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ORIGINAL PAPER

A co-design method for including stakeholder perspectives in nature-based flood risk management

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Abstract
Intervention methods to establish commitment to (collaborative) action are of potential interest to researchers and policymakers intent upon including stakeholder perspectives in natural risk governance (Scolobig, Nat Hazards 81:27–43, 2016). In this paper, a 6-step co-design method for engaging with local people in collaboratively envisioning nature-based solutions for flood defence is described. The problem structuring base of the participatory method is extended to accommodate the multi-actor situation and the local context of flood risk management. The intervention method is applied in a workshop in the Houston–Galveston Bay area in October 2014. At that time there was strong contestation surrounding the proposed Ike Dike with alternative combinations of nature-based and smaller conventional engineering solutions being proposed. The results indicate that the local participants were able to envision a wide range of future outcomes for the bay and were able to use the insights on nature-based solutions and the social contacts that they acquired at the transdisciplinary workshop to mobilize commitment to joint action. This action focused on collaboration rather than specifying ecological or technical infrastructural requirements and was instrumental in initiating more open discourse on flood defence options for the Houston–Galveston Bay area. The paper concludes that the generic applicability of the co-design method is limited by the requirement to understand and accommodate local circumstances and participants' insights within the workshop.

Keywords Transdisciplinary co-design · Nature-based solutions · Flood risk management · Visioning · Participatory disaster risk reduction · Co-creation

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1 Introduction

Place-based knowledge of the local environment forms an essential ingredient in the design of nature-based solutions to flooding problems (Slinger & Vreugdenhil 2020; Bridges et al. 2021; Slinger 2021). The conventional means of acquiring such knowledge in the engineering field draw on field survey methods, satellite image analysis, data from existing engineering and geomorphological databases, mathematical model simulation and physical scale model testing (see Bosboom and Stive 2015; Wijnberg et al. 2015). Similarly, in the field of ecology, such knowledge is drawn from field surveys, satellite image analysis, environmental databases and mathematical and conceptual modelling (see Pennekamp et al. 2017). Further, in the social science field a diversity of methods are used to deepen understanding of the social situation and the impacts of nature-based flooding solutions on society (see Van Zandt et al. 2012; Vanclay et al. 2015; Hamideh and Rongerude 2018; Albert et al. 2021). All of these fields take the locality of the flooding problem into account, but do not necessarily seek to take multiple perspectives of stakeholders and the lived experience of their social and natural environment into account in designing solutions (Nogueira de Andrade and Szlafsztein 2015; Scolobig 2016).

But, how can we include the lived experience of people in designing nature-based solutions for their locality? Building on seminal work by Pearce (2003), there has been a surge in the publication of cases of participatory disaster risk reduction involving communities (Baudoin 2016; MacAskill 2019; Ali and George 2022), issues involved in integrating such approaches into planning cycles and policy processes (Marengo et al. 2017; Bisello et al. 2021; Frantzeskaki 2019), and the inclusion of local knowledge (D'Hont and Slinger 2023). Indeed, Vallance (2015) states that "Despite broad scholarly consensus that public participation in disaster recovery is highly desirable, in practice, appropriate and effective forms of community involvement are difficult to achieve." Of particular interest are inter- and transdisciplinary methods that move beyond a focus on the resulting artefact, and explore the steps taken in the collaborative design process itself (Sander and Stappers 2008; MacAskill 2019). By considering these steps and the embedding within the local context, we can deepen knowledge on the design of effective participatory engagement processes.

This paper therefore describes and reflects upon a transdisciplinary co-design method for engaging with local people in collaboratively designing nature-based solutions. It clarifies the problem structuring methodological base of the method and its extension to account for a multi-actor situation (see Cunningham et al. 2014) and the context of a flooding problem. An intervention in the Houston–Galveston Bay area in 2014 serves to illustrate the application of the method in practice. Such an intervention aims to establish commitment to (collaborative) action, working with rather than 'on behalf' of the group of people concerned (Mercer et al. 2008; Ackermann 2012). Accordingly, the influence of the intervention on the then polarized flood management discourse in Texas is described and the differences between Texan and Dutch flood risk management contexts in facilitating collaborative action at the time, are highlighted.

The paper is structured as follows. First, the theoretical background to the co-design method and its composite steps are presented in Sect. 2. Next the methods adopted in applying the intervention in Texas are described in Sect. 3. The situation in Texas six years after Hurricane Ike struck the Galveston Bay area, the deaths and damage that resulted and the subsequent heated debate regarding potential flood protection measures form the background context to this intervention (Zane et al. 2011; Hamideh & Rongerude 2018;

Brody et al. 2022). Particular attention is paid to the how the Dutch came to be involved and the actions necessary to ensure embedding within this highly contested local context. The process and outcomes of the co-design workshop are detailed in the results, before the efficacy of the method in achieving commitment to action is described (Sects. 4, 5). After reflections on the role of local knowledge in enabling nature-based flood defence and differences in this regard between the Netherlands and Texas, the paper concludes in Sect. 6 with insights on the potential wider applicability of the method.

2 Theoretical background

Problem structuring methods are a core policy analytic technique (Thissen and Walker 2013) and have been applied in the soft system sciences for over 50 years (Ackerman 2012; Smith and Shaw 2019; Enserink et al. 2022). They are uniquely suitable for analyzing strategically complex problems with many applications focusing on deepening the shared understanding of the material system and the associated human decision making (see Eden and Ackermann 1998; Mingers and Rosenhead 2004). Apart from group model building techniques and group decision rooms (Rouwