ways: directly from improvements to USACE's FRM process, and indirectly through improving the Quality of Public Engagement. The direct pathway might include initiatives to address public perceptions and understanding of USACE's FRM process. USACE FRM improvements could improve the quality of public engagement by explicitly encouraging collaboration and communication between laypersons and USACE in the planning process. In addition, the reviewed literature suggests that educating stakeholders about the risks they are susceptible to in an actionable way has great beneficial potential, if done in a way that accounts for what they can do to reduce the risks they face from floods. Stakeholder education may also decrease pressure on Congress to fund structural flood management projects, which may be counterproductive in the long-term.

Interview results suggest that USACE is making an effort to partner with external stakeholder groups, but has difficulty growing these partnerships because of resource limits. Efforts are also underway to improve internal collaboration, coordination, and communication, but barriers that are creating difficulties in working with external partners also create internal issues. Limited resources, in addition to increased employee turnover and some organizational culture artifacts, were cited as causes for why internal collaboration is not better. However, many expressed that current internal coordination was already good, and some blamed a lack of collaboration on idiosyncrasies of individual working groups or group members, rather than systemic issues.

Future work should seek effective methods for identifying stakeholder perceptions and improving stakeholder engagement in USACE FRM processes. Future work should also expand use of decision analysis-based mental modeling methods, for example in optimizing other processes that are part of USACE's mission. A few possible avenues may be coupling a mental model influence diagram method with statistical techniques (e.g., structural equation modeling) or machine learning algorithms to provide more refined information about the degree of influence between nodes in the model. More specific knowledge about how concepts relate to each other in mental model influence diagrams will help to inform future actions of USACE research teams, managers, and policymakers alike.

The comparative analysis of engineer and planner perceptions represents a first effort to understand the current views of USACE engineers and planners on the agency role and needs for FRM in a post-Katrina world. Future research in this area should take two directions. First, concerning the FRM process specifically, efforts should be taken to understand the key issues that a FRM process should address, and each step of the current process should be assessed for the extent to which it meets these needs. Steps in the process that add less value to the outcome should be considered for revision or removal from the FRM process. Second, concerning the tension this research has uncovered between engineers and planners in their need for project versus system optimization, future work should focus on identifying methods and processes that reduce this tension. Ultimately, both groups are interested in doing the best they can to help USACE effectively serve citizens and the various stakeholder groups they make up.

The engineer's focus on project performance and the planner's goal of portfolio performance are not mutually exclusive goals. Concerning the balance between project study phase costs and staff availability, decision analytic techniques like value of information[60,61] can be used to estimate the utility of acquiring additional information before resources are spent to obtain that information. The peer review process might also be simplified to the extent that some redundancies can be eliminated without adversely affecting project quality. In principle, these changes may serve to reduce the amount of staff

time and resources used unnecessarily, balancing the work-effort equation in a way that does not compromise project quality for system efficiency. A crucial constraint in identifying the best way to serve the public good is in identifying an acceptable tradeoff between similar, though seemingly mutually exclusive, ends.

ACKNOWLEDGMENTS

We would like to thank Drs. Jack Davis and Edmond Russo of the US Army Corps for advice and discussions. Gordon Butte, Sarah Thorne, Alexander Tkachuk, and Laure Canis helped in manuscript preparation and review. Information described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted under the sponsorship of the Civil Works Basic Research Program by the U.S. Army Engineer Research and Development Center. Permission was granted by the USACE Chief of Engineers to publish this material.

REFERENCES

1. Cigler BA. The "Big Questions" of Katrina and the 2005 great flood of New Orleans. Public Administration Review, 2007; 67:64–76.
2. Johnson BB. Testing and expanding a model of cognitive processing of risk information. Risk Analysis, 2005; 25(3):631–650.
3. Gheytanchi A, Joseph L, Gierlach E, Kimpara S, Housley J, Franco ZE, Beutler LE. The Dirty Dozen – Twelve failures of the Hurricane Katrina response and how psychology can help. American Psychologist, 2007; 62(2):118–130.
4. Fleming G. Learning to live with rivers: The ICE's report to government. Proceedings of the Institution of Civil Engineers-Civil Engineering, 2002; 150:15–21.
5. Fleming G. How can we learn to live with rivers? The findings of the Institution of Civil Engineers Presidential Commission on flood-risk management. Philosophical Transactions of the Royal Society of London Series a-Mathematical Physical and Engineering Sciences, 2002; 360(1796):1527–1530.
6. National Research Council. First Report from the NRC Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program. Washington, DC: The National Academies Press, 2008.
7. U. S. Army Corps of Engineers, New Orleans District. Louisiana Coastal Protection and Restoration Technical Report Draft. 2008.
8. Working Group for Post-Hurricane Planning for the Louisiana Coast. A New Framework for Planning the Future of Coastal Louisiana after the Hurricanes of 2005. Cambridge, MD: University of Maryland Center for Environmental Science, 2006.
9. Hecker EJ, Zepp LJ, Olsen JR. Presented at the The European Conference on Flood Risk Management. Keble College, Oxford, UK, 2008.
10. Rabbon PD, Zepp LJ, Olsen JR. Presented at the European Conference on Flood Risk Management. Keble College, Oxford, UK, 2008.
11. U.S. Army Engineer Institute for Water Resources. Alexandria, VA: U.S. Army Corps of Engineers, 2009.
12. Lave TR, Lave LB. Public perception of the risks of floods: Implications for communication. Risk Analysis, 1991; 11(2):255–267.
13. Vari A, Linnerooth-Bayer J, Ferencz Z. Stakeholder views on flood risk management in Hungary's Upper Tisza Basin. Risk Analysis, 2003; 23(3):585–600.
14. USEPA. Terms of Environment: Glossary, Abbreviations, and Acronyms. Washington, DC: United States Environmental Protection Agency, 1997.
15. Kolkman MJ, van der Veen A, Geurts P. Controversies in water management: Frames and mental models. Environmental Impact Assessment Review, 2007; 27(7):685–706.
16. Wagner K. Mental models of flash floods and landslides. Risk Analysis, 2007; 27(3):671–682.
17. Siegrist M, Gutscher H. Flooding risks: A comparison of lay people's perceptions and expert's assessments in Switzerland. Risk Analysis, 2006; 26(4):971–979.
18. Bostrom A, Fischhoff B, Morgan G. Characterizing mental models of hazardous processes: A methodology and an application to radon. Journal of Social Issues, 1992; 4:85–100.
19. Godfrey-Smith P. On folk psychology and mental representation. Pp. 147–161 in Chlapin H, Staines P , Slezak P, (eds). San Diego, CA: Elsevier Inc., 2004.
20. Morgan MG, Fischhoff B, Bostrom A, Atman C. Risk Communication: A Mental Models Approach. New York: Cambridge University Press, 2002.
21. Doyle JK, Ford DN. Mental models concepts for system dynamics research. System Dynamics Review, 1998; 14(1):3–29.
22. Doyle JK, Ford DN. Mental models concepts revisited: Some clarifications and a reply to Lane. System Dynamics Review, 1999; 15(4):411–415.
23. Gruntfest E, Ruin I, Hayden M, Schmidt C. Presented at the 33rd Annual Hazards Research and Applications Workshop, Broomfield, CO, 2008.
24. Rasid H, Haider W. Floodplain residents' preferences for non-structural flood alleviation measures in the Red River basin, Manitoba, Canada. Water International, 2002; 27(1):132–151.
25. Buckland J, Rahman M. Community-based disaster management during the 1997 Red River Flood in Canada. Disasters, 1999; 23(2):174–191.
26. Clark DE, Novotny V, Griffin R, Booth D, Bartosova A, Daun MC, Hutchinson M. Willingness to pay for flood and ecological risk reduction in an urban watershed. Water Science and Technology, 2002; 45(9):235–242.
27. Regnier E, Harr PA. A dynamic decision model applied to hurricane landfall. Weather and Forecasting, 2006; 21:764–780.
28. Pielke RA. Nine fallacies of floods. Climatic Change, 1999; 42(2):413–438.
29. Lynch AH, Brunner RD. Context and climate change: An integrated assessment for Barrow, Alaska. Climate Change, 2007; 82:93–111.
30. Johnson BB, Slovic P. Lay views on uncertainty in environmental health risk assessment. Journal of Risk Research, 1998; 1:261–279.
31. Viscusi WK. The lulling effect: The impact of child-resistant packaging on asprin and analgesic ingestions. The American Economic Review, 1984; 74(2):324–327.
32. Pahl-Wostl C. The implications of complexity for integrated resources management. Environmental Modelling & Software, 2007; 22(5):561–569.
33. Fischhoff B, Slovic P, Lichtenstein S. Lay foibles and expert fables in judgments about risk. The American Statistician, 1982; 36(3, pt. 2):240–255.
34. Fischetti M. Drowning new orleans. Scientific American, 2001; 284:76–85.

