EJTIR

Issue 16(1), 2016
pp. 273-293
ISSN: 1567-7141
tlo.tbm.tudelft.nl/ejtir

Joint Fact-Finding in Practice: Review of a Collaborative Approach to Climate-Ready Infrastructure in Rotterdam

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Joint fact-finding has been advanced as a method for helping stakeholders grappling with technically intensive policy and planning challenges to collaboratively engage in research and arrive at shared sets of facts to inform their decision-making. This paper introduces joint fact-finding and considers its application in the context of infrastructure stakeholders aiming to assess and increase the resilience of their infrastructure systems to climate change. A set of evaluative criteria is introduced, which are proposed for assessing joint fact finding processes both procedurally and substantively in terms of the outcomes, considering them to be both arenas for collaborative governance and joint knowledge production efforts. These criteria are applied to a case in Rotterdam, the Netherlands. This case suggests that joint fact-finding can provide value, but also reveals some lessons. For the efforts themselves, these lessons relate to: The practical applicability of the outcomes; the inherently contingent nature of the outcomes when addressing wicked problems; questions of representation from stakeholder groups; and the importance of leadership and good process design. The following observations are made regarding the criteria: While they are typically interdependent, both process and outcomes should be evaluated; and more attention should be paid to the method and metrics of evaluation, while recognizing that there is no single formula or approach that can be applied, given the heterogeneity of the criteria.

Keywords: *climate adaptation, collaborative planning, infrastructure, joint fact-finding, joint knowledge production, Rotterdam*

1. Introduction

Climate change is an archetypal 'wicked' or even 'super wicked' problem (Levin et al., 2012; Rittel and Webber, 1973). It poses a range of threats to our infrastructure systems, including our transportation networks (Bles et al., 2012; Bollinger et al., 2014; Gopalakrishna et al., 2013). Many of these threats - including increases in average surface temperatures and mean sea level rise – are emerging relatively slowly, but may have profound impacts on the long-term viability of critical infrastructures (IPCC, 2013). Furthermore, climate change may be contributing to an

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increase in the frequency and intensity of extreme weather events, which could have significant episodic impacts (IPCC, 2013). Assessment of and response to these threats is complicated by the uncertain and dynamic nature of climate change, and disaggregated knowledge and responsibility (Bollinger et al., 2014).

Transportation agencies are increasingly aware of the climate threats they face, and the solutions available to them as they consider how to adapt (Bles et al. 2012; Hodges, 2011; PWC, 2010; RWS, 2008; Schweikert et al., 2014; USDOT, 2012). However, infrastructure planning is not simply a matter of civil engineering, in which experts translate unambiguous and uncontested goals into *the* best solutions using universally supported standards and models. Resource scarcity; competing interests and perspectives; unclear allocation of responsibility; interdependencies between different infrastructure systems and across jurisdictional boundaries; and different risk tolerances are just some of the factors that make infrastructure planning and decision-making as much a *governance* challenge as it is a technical matter (Biesbroek et al., 2011; Birkmann et al., 2010; Moser and Ekstrom, 2010). Transportation networks are part of dynamic and complex 'systems of systems' that enable critical interactions between people, products and services (Maas et al., 2004). These systems involve interdependencies between infrastructures, like the reliance of rail systems on the electricity grid and urban roadways on stormwater sewers (Dongen, 2013; Nieuwenhuis, Luiijf and Klaver, 2008). These complexities and ambiguities can result in 'institutional voids' (Hajer, 2003). Persistent uncertainty, whether real or perceived, exacerbates the governance challenges associated with adapting to climate change, as it renders conventional approaches to collecting and using scientific information insufficient (Van der Sluijs, 2012).

Collaborative approaches that bring actors together to collectively evaluate risks and devise climate adaptive strategies and solutions have been promoted as a way to move forward (Susskind, 2010). These approaches are designed to not only meet technical needs, but also recognize the myriad of interests and other factors behind stakeholder preferences, and generate decisions that are stable and widely supported (Innes and Booher, 2010; Susskind and Cruikshank, 1987; Susskind, 2010). *Joint fact-finding* (JFF) is a particular type of collaborative approach for tackling wicked problems by bridging divides between both science and policy, and different stakeholders in situations in which the facts are uncertain and contended, and coming to a shared view of them is valuable for moving towards an appropriate plan of action. In the context of climate change, it is an approach for managing the effective integration of climate information into policy decisions, while accounting for the variety of interests and concerns of the various stakeholders, and unclear governance arrangements.

This paper considers how infrastructure operators, decision-makers and other stakeholders can collectively make effective use of the information and resources they have by examining a case in Rotterdam, the Netherlands that one of the authors was directly involved with. This case provides an opportunity to examine the potential benefits of and challenges to employing JFF techniques in cases that involve complex institutional environments and high levels of uncertainty. There are relatively few examples of JFF in practice, and even fewer that involve adapting infrastructure to climate change. We assess this case in terms of both its efficacy as an arena for collaborative governance and as a vehicle for the co-production of knowledge. We consider both the process and its outcomes via a set of criteria we borrow from others and integrate. We conclude with a more general set of observations and recommendations for enhancing the application of JFF, particularly in situations with high degrees of uncertainty, complexity and institutional ambiguity. We also assess the evaluative criteria employed, noting considerations that should be taken into account should they be used further in the future.

2. Governance challenges in adapting to climate change

Despite increasing recognition of the threats posed, climate change adaptation is not, for the most part, well integrated into infrastructure planning and decision-making (Hodges, 2011; Schweikert et al., 2014; Zimmerman and Faris, 2010). Uncertainty about the future is often identified as a substantial barrier to action, and significant resources are devoted to addressing technical uncertainty and increasing our understanding with ever more precise models. Yet, due to the wicked nature of climate change, it is arguable that we will never have an adequate technical understanding of the risks to allow us to make resolute decisions. Instead, we need to confront the governance challenges associated with making better adaptation decisions despite persistent uncertainty (Mearns, 2010). We must also appreciate the interconnectedness of infrastructure systems, and the subsequent need for robust coordination; the implications of climate change beyond the obvious physical costs of responding, including the social and economic costs down the line when systems fail; and the need for greater flexibility and dynamic approaches in both the physical design and management of infrastructures (Bollinger et al., 2014; Willbanks et al., 2012; Zimmerman and Faris, 2010).

The shortcomings in effectively integrating climate change into infrastructure planning and decision-making are not simply a product of uncertainty in climate models, or a lack of technical understanding around how best to adapt. They are also, and perhaps more so, a result of the substantial challenges associated with altering the decision-making institutions responsible for various infrastructure systems so that they can effectively incorporate climate change and address institutional voids. It is a question of how we can mainstream adaptation into existing infrastructure policy domains and associated institutions, and facilitate interactions across institutional divides as necessary (Hodges, 2011; Moser and Ekstrom, 2010; Uittenbroek, Janssen-Jansen and Runhaar, 2013).

The interconnected nature of physical infrastructures creates inherent interdependencies in their governance; decisions made in one area have knock-on effects in others (Dongen et al., 2013; Nieuwenhuis, Luiijf and Klaver, 2008). For example, if energy sector decision-makers in a coastal city decide not to invest resources into protecting their network from increasing flood risks, they are not only leaving their own infrastructure open to failure, but also other systems – like water and transportation networks – that depend upon the electricity grid to function. These kinds of interdependencies also exist within the same sectors, but across scales and areas of responsibility. While users view and use roads as contiguous networks to move from point to point, in many countries the infrastructure along any given route is typically owned and managed by different levels of government. Furthermore, there are often multiple agencies at each level of government with different areas of responsibility.

Despite these interdependencies, those planning and managing infrastructures often work in silos, interacting with their counterparts in other networks on a limited basis (Measham et al., 2011). This is not surprising; the complex webs of actors, policies and processes revolving around any particular area of infrastructure are already dauntingly complex and involve the application of specialized knowledge. It may not be realistic to expect each actor to understand the nuances of others' tasks. This being said, the absence of a shared, comprehensive understanding and coordination around the complex and highly interdependent webs of infrastructure makes systemic change difficult. There are weak incentives to address institutional voids, coordinating the integration of new conditions, and considering the cascading impacts of decisions beyond each agencies' own area of responsibility.

Anguelovski and Carmin (2011) assert that - when compared to mitigation planning, which is more institutionalized in cities and driven by wider global and national trends - the approaches being taken to adaptation planning are more heterogeneous and homegrown. On the up side, this can foster entrepreneurship in the quest for tailor-made solutions that best meet the

particular needs of each situation. The downside is that the lack of methodical institutionalization - and resources associated with it – may be a key factor behind the slow uptake and integration of adaptation into planning and decision-making (Anguelovski and Carmin 2011).

2.1 Science-policy interface: The climate information usability gap and co-production of knowledge

One of the most significant challenges associated with integrating climate change into infrastructure planning is that even when relevant scientific information is available it is not in formats accessible and useable to, and legitimate in the eyes of, those charged with making infrastructure decisions. Lemos, Kirchhoff and Ramprasad (2012) identify a *climate information usability gap* between the climate data scientists are generating and see as important, and what practitioners are actually incorporating into their decision-making. They enumerate a set of barriers that constitute this usability gap, including: lack of salience of the data provided, in the eyes of users; preference for the familiar and commensurate risk aversion; insufficient capacity to use the data that is available; lack of discretion and legal limitations around what is possible; and general lack of relationships and very different professional backgrounds between information producers and users (Lemos, Kirchhoff and Ramprasad, 2012).

Challenges associated with the co-production of knowledge at the science-policy interface can also inhibit adaptive efforts (Hegger et al., 2012). Jasanoff (1990) characterizes scientists advising environmental and other public policy matters as the 'fifth branch of government' because of their influence, and notes the pitfalls and naiveté associated with relying on traditional methods of ostensibly neutral scientific panels, peer review and objective expert advice when evaluating data, because of the significant critiques regularly levelled at scientists' credibility. Van Buuren and Edelenbos (2004) suggest that these critiques may be warranted, with much of the knowledge production occurring within separate 'knowledge coalitions' that contain both researchers and policy-makers and are oppositional to one another within policy domains. They conclude that the most significant divide is not between the science and policy worlds, but between coalitions, and suggest that we need to "establish links among different knowledge production coalitions in order to prevent 'knowledge battles'" (Van Buuren and Edelenbos, 2004: 297). While focused on the science-policy divide, Jasanoff (1990) similarly advocates for advisory processes that engage scientists to negotiate consensus on regulatory science, recognizing the limits of science and suite of policy issues that must be balanced. Hegger et al. (2012) call for 'joint knowledge production', which they typify as a manifestation of both 'mode 2 research' and 'post-normal science', with an emphasis on practices that recognize, account for, and are accountable to the local context and stakeholders beyond scientists in science-policy debates.

Whether it is to bridge the usability gap or foster effective boundary management between scientists coming from different coalitions and between scientists and other actors, effective approaches to joint knowledge production are seen as necessary and largely insufficient in current policy discussions, including around climate adaptation (Van Buuren and Edelenbos, 2004; Hegger et al., 2012).

2.2 Collaborative approaches and tools

Despite the gaps, decision makers' understanding of how to effectively integrate climate change adaptation into decision-making is improving. Lemos, Kirchhoff and Ramprasad (2012) identify a set of potential opportunities for overcoming the barriers. Many of these opportunities are relational in nature, emphasizing the importance of fostering connections and building trust between scientists generating climate data, infrastructure planners and other key stakeholders. There are various decision support tools and models designed to facilitate the integration of adaptation into infrastructure planning (see, for example, Bollinger et al., 2014; Hodges, 2011; Nieuwenhuis, Luiijf and Klaver, 2008; Maas, 2012; Schweikert et al., 2014; Simpson et al., 2005; Termeer et al., 2011; van Vuuren et al., 2011). The need for enhanced, truly multi-stakeholder collaboration is implicit or explicit across these approaches, especially if we are to tackle

emerging threats that are not yet well institutionalized in an integrated manner (Willbanks et al., 2012; Zimmerman and Faris, 2010). However, it is notable that there are important critiques of the value and viability of collaborative approaches to adaptation planning in current institutional environments (see, for example, Burton and Mustelin, 2013; Few, Brown and Tompkins, 2007).

Furthermore, this is not to say that the conventional tools used to support decision-making – like econometric and transportation forecasting and modelling - are unimportant. To the contrary, the best decisions are those informed by good data and credible forecasts of the future. However, even the best datasets and models cannot provide the single right path forward. Persistent uncertainty, differing values and risk tolerances, and competing visions of the future make decisions around infrastructure planning both technical *and* political. This is particularly true in situations with high degrees of irresolvable uncertainty, as is the case under climate change. Data should inform decision-making processes that also account for the interests and perspectives of the various parties with a stake in the infrastructure systems at hand.

Those wrestling with how to integrate climate change into infrastructure planning and decision-making in practice recognize the critical need for greater coordination. In the United States, the Hurricane Sandy Rebuilding Task Force (2013) recommended that agencies provide "a forum to coordinate and discuss large-scale, regional infrastructure projects and map the connections and interdependencies between them, saving money and getting better results for all levels of government". In the Netherlands, the Delta Programme emphasizes the importance of multi-stakeholder engagement, stating (2013: 6): "[We] collaborate with all stakeholders from the outset – government authorities, businesses, knowledge institutes and social organisations […] In that way, all the relevant facts can be collected, investigated and shared. We carry out the analyses together and then establish and discuss the viable and promising solutions with each other. […] This approach provides new insights, creates widespread support for the decisions and measures to be taken later, and presents opportunities to link other (spatial and economic) developments." Infrastructure planners and other stakeholders need to find new ways of sharing knowledge and making complementary decisions if climate change is going to be effectively accounted for.

Collaborative approaches to planning and decision-making are most successful when they are well structured. Fortunately, there are viable models for bringing decision-makers and other stakeholders together (Ansell and Gash, 2008; Innes and Booher, 2010; Susskind and Cruikshank, 1987). They bring the right people to the table, and focus on the prioritized issues and options of those present. Situation or stakeholder assessments can be used to enumerate the actors, issues, options, and potential stakeholder representatives at the table (Carpenter and Kennedy 2001; Susskind and Thomas-Larmer 1999). Processes must be seen as 'fair, efficient, stable and wise' as they manage learning and debate and lead to widely supported and implementable outcomes (Susskind, Levy and Thomas-Larmer 1999). Finally, collaborative processes must have mechanisms for dealing with both technical information and other sorts of knowledge (Karl, Susskind and Wallace, 2007). Since the success of processes is, at least in part, dependent on the quality of the ways in stakeholders are involved, relevant actors must be invited to participate, and have equal access and ability to engage. Transparent and flexible, yet well designed and managed, processes are required, with stakeholders that are willing to cooperate to improve their own situation while improving the infrastructure system as a whole. In the next section we introduce joint fact-finding as a collaborative approach intended for situations with substantial scientific or technical questions.

3. Joint Fact-Finding: Collaboratively reconciling science and policy

Many of the issues associated with integrating climate change into infrastructure planning and decision-making are technical in nature – this includes both understanding the potential impacts of climate change, and efficacy of various possible responses. Decisions must be informed by

robust scientific and technical information. Unfortunately, it is often unclear where, and whom, that information should come from, how it should be assessed, and how any options proposed should be evaluated. Joint fact-finding (JFF) is an approach proposed to help groups to work through these kinds of science-intensive questions collaboratively (Adler et al., 2011; Ehrmann and Stinson, 1999; Karl, Susskind and Wallace, 2007; McCreary, Gamman and Brooks, 2001). JFF may be a viable way to engage in the kinds of boundary management that has been deemed necessary around scientifically and technically complex policy challenges, like adapting to climate change. That is, it offers a way to overcome the barriers to knowledge transfer between research and policy arenas, and facilitate the kind of joint knowledge production that Van Buuren and Edelenbos (2004), Hegger et al. (2012) and others have called for. In fact, Van Buuren and Edelenbos (2004) conclude by suggesting that JFF may be a way to facilitate fruitful interactions among knowledge production coalitions.

Technical experts and other knowledge providers – including local and traditional knowledge holders – become partners in the process, working with other stakeholders. *Figure 1* outlines an archetypal JFF process; in practice, processes are tailored to the particulars of the given situation. As with any collaborative process, stakeholders, including the relevant agencies and/or infrastructure owners, have to buy into the notion that they are going to work together, and the resources must be available to support the process. Professional neutral assistance can be invaluable as parties assess the viability of and, depending on the assessment, structure a JFF process (McCreary, Gamman and Brooks, 2001).

A key step in the JFF process is defining the critical information gaps (i.e., what facts are needed), and translating them into researchable questions. The resulting data will be much more credible to stakeholders if they play a role in this initial framing stage. Likewise, ideally stakeholders are involved in deciding who should answer research questions, and in identifying which methods can and should be used to conduct the associated research. There are often multiple ways to answer a question, and thus a mixed methods approach can be appropriate, while recognizing that there is a trade-off between comprehensiveness and the expenditure of resources, including time (Adler et al., 2011).

Rather than conducting their research in a black box, technical experts involved in JFF processes should work with other stakeholders, keeping them abreast of methodological decisions made and data collected as their work unfolds. This takes a strong degree of commitment on the part of researchers that are not always accustomed to working collaboratively with people outside their respective disciplines (Andrews, 2002). JFF groups should collectively receive and consider the results; while they may have different interpretations, this leads to an agreed-upon knowledge base. This is the basis on which they can discuss the implications, nature of any persistent uncertainties and assumptions made in the research process, and possible policy responses that could be adopted in response (Karl, Susskind and Wallace, 2007).

There are various tools and approaches that can complement JFF processes instigated to consider the adaptation of infrastructures to climate change. These include scenario planning and group model building. These tools may offer effective ways for stakeholders to collectively grapple with the risks and uncertainty they face. Role-play simulation exercises can serve as a valuable tool for working with groups to experiment with new options, tools and approaches in a safe environment (Schenk and Susskind, 2014; Susskind and Rumore, 2013).

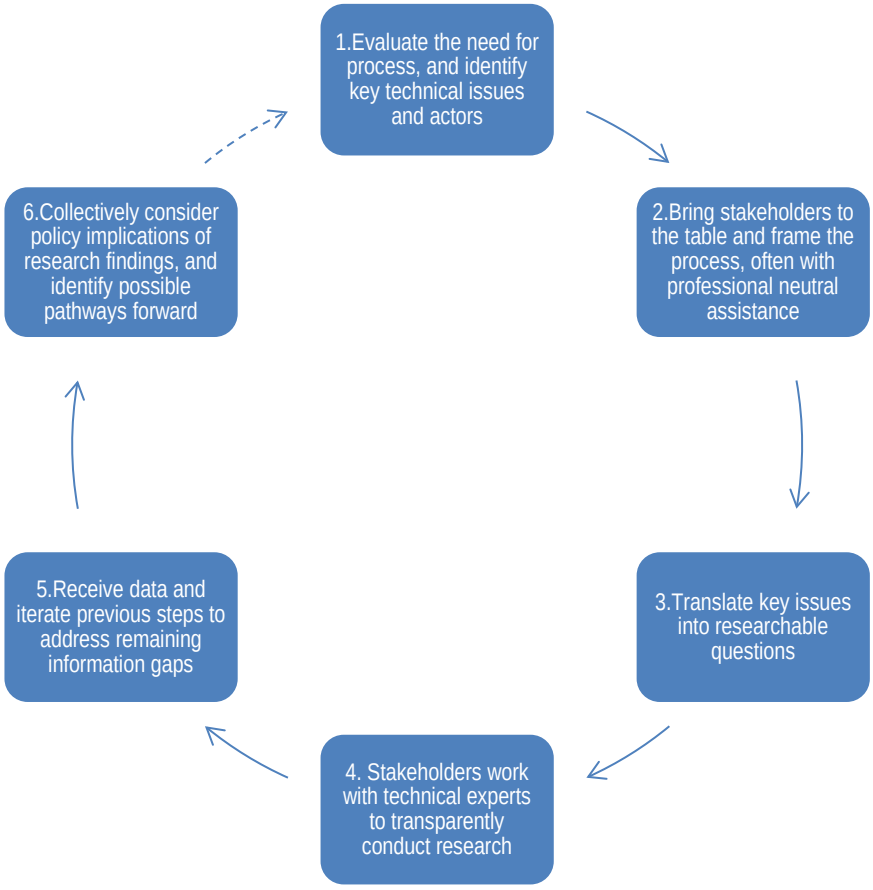

Figure 1. Steps in the Joint Fact-Finding Process. Adapted from: MIT Science Impact Collaborative and the Consensus Building Institute, 2013

4. Criteria for assessing the efficacy of joint knowledge production efforts

Evaluating the efficacy of joint knowledge production efforts, including JFF processes, is critically important, particularly if we aim to enhance their use in practice over time. Evaluation requires the delineation of a robust set of criteria. We assert that successful JFF processes are strong procedurally *and* substantively and should be evaluated accordingly. To this end, we propose applying a set of criteria that can be used to evaluate JFF as both a collaborative approach and a knowledge production effort, considering both process and outcomes.

Ansell and Gash (2008) proposed a set of criteria for assessing projects as vehicles for advancing collaborative governance:

- *Resource and power imbalances* – Are there substantial differences in capacity and access to resources? If so, stronger actors may manipulate at the expense of others.
- *Interdependency and incentives to participate* – Are the parties incentivized to engage with one another, and do they have faith that the can benefit from participating? If not, they are unlikely to invest the resources and fully engage in good faith.
- *History of conflict or cooperation* – Do the parties view each other antagonistically? If so, perceived interdependence may still allow for fruitful collaboration, but it must be recognized and accounted for in process design.
- *Leadership* – Is there a party that is taking responsibility for supporting the process and advancing it procedurally? Such a party, which is often a professional neutral,

can play critical roles in maintaining ground rules, building trust and facilitating fruitful dialogue.

- *Institutional design* – Is the process robust, engaging all of the necessary stakeholders, maintaining transparency and clear procedures, and working within established timelines? Inadequate design can leave a process short of its objectives.
- *Opportunities for face-to-face dialogue and trust building* – Do parties have the chance to engage one another directly and build trust, despite their differences? This is often a precursor to moving beyond preconceptions and initial positions, and developing creative solutions.
- *Emergence of shared understanding and commitment* – Do participants have a shared understanding of what the challenge is, and common commitment to addressing it? While differences are inherent, a shared framing and commitment to looking for mutually advantageous outcomes is often key to success.

The Ansell and Gash (2008) criteria are generally applicable to collaborative efforts. Hegger et al. (2012) advance a complementary set of 'success conditions' that focus more on what might constitute a successful 'joint knowledge production effort':

- *Proposition 1.* The success of joint knowledge production projects is enhanced in cases in which the broadest possible coalition of actors is formed, within the practical and strategic limits present. This likely entails both in- and exclusion of actors.
- *Proposition 2.* The chance that joint knowledge production is successful is enhanced in cases in which participating actors deliberate on the nature and denomination of the policy problem (un-, badly-, moderately- or well-structured) and the type of outcome? (ideas, closure on problem definition, concepts, arguments or solutions) to be expected.
- *Proposition 3.* Actors in joint knowledge production projects can be expected to have diverging and implicit perspectives on the world around them. The success of joint knowledge production will be enhanced if the different perspectives of stakeholders are recognised and taken into account. In this, boundary objects can play a mediating role.
- *Proposition 4.* The chance that joint knowledge production is successful is enhanced if actors decide, consciously and reflexively, which role to pursue in a project, how to define their identity in relation to the other actors, and to make their choices known to these other actors.
- *Proposition 5.* The chance that joint knowledge production is successful is enhanced in cases in which the role of researchers and their knowledge is clear.
- *Proposition 6.* The chance that joint knowledge production is successful could be enhanced through novel forms of reward structure, but more experience with such examples is needed.
- *Proposition 7.* The chance that joint knowledge production is successful is enhanced through the availability of specific resources (boundary objects, facilities, organizational form and competences) facilitating communication between communities with different epistemologies.

Hegger et al. (2012) assess whether or not these conditions enhance or weaken the perceived salience, credibility and legitimacy (as outlined by Cash et al., 2002) of joint knowledge produced. There are elements of these two sets of criteria that are similar or interrelated. For example, Hegger et al. (2012) assert that JFF processes are enhanced when the broadest group of

stakeholders possible is engaged, and Ansell and Gash (2008) emphasise "interdependency and incentives to participate". There are also some elements on one list but not the other. For example, Ansell and Gash (2008) propose 'leadership' as a criteria, while Hegger et al., (2012) do not. We assert that both sets of criteria have merit, if JFF processes are to be evaluated based on their ability to facilitate both collaborative governance and joint knowledge production. Where we feel that neither is quite sufficient is in emphasizing the importance of the outcomes, which are critical if JFF efforts are to contribute to decision-making in practice rather than simply to knowledge for knowledge sake. To this end, we propose integrating the two sets of criteria, and adding the salience, credibility and legitimacy of the data generated as discrete benchmarks to emphasize the importance of the outcomes. We arrive at the following set of 10 criteria:

1. Broad stakeholder representation
2. Interdependency and incentives to participate
3. Shared understanding of the challenge
4. Resources available, and imbalances not acute
5. Cooperative relationships, and mechanisms for managing conflict
6. Facilitative leadership, and role allocation
7. Adequate process design
8. Meaningful dialogue facilitated
9. Researchers integrated and roles clear
10. Outcomes salient, credible and legitimate to stakeholders

We next consider a case of JFF in the Netherlands, and evaluate it using the ten criteria outlined above. We then make some wider observations on the practice of JFF, and a higher-level assessment of these criteria, drawing from their application to the case. It is here that we consider whether or not these success conditions can adequately promote and assess *good* JFF.

5. A practical case: Climate adaptation in Rotterdam North

A recent climate adaptation project in Rotterdam, the Netherlands (*figure 2a*), provides an instructive example of a joint fact-finding effort in practice. While not archetypal in all ways of the JFF approach as sketched in *figure 1*, the case represents a rare (if not unique), real-world application of JFF in the context of climate adaptation for multiple infrastructures. It involves various infrastructure owners grappling with how to tackle the wicked problem of climate change in the face of both physical uncertainties and institutional ambiguities.

Rotterdam is a particularly appropriate venue for a case like this because it has long been a living lab for climate adaptation research (Mees, Driessen and Runhaar, 2014; Uittenbroek, Janssen-Jansen and Runhaar, 2013), and thus is primed for this kind of trial of JFF as a way to further enhance already robust practice. The transaction costs were manageable, as the actors were accessible, and willing and able to engage in the JFF process. We add to the body of case studies in Rotterdam, and in particular to recent contributions to the literature on knowledge production (see, for example, Groot et al., 2015). Groot et al. (2015) provide a high-level examination of the integration of research into climate adaptation, while we frame and discuss the application of a particular approach (JFF), and associated evaluative criteria.

We first outline the case, and then evaluate it as a JFF effort, according to the criteria introduced above. This assessment is based on primary sources; one of the co-authors was directly involved in project design and implementation, providing first-hand exposure and access to project documents, including meeting minutes, post process surveys and assessment feedback collected

from participants, inform this appraisal (see Geerdink and Maas, 2014). This assessment was conducted post-hoc, and was not built into the project itself.

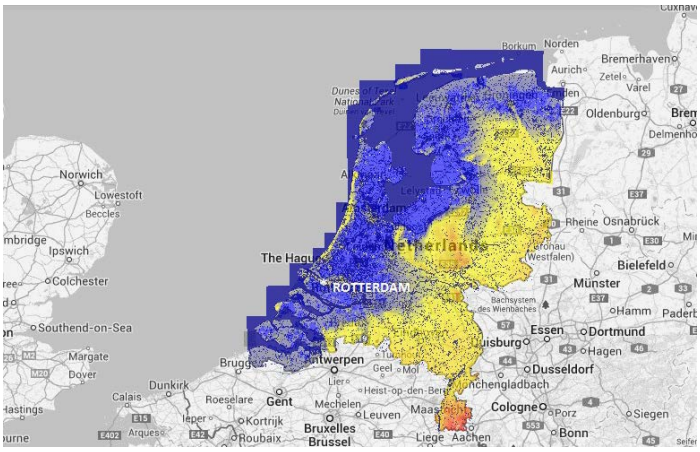

Figure 2a. Location of Rotterdam within the Netherlands. Dark shaded areas below sea level. Retrieved from http://openworks.me/2013/06/oscity-netherlands/ on 1-4-2015. Copyright Open Source City, Reprinted with permission

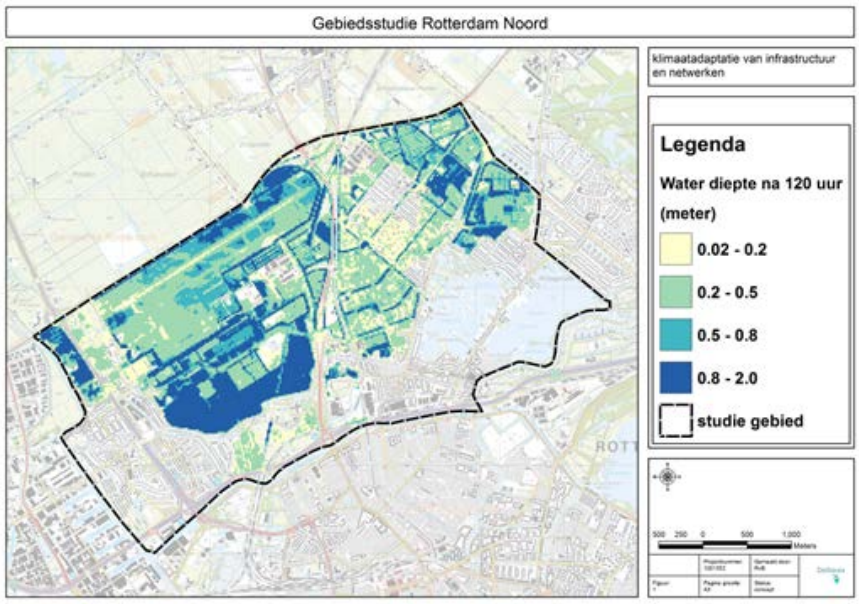

Figure 2b. Location of Case Study and water depth 120 hours after flooding

Source: Geerdink and Maas (2014).

The study was commissioned by the City of Rotterdam and Dutch Ministry of Infrastructure and Environment to identify and evaluate the vulnerabilities of transportation infrastructure to climate change. It also explored the interdependencies between the transportation network and other infrastructure systems in the Rotterdam North area, including the electrical, wastewater, natural gas and transportation grids. For the full report we refer the reader to Geerdink and Maas (2014). The questions of if, how, and when infrastructures should adapt to climate change were regarded as well suited to a JFF process because of the low level of available scientific information, high degree of uncertainty around future scenarios, the institutional ambiguity, and the poor preparedness of institutions to integrate climate change into their processes. The scope of the study was limited geographically (Rotterdam North region, about 15 sq. km.), to one hypothetical extreme weather event (flooding), to a specific timeframe (situation five days after a

flooding event – see *figure 2b*) and to four interconnected infrastructure systems (road network, electricity network and pipelines for wastewater and gas). The process that was followed is outlined in *Table 1* and discussed further below.

Table 1. Process overview case study Rotterdam North by steps of JFF framework

Step in JFF process (from figure 1)	Implementation in Rotterdam case
Step 1 Evaluate need, identify key issues and actors	Pre kick-off consultations
Step 2 Bring stakeholders together and frame process Step 3 Translate key issues into questions	Workshop I (Kick-off)
Step 4 Stakeholders and experts conduct research	Research projects on (1) vulnerability assessment and (2) adaptation design
Step 5 Receive data, feedback and iterate to answer questions	Workshops II (Blue Spots) and III (Synthesis)
Step 6 Identify policy implications and revert to Step 1 if needed	Synthesis workshop (III)

5.1 Steps in the Rotterdam North climate adaptation JFF process

Step 1: Pre-kick off consultations

The municipality of Rotterdam was the convener for the process and selected a representative of a national research institute as a neutral facilitator. Stakeholders involved in infrastructure maintenance and investment decisions, local and regional authorities, the district water boards, disaster preparedness bodies, and researchers interested in risk management and vulnerability assessment were identified by the conveners and facilitation team and invited to participate. The municipality and the transportation agency contributed financially; all other stakeholders gave their time, and developed and shared data within the project. A motivation to participate that was shared by all was their knowledge of and responsibility for infrastructure in this area. For the most part, the stakeholders had no history of conflict or close cooperation, yet their respective infrastructures and areas of responsibility are extensively interconnected.

Steps 2 and 3: Workshop I (Kick-Off)

During the first workshop, stakeholders identified and discussed the knowledge gaps that needed to be addressed. Examples included: The viability of the highway for evacuation in case of flooding; which networks are crucial before, during and after flooding; where are drinking water pipes located in dikes; and what is the order of cascading events, should catastrophic failure occur during a flood. Participants agreed that a detailed vulnerability analysis was needed of their infrastructure systems, and that scientists and technical experts should contribute. Thus a preliminary research agenda emerged during the first workshop. A majority of stakeholders advised that the research should stay grounded in the realities of the case rather than using very theoretical models and information. The possibility of gaining practical knowledge was the incentive for them to participate in this JFF process. All parties agreed that the consequences of extreme weather events for different parties needed to be identified to generate more support for subsequent adaptation efforts. The researchers and stakeholder representatives discussed the boundaries, assumptions, flood scenarios, and data necessary for decision-making. The collaborative nature of the process helped participants to move beyond preconceptions and initial positions to a shared understanding of the climate risks, data gaps, and possible responses. Stakeholders used this new shared framing of the situation to generate a set of research questions for a set of independent experts, which were tasked with conducting research between workshops I and II.

Step 4: Research projects (two rounds)
New and in-depth research was conducted between workshops I and II, and between workshops II and III. After workshop I, the facilitator organized two meetings with the researchers - one to elaborate and cluster the stakeholder questions into a shared research agenda and the other to decide on the balance between methodological and practical aspects of the projects. Network vulnerability assessments were carried out as factual input to workshop II. During workshop II, questions of operational nature emerged that concerned interdependencies between asset managers (see step 5). These were answered before Workshop III (synthesis) to allow recommendations to be drawn up.

Step 5: Workshop II – Blue Spots
In the second workshop, the results of the individual network vulnerability assessments were discussed to identify the most vulnerable areas (so-called 'blue spots'), and how practitioners could use this knowledge. The dialogue among parties fostered a better, shared understanding of the failure mechanisms and cascading effects between infrastructures. Because of the practical applicability of the models developed and the candidness of the researchers on their assumptions and boundaries, the results of the vulnerability analyses were widely accepted. In addition, these interactions exposed new knowledge gaps that needed to be addressed, including: How long it would take to repair local electricity grid stations after flooding and sudden shutdown; and the protocol for preventive shutdowns, and who is responsible for decision-making. Between the second and the third workshops, researchers worked with the infrastructure managers to answer these questions. The answers proved to be relevant for almost all stakeholders, because of the dependencies of their own systems, like drinking water pumping stations and transportation management systems, on the electrical grid.

Step 6: Workshop III – Synthesis
In the third workshop, stakeholders discussed the results of all the studies and translated them into information that would have value in practice. Together, parties visualized the interconnectedness between infrastructure networks. The earlier research process of collaborative data collection, modelling and analysis, and sharing of outputs enabled this work. The main results of the process were a more comprehensive and integrated understanding of the interdependencies and vulnerabilities of critical infrastructures, and a shared awareness of the role of cascading effects. Stakeholders learned that the infrastructures in the case study area are, independently, not very vulnerable to climate change. However, the cascading effects that can result from their interdependencies may significantly increase the impacts of extreme weather events. Stakeholders identified possible pathways forward, with recommendations ranging from the technical and design-oriented to organizational and informational. Examples of this include improved highway designs and advanced evacuation route information. However, a collective evaluation of likely policy implications was not possible due to time and budget constraints. A fourth meeting was suggested to address these knowledge gaps, but deemed unfeasible within this project. The researchers had focused on vulnerability models and technical responses, and not on assessing the policy environment and implementation strategies.

The materials aggregated via this process have been accepted as important contributions to the knowledge base for adaptation measures in the region. The study did not deliver a scientific report, as had been expected by some stakeholders, but contributed to a common understanding of the vulnerabilities, rooted in information that was viewed by all stakeholders as credible and legitimate. Soon after the project, some participants, like the energy infrastructure manager and the asset manager of the local authority proceeded to integrate the results into their asset management strategies and operational activities. However, some feel that only an extended written report would have value for policy-making, and thus see the results as less legitimate.

5.2 Findings from the Rotterdam case study

A set of criteria for evaluating collaborative joint knowledge production efforts was introduced in section 4 of this paper. *Table 2* below considers the Rotterdam case against these criteria, assessing whether and how it met these conditions and providing simple (poor, satisfactory and excellent) evaluations against each criterion.

Table 2. Assessment and evaluation of the Rotterdam case against criteria

Criteria	*Assessment*	*Evaluation*
1. Broad stakeholder representation	This project focused on the interdependencies among different infrastructure systems – namely the road, electricity, wastewater and gas grids - bringing together experts from each system. It is notable that it was largely technicians and advisors from each system at the table, rather than decision-makers. Representatives from the City of Rotterdam and the Ministry of Infrastructure and the Environment also participated. Non-governmental actors, like infrastructure users, were not directly represented at the table.	Satisfactory
2. Interdependency and incentives to participate	Participants joined the workshops and contributed time, funds and/or data. The incentive was genuine curiosity in obtaining new knowledge and in developing practical tools and guidelines. Parties had been sensitized by recent extreme weather and flooding events in the country that had exposed multi-infrastructure adaptation challenges. They had a realistic understanding of the possible scale of climate change impacts, but less of the interdependencies during extreme events.	Excellent
3. Shared understanding of the challenge	At the outset, the interdependencies between the parties were not obvious, but all agreed to the central objective of identifying them. As such, the emergence of a shared understanding was a built-in feature of the process. Although individual interests differed, the stakeholders were able to build a common framework of the causes and effects of infrastructure failures. In addition, the final workshop focused on fostering co-operation to address interdependent risks. This added an additional dimension to the process.	Satisfactory
4. Resources available, and imbalances not acute	The municipality of Rotterdam financed a large part of this research, however the transport agency and research organizations contributed as well. The resources, both in kind and in money, were discussed in the pre-kick off and kick-off phases. During the JFF process, parties did not use their power imbalances, including those associated with funding disparities, to influence the direction of the work.	Excellent
5. Cooperative relationships, and mechanisms for managing conflict	There is little history of significant conflict or close cooperation among the stakeholders. Although areas of responsibility for daily operations were mutually understood and well aligned, stakeholders were operating autonomously. The issues focused on in the project were not controversial, so conflict was not a factor.	Satisfactory
6. Facilitative leadership, and role allocation	The project owners identified a neutral facilitator to broker the supply and demand of information and process the research questions. Stakeholder roles were clearly identified and managed, which allowed participants to lead the process of information production and sharing in their respective fields.	Excellent
7. Adequate process design	A lot of effort was put into setting the stage correctly at the outset. The first phase of consultations allowed for careful preparation around the key issues. Because of the incentives to participate and opportunities for face-to-face meetings and trust building, the stakeholders could position themselves and take on appropriate	Satisfactory

	and fulfilling roles during the research, data collection and data analysis phases. The process was designed and agreed upon beforehand, and completed largely as envisaged. Two workshop events had to be postponed due to subject complexity, and extra effort was required to reach agreement on research questions and obtain required data, but the process was able to handle these changes (although they did result in higher costs).	
8. Meaningful dialogue facilitated	In the post-process debrief, participants reported that the transparency of information sharing, collective decision-making and equal treatment of all participants were key contributors to trust building amongst stakeholders. These factors allowed for meaningful dialogue among participants.	Excellent
9. Researchers integrated and roles clear	The broader context of the project included a large research programme, which aimed to develop a multi-disciplinary framework for climate adaptation measures. As a result, discussions about a common framework and positioning of experts could be held very early in the process, with information from this programme as background. Several translation challenges emerged in the project, as researchers and other stakeholders worked to appreciate and address each other's needs. For example, climate scientists struggled to convey information that would be useful for infrastructure managers, and infrastructure mangers struggled with translating broad climate data into their specific contexts. These challenges were largely overcome, but it involved time-consuming bridge building.	Excellent
10. Outcomes salient, credible and legitimate to stakeholders	Information generated through this project is seen as *credible* by stakeholders because they buy into the research approaches taken and find the results trust-worthy. Credibility was enabled via the transparency of the data, models, assumptions and boundaries used, and the general credibility of the research institutes involved. The process was seen as *legitimate* by those involved because it was robust and perceived to be unbiased and balanced. Key stakeholders were directly involved in framing the research agenda, and trusted the experts, leading to a perception of fairness and broad endorsement from within and across institutions. The legitimacy may be externally questioned due to the absence of many stakeholder groups, including citizens and interest groups in Rotterdam North, although no opposition emerged through or as a result of this process. The *salience* of the information is less certain; participants report that the outcomes provided useful insights that will inform their work over time, but some lamented that there was no formal report generated that could directly influence changes in decision-making. The project was not set up to facilitate shared decision-making, but rather for 'gaining new insights'. This framing may have been problematic because, as a result, it was technical experts and not higher-level decision-makers at the table for most participating groups. The lack of attention to implementation may have reduced saliency.	Poor salience; satisfactory credibility and legitimacy

5.3 Challenges in the Rotterdam case study

The assessments in *table 2* suggest that this case of JFF in Rotterdam may be regarded as an effective joint knowledge production effort to tackle a wicked problem of how to adapt to climate change, at least procedurally. At the same time, there were shortcomings and governance challenges, and the value of the outcomes as tools to enhance decision-making (i.e., their *salience*) has been questioned. We discuss these shortcomings below. In the next section, we discuss the implications of this assessment on the ten evaluative criteria applied.

A 'climate information usability gap' between what climate scientists view as important and what infrastructure stakeholders see as germane and useful for their decision-making led to delays and barriers in data collection and interpretation between the kick off and the second workshop. The researchers received clear instructions on how to proceed and started asking the stakeholders for information and data. But, these requests were not specific enough or the requested data was not available, limiting how much stakeholders could deliver. This precipitated a debate on the availability and necessity of information in certain formats. The stakeholders did not know what climate data was necessary for the researchers' models. Researchers sometimes found it difficult to extract practically useful data from the broad research base available (e.g. spatially and temporally detailed weather forecasts). The appropriate levels of detail, time horizon and increments (monthly or yearly), and geography of networks had to be determined through extensive deliberation. This required further facilitation and clarification of the process.

Finding the right match between information supply and demand proved to be a continuous balancing act. Despite an appropriately comprised group, continuous attention to convergence was critical to finding and maintaining this balance. In between the workshops it took substantial effort on the part of the facilitator to answer researchers' questions, connect researchers with each other and to stakeholders, and to keep the researchers focused on stakeholders' questions. This affirms the critical importance of facilitative leadership.

A well-designed and executed joint fact-finding process can facilitate valuable interactions between stakeholders and create an agreed upon knowledge base, but this does not inherently translate into better decision-making, nor better decisions. A shortcoming in this case was that the key stakeholder organizations and agencies were involved, but it was generally not the decision-makers – that is, those with the capacity to build bridges across the institutional void - at the table. As a result, the collaboratively developed recommendations were not automatically translated into actual decision-making, and subsequently into improved policies in practice. That is, the JFF effort did not result in collaborative action directly after the process, although it may over time.

A common trait of the above shortcomings is that they may threaten the (3) emergence of a shared understanding of the challenges and (10) the generation of outcomes that are *salient, credible* and *legitimate*. In particular, the participation of decision makers can be of critical importance to the development of realistic policy options, and for engendering support. If decision makers are not involved in the JFF process, the evaluation of policy impact and political feasibility will rely on the experts, who might be incapable or unwilling to venture into the decision makers' territory. The lack of a direct connection to decision-making may also influence (2) the incentive of stakeholders to participate. In the Rotterdam case, some parties persisted in requesting written reports to influence decision makers within their organizations and were frustrated by their absence. However, participation remained at original levels, suggesting that participants remained committed. Nonetheless, managing these challenges within the JFF process put pressure on (6) the leadership and (5) the management of relationships as one had to navigate this boundary and deal with expert requests for detailed written reports.

6. Conclusions

The Rotterdam North case provides some insights into the effective application of joint fact-finding (JFF) as an approach to joint knowledge production, particularly in cases with high degrees of uncertainty and complexity, like adapting interconnected infrastructure systems to enhance their overall climate resilience. Applying the evaluative criteria introduced in section 4 to the case has also revealed some insights into how we might enhance and apply such criteria to

best assess JFF efforts. We conclude with some overarching observations and remaining questions around both the application of JFF, and criteria for evaluating such efforts.

6.1 Criteria for evaluating joint fact-finding efforts

The ten criteria introduced in section 4 – which draw directly from Ansell and Gash (2008), Hegger et al. (2012), and Cash et al. (2002) - provided an instrument for assessing the Rotterdam case, and may prove useful in assessing other cases involving JFF. Below are some reflections on the value in and challenges associated with using these criteria.

Process vs. outcomes

While good process may be an essential precursor to good outcomes in many if not most situations, we believe it is useful to assess them separately and consider the outcomes on their own merit. This is particularly true if we wish to see practically oriented JFF processes. The ten criteria are largely process-related, but we included the *salience, legitimacy* and *credibility* criteria to directly and systematically consider the outcomes.

Because outcomes are shaped by process, deficiencies on one side often relate to deficiencies on the other. The identification of shortcomings in terms of either process or outcomes can thus be beneficial in instigating a more critical examination of the other side to identify correlated shortcomings. For example, the identification of stakeholder gaps may instigate more thorough consideration of whether or not the outcomes are truly salient, credible and legitimate to *all* stakeholders or only those at the table. In the Rotterdam case, questions around the salience of the outcomes led us to take a more critical look at who was representing stakeholders at the table and consider how the process might have been designed to have a greater impact on decision-making in practice.

Method and metrics for evaluation

We have said little about the methods and metrics for operationalizing these ten criteria. For the purposes of this paper, we applied a crude (poor, satisfactory and excellent) metric. In part this is because the criteria are heterogeneous and a deeper examination is beyond the scope of this paper. Nonetheless, if these criteria are deemed useful, a more critical evaluation of how they can be effectively measured will be warranted in future work.

Some criteria are harder to evaluate than others. For example, the question of whether 'meaningful dialogue was facilitated' is very subjective, and likely to vary among participants. An extroverted participant that actively engages in discussion and advances his or her interests and perspective is likely to have a different opinion than a participant in the same process that feels procedurally and substantively ignored. In contrast, good process design may flex to fit each situation but can still be assessed against an externally established set of best practices, like those outlined in section 3. Post-process surveys, debriefs and follow-up interviews can help to get a sense of what participants think, ideally leading to enhancements to JFF practice over time.

Criteria also vary in terms of who is best positioned to evaluate them. Credibility from the perspective of the stakeholders being asked to accept the outcomes is more important than in the eyes of an external reviewer. In contrast, factors like the emergence of post-process opposition (or lack thereof) may be used to externally assess whether or not there was broad stakeholder participation.

6.2 Joint fact-finding

The successes and shortcomings of the Rotterdam case highlight ways in which JFF shows promise and faces challenges in practice. JFF shows promise as a decision-support tool in various science-intensive deliberations, including around nascent and complex challenges like adapting to climate change, but hurdles must be recognized and addressed.

Knowledge vs. practice

A substantial challenge is using JFF to influence better decision-making, rather than for research or informational purposes with no clear connection to practice. The Rotterdam case was designed to 'gain new insights'; if and how they might translate into better practice for the various infrastructure owners involved is unclear. Participants were critical of this lack of salience, as they recognized the benefit there would be in linking the valuable knowledge developed more directly to decision-making within and among their organizations. Unfortunately, this disconnect may be all too common in JFF efforts, as stakeholders appreciate the value of joint knowledge production and are willing to participate, but find it challenging to integrate into existing decision-making processes. The full value of JFF is contingent on finding ways to couple or embed it within decision-making processes, rather than organizing stand-alone efforts and hoping that the outcomes will percolate into practice.

Filling the institutional void

JFF has traditionally been applied in cases in which scientific or technical information is in dispute, but the institutional environment is fairly well established. The Rotterdam case suggests that JFF can help stakeholders to grapple with shared challenges in 'institutional voids' when there is ambiguity around who should act and when. That is, JFF can be an effective boundary object between organizations and institutions; it can help stakeholders to collectively assess shared threats for which responsibility is unallocated or unclear. This is particularly valuable when new threats are emerging, as with climate change. Responsibility for the potentially significant cascading impacts of climate change on interconnected infrastructures is unclear among the discrete infrastructure owners, so it behoves them to engage in a JFF effort to develop a shared understanding of the challenges as a step in ultimately making decisions that address these challenges effectively and efficiently, identifying and coordinating their discrete and newly identified shared responsibilities. It is notable that drawing explicit connections to actual decision-making becomes all the more difficult and important in these voids because the associated forums for decision-making are often unclear or incomplete.

Addressing wicked problems

The adaptation of interconnected infrastructures to climate change is not challenging solely because it is happening in an institutional void. It is also a particularly 'wicked problem' because of the high degree of uncertainty and dynamic nature of conditions over time. JFF efforts have traditionally aimed to arrive at a shared set of facts for decision-making that are salient, credible and legitimate to all stakeholders. The wicked nature of climate change may make any set of facts arrived at more contingent in nature. As a consequence, the goal of JFF efforts may need to be loosened to devising a shared set of facts for contextual use, while stakeholders acknowledge that they are incomplete and likely to change over time. Stakeholders may even disagree on how they expect those facts to change in the future, but they arrive at a shared set of information that they will apply to the current decision-making situation. Nonetheless, arriving at shared sets of facts, no matter how contingent, in wicked contexts may prove particularly challenging due to the persistence of uncertainty and associated ability of stakeholders to maintain the set of facts that they believe or that suits them best, rather than moving away from them through collective learning. Furthermore, divergence in opinions on what the future might look like may limit longer-range planning and decision-making.

Stakeholder engagement

Broad stakeholder participation is a cornerstone of successful JFF processes. The Rotterdam process engaged the different infrastructure owners, key municipal and national government agencies, and external technical experts. It did not engage other stakeholders, including local residents and interest groups (e.g., environmentalists). The absence of other stakeholders may not have been problematic here, given the limited scope of the process and relatively uncontroversial outcomes. However, assessing who has a stake in any given deliberation and ensuring that they

are adequately represented at the table is critically important to advancing 'fair, efficient, stable, and wise' processes and outcomes, easing implementation, and minimizing opposition later (Susskind, Levy and Thomas-Larmer, 1999).

The Rotterdam case underscores the importance of having the right representation at the table. Because of the informational nature of the project, most infrastructure owners sent technical representatives, which may have made more technically complex discussions possible but potentially stymied the translation of the outcomes into decision-making in practice. JFF processes need to strike a balance between involving those that are most astute technically and those that have the authority to advance implementation. The concurrent engagement of representatives from different levels of each organization or constituency (e.g., via a stakeholder management group and parallel technical working group) may be beneficial here.

Facilitative leadership and process design

A lot of effort was put into facilitating by the convener of the Rotterdam North case. The success of the exercise underscores how important facilitative leadership is. Designing and facilitating processes like this is often an underappreciated yet critical skillset. The process challenges that inherently emerge, as was the case in Rotterdam, suggest that greater professionalization and honing of robust best practices may be beneficial.

Notably, the promise of structured JFF processes may be incompletely realized in institutional voids when it is unclear who can and should step up and design and facilitate the process. Experienced external organizations may play important roles here, as they have the broader perspective to recognize gaps, and the organizational flexibility to develop initiatives and seek support and partnerships to address them.

References

Adler, P.S., T. Bryan, M. Mulica and J. Shapiro (2011). *Humble Inquiry: The Practice of Joint Fact Finding as a Strategy for Bringing Science, Policy, and the Public Together*. http://www.mediate.com/pdf/Joint Fact Finding.pdf (Last accessed: July 16, 2014).

Andrews, C.J. (2002). *Humble Analysis: The Practice of Joint Fact-Finding*. Westport, CT: Praeger.

Anguelovski, I. and J. Carmin (2011). Something borrowed, everything new: Innovation and institutionalization in urban climate governance. *Current Opinion in Environmental Sustainability*, 3: 1-7.

Ansell, C. and A. Gash (2008). Collaborative Governance in Theory and Practice. *Journal of Public Administration Research and Theory*, 18(4): 543-571.

Biesbroek, R., J. Klostermann, C. Termeer and P. Kabat (2011). Barriers to climate change adaptation in the Netherlands. *Climate Law,* 2: 181–199.

Birkmann, J., M. Garschagen, F. Kraas and N. Quang (2010). Adaptive urban governance: New challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science,* 5: 185–206.

Bles, T.J., M.R. van der Doef, R. van Buren, J.T. Buma, R.J. Brolsma, A.A.M. Venmans and J.J. van Meerten (2012). *Investigation of the blue spots in the Netherlands National Highway Network.* Deltares.

Bollinger, L.A., C.W.J. Bogmans, E.J.L. Chappin, G.P.J. Dijkema, J.N. Huibregtse, N. Maas, T. Schenk, M. Snelder, P. van Thienen, S. de Wit, B. Wols and L.A. Tavasszy (2014). Climate adaptation of interconnected infrastructures: A framework for supporting governance. *Regional Environmental Change*, 14: 919–931.

Burton, P. and J. Mustelin (2013). Planning for Climate Change: Is Greater Public Participation the Key to Success? *Urban Policy and Research*, DOI:10.1080/ 08111146.2013.778196

Buuren, A. van and J. Edelenbos (2004). Why is joint knowledge production such a problem? *Science and Public Policy*, 31(4): 289–299.

Carpenter, S.L. and W.J.D. Kennedy (2001). Analyzing the Conflict. In *Managing Public Disputes: A Practical Guide for Professionals in Government, Business and Citizen's Groups*. Hoboken, NJ: John Wiley & Sons. Pp. 71-91.

Cash, D., W. Clark, F. Alcock, N. Dickson, N. Eckley and J. Jäger (2002). *Salience, Credibility, Legitimacy and Boundaries: Linking Research, Assessment and Decision Making*. John F. Kennedy School of Government, Harvard University Faculty Research Working Papers Series, RWP02-046.

Delta Programme (2013). *Delta Programme 2014 - Working on the delta: Promising solutions for tasking and ambitions.* The Hague, NL: The Ministry of Infrastructure and the Environment, and the Ministry of Economic Affairs.

Dongen, K. van, D. Stolk, L. Weber and M. de Lange (2013). *Informatiepreparatie overstromingsrisico's en domino effecten; een verkenning*.

Ehrmann, J.R. and B.L. Stinson (1999). Joint fact-finding and the use of technical experts. *The Consensus Building Handbook: A comprehensive guide to reaching agreement.* L. Susskind, S. McKearnan and J. Thomas-Larmer, eds. London, UK: Sage. Pp. 375-400.

Few, R., K. Brown and E.L. Tompkins (2007). Public Participation and Climate Change Adaptation: Avoiding the Illusion of Inclusion. *Climate Policy*, 7: 46-59.

Geerdink, T. and N. Maas (2014). *Gebiedsstudie Rotterdam Noord*. INCAH - Infrastructure Networks Climate Adaptation and Hotspots, Project Thema 5, KvK rapport nummer 150/2014 (D1165).

Gopalakrishna, D., J. Schroeder, A. Huff, A. Thomas and A. Leibrand (2013). *Planning for Systems Management & Operations as part of Climate Change Adaptation*. Washington, DC: Federal Highway Administration.

Groot, A.M.E., P.R. Bosch, S. Buijs, C.M.J. Jacobs and E.J. Moors (2015). Integration in urban climate adaptation: Lessons from Rotterdam on integration between scientific disciplines and integration between scientific and stakeholder knowledge. *Building and Environment*, 83: 177-188.

Hajer, M. (2003). Policy without polity? Policy analysis and the institutional void. *Policy Sciences,* 36: 175-195.

Hegger, D., M. Lamers, A. Van Zeijl-Rozema and C. Dieperink (2012). Conceptualising joint knowledge production in regional climate change adaptation projects: Success conditions and levers for action. *Environmental Science & Policy*, 18: 52–65.

Hodges, T. (2011). *Flooded Bus Barns and Buckled Rails: Public transportation and climate change adaptation*. FTA Report No. 0001. Washington, DC: Federal Transit Administration.

Hurricane Sandy Rebuilding Task Force (2013). *Hurricane Sandy Rebuilding Strategy: Stronger Communities, A Resilient Region.* U.S. Department of Housing and Urban Development. http://portal.hud.gov/hudportal/HUD?src=/sandyrebuilding

Innes, J.E. and D.E. Booher (2010). *Planning with Complexity: An Introduction to Collaborative Rationality for Public Policy.* New York, NY: Routledge.

IPCC [Intergovernmental Panel on Climate Change] (2013). Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, Eds. Cambridge, UK and New York, NY: Cambridge University Press.

Jasanoff, S. (1990). *The Fifth Branch: Advisers as Policy Makers*. Cambridge, MA: Harvard University Press.

Karl, H.A., L.E. Susskind and K.H. Wallace (2007). A Dialogue, Not A Diatribe: Effective Integration of Science and Policy through Joint Fact Finding. *Environment*, 49(1): 20-34.

Lemos, M.C., C.J. Kirchhoff and V. Ramprasad (2012). Narrowing the climate information usability gap. *Nature Climate Change,* 2: 789-794.

Levin, K., B. Cashore, S. Bernstein and G. Auld (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences,* 45: 123-152.

Maas, N. (2012). *Modeling as knowledge brokerage instruments*. Delft, NL: TNO.

Maas, N., S. in't Veld, M. Dekker and R. Van der Klauw (2004). *Integral Approach of Transport in Dense Urban Areas.* Rotterdam, NL: 16th CIB World Building Congress (conference paper).

McCreary, S.T., J.K. Gamman and B. Brooks (2001). Refining and Testing Joint Fact-Finding for Environmental Dispute Resolution: Ten Years of Success. *Mediation Quarterly* 18: 329–48. doi:10.1002/crq.3890180403.

Mearns, L.O. (2010). The drama of uncertainty. *Climatic Change,* 100: 77-85.

Measham, T.G., B.L. Preston, T.F. Smith, C. Brooke, R. Gorddard, G. Withycombe and C. Morrison (2011). Adapting to climate change through local municipal planning: barriers and challenges. *Mitigation and Adaptation Strategies for Global Change,* 16: 889–909.

Mees, H.L.P., P.P.J. Driessen and H.A.C. Runhaar (2014). Legitimate adaptive flood risk governance beyond the dikes: the cases of Hamburg, Helsinki and Rotterdam. *Regional Environmental Change,* 14(2): 671-682.

MIT Science Impact Collaborative and the Consensus Building Institute (2013). *Tool: Joint Fact-Finding.* http://scienceimpact.mit.edu/tools/jff/ (Last accessed: July 16, 2014).

Moser, S.C. and J.A. Ekstrom (2010). A framework to diagnose barriers to climate change adaptation. *PNAS,* 107(51): 22026-22031.

Nieuwenhuis, A., E. Luiijf and M. Klaver (2008). Modeling dependencies in critical infrastructures. In *Critical Infrastructure Protection II*. M. Papa and S. Shenoi, Eds. New York, NY: Springer.

PWC [PricewaterhouseCoopers LLP] (2010). *Adapting to climate change in the infrastructure sectors: Maintaining robust and resilient infrastructure systems in the energy, transport, water and ICT sectors*. A report for the Adapting to Climate Change Programme, UK Department for Environment, Food and Rural Affairs.

RWS [Rijkswaterstaat] (2008). *Actieplan klimaatverandering Weginfrastructuur en binnenvaart*. End report. Delft, NL.

Rittel, H.W.J. and M.M. Webber (1973). Dilemmas in a General Theory of Planning. *Policy Sciences,* 4: 155-169.

Schenk, T. and L. Susskind (2014). Gaming for Action: Role-Play Simulation Exercises for Participatory Action Research on Climate Change Adaptation. *Action Research for Adaptation Practices: Developing and applying knowledge for governance*. A. van Buuren, J Eshuis and M. van Vliet, eds. London, UK: Routledge.

Schweikert, A., P. Chinowsky, K. Kwiatkowski and X. Espinet (2014). The infrastructure planning support system: Analyzing the impact of climate change on road infrastructure and development. *Transport Policy,* 35: 146–153.

Simpson, D.M., T.D. Rockaway, T.A. Weigel, P.A. Coomes and C.O. Holloman (2005). Framing a new approach to critical infrastructure modelling and extreme events. *International Journal of Critical Infrastructures*, 1(2/3): 125-143.

Sluijs, J.P. van der (2012). Uncertainty and Dissent in Climate Risk Assessment: A Post-Normal Perspective. *Nature and Culture,* 7(2): 174–195.

Susskind, L. (2010). Responding to the risks posed by climate change: Cities have no choice but to adapt. *Town Planning Review,* 81(3). doi:103828/tpr.2010.5.

Susskind, L. and J. Cruikshank (1987). *Breaking the impasse: Consensual approaches to resolving public disputes*. New York, NY: Basic Books.

Susskind, L., P. Levy, and J. Thomas-Larmer (1999). *Negotiating Environmental Agreements: How To Avoid Escalating Confrontation Needless Costs And Unnecessary Litigation*. Washington, DC: Island Press.

Susskind, L. and J. Thomas-Larmer (1999). Chapter 2: Conducting a Conflict Assessment. In *The Consensus Building Handbook: A comprehensive guide to reaching agreement*. Thousand Oaks, CA: Sage Publications. Pp. 99-136.

Susskind, L. and D. Rumore (2013). Collective Climate Adaptation: Can Games Make a Difference? *Solutions Journal*, 4(1). http://thesolutionsjournal.com/node/2021 (Last accessed: June 26, 2014).

Termeer, C., A. Dewulf, H. van Rijswick, A. van Buuren, D. Huitema, S. Meijerink, T. Rayner and M. Wiering (2011). The regional governance of climate adaptation: A framework for developing legitimate, effective, and resilient governance arrangements. *Climate Law,* 2: 159–179.

Uittenbroek, C.J., L.B. Janssen-Jansen and H.A.C. Runhaar (2013). Mainstreaming climate adaptation into urban planning: Overcoming barriers, seizing opportunities and evaluating the results in two Dutch case studies. *Regional Environmental Change,* 13: 399–411.

USDOT [United States Department of Transportation] (2012). *DOT Transportation and Climate Change Clearinghouse*. http://climate.dot.gov (Last accessed: January 22, 2015).

Vuuren, D.P. van, M. Isaac, Z.W. Kundzewicz, N. Arnell, T. Barker, P. Criqui, F. Berkhout, H. Hilderink, J. Hinkel, A. Hof, A. Kitous, T. Kram, R. Mechler and S. Scrieciu (2011). The use of scenarios as the basis for combined assessment of climate change mitigation and adaptation. *Global Environmental Change*, 21: 575–591.

Willbanks, T., S. Fernandez, G. Backus, P. Garcia, K. Jonietz, P. Kirshen, M. Savonis, B. Solecki, L. Toole, M. Allen, R. Bierbaum, T. Brown, N. Brune, J. Buizer, J. Fu, O. Omitaomu, L. Scarlett, M. Susman, E. Vugrin and R. Zimmerman (2012). *Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report to the U.S. Department of Energy in Support of the National Climate Assessment.* Oak Ridge, TN: Oak Ridge National Laboratory.

Zimmerman, R. and C. Faris (2010). Chapter 4: Infrastructure impacts and adaptation challenges. New York City Panel on Climate Change 2010 Report. *Annals of the New York Academy of Sciences*, 1196.