35. Graham WJ. Should dams be modified for the probable maximum flood? Journal of the American Water Resources Association, 2000; 36(5):953–963.
36. Faulkner H, Parker D, Green C, Beven K. Developing a translational discourse to communicate uncertainty in flood risk between science and the practitioner. Ambio, 2007; 36(8):692–703.
37. Tapsell SM, Turnstall SM. "I wish I'd never heard of Banbury": The relationship between 'place' and the health impacts from flooding. Health & Place, 2008; 14:133–154.
38. Considine TJ, Jablonowski C, Posner B, Bishop CH. The value of hurricane forecasts to oil and gas producers in the Gulf of Mexico. Journal of Applied Meteorology, 2004; 43(9):1270–1281.
39. McClure J, Williams S. Community preparedness: Countering helplessness and optimism. Palmerston North, Netherlands: Dunmore Press, 1996. Pp. 237–254.
40. Lenntorp E. Hell or high water? An economic analysis of the Swedish institutions for flood risk management. The Geneva Papers, 2008; 33:323–336.
41. Otto K, Boos A, Dalbert C, Schops D, Hoyer H. Posttraumatic symptoms, depression, and anxiety of flood victims: The impact of the belief in a just world. Personality and Individual Differences, 2006; 40(5):1075–1084.
42. Pahl-Wostl C. The importance of social learning in restoring the multifunctionality of rivers and floodplains. Ecology and Society, 2006; 11(1). Available at: http://www.ecologyandsociety.org/vol11/iss1/art10/.
43. McCarthy P, Talley WK. Evidence on risk compensation and safety behaviour. Economics Letters, 1999; 62:91–96.
44. Pretzman S. The effects of automobile safety regulation. Journal of Political Economy, 1975; 83(4):677–725.
45. Downs JS, Bruine de Bruin W, Fischhoff B. Parents' vaccination comprehension and decisions. Vaccine, 2008; 26 1595–1607.
46. Wood MD, Mukherjee A, Bridges T, Linkov I. A mental modeling approach to study decision-making in dynamic task environments. In Chinyio E, Olomolaiye P, (eds). London: Wiley-Blackwell, 2010.
47. Darisi T, Thorne S, Iacobelli C. Influences on decision making for undergoing plastic surgery: A Mental Models and quantitative assessment. Plastic and Reconstructive Surgery, 2005; 116:907–916.
48. Lowe TD, Lorenzoni I. Danger is all around: Eliciting expert perceptions for managing climate change through a mental models approach. Global Environmental Change-Human and Policy Dimensions, 2007; 17(1):131–146.
49. Read D, Bostrom A, Morgan MG, Fischhoff B, Smuts T. What do people know about global climate change? 2. Survey studies of educated laypeople. Risk Analysis, 1994; 14(6):971–982.
50. Bostrom A, Morgan MG, Fischhoff B, Read D. What do people know about global climate-change .1. mental models. Risk Analysis, 1994; 14(6):959–970.
51. Hill SD, Thompson D. Understanding managers' views of global environmental risk. Environmental Management, 2006; 37(6):773–787.
52. Palmgren CR, Morgan MG, De Bruin WB, Keith DW. Initial public perceptions of deep geological and oceanic disposal of carbon dioxide. Environmental Science & Technology, 2004; 38(24):6441–6450.
53. Decision Partners LLC. Success Stories, 2010. Available at: http://www.decisionpartners.com/success.html, Accessed on September 20, 2010.
54. Howard RA, Matheson JE. Influence diagrams. Decision Analysis, 2005; 2(3):127–143.
55. Linkov I, Wood MD, Bridges T, Kovacs D, Thorne S, Butte G, Presented at the 2009 IEEE International Conference on Systems, Man, and Cybernetics. San Antonio, TX, 2009.
56. Brown JR, Morris EA, Taylor BD. Planning for cars in cities: Planners, engineers, and freeways in the 20th century. Journal of the American Planning Association, 2009; 75(2):161–177.
57. Russell JS. Uncivil engineering + infrastructure, a role for architects. Architectural Record, 1993; 181(6):98–99, 145
58. American Planning Association. What is planning? 2010. Available at: http://www.planning.org/aboutplanning/whatisplanning.htm#2, Accessed on July 8, 2010.
59. Yoe C. National Economic Development Procedures Manual: National Economic Development Costs. West Chester, PA: Greely-Polhemus Group, IWR Report 93-R-12, 1993.
60. Linkov I, Moberg EA. Multi-Criteria Decision Analysis: Environmental Applications and Case Studies. Boca Raton, FL: CRC Press, 2011.
61. Linkov I, Bates ME, Canis LJ, Seager TP, Keisler JM. A decision-directed approach for prioritizing research into the impact of nanomaterials on the environment and human health. Nature Nanotechnology, 2011; 6:784–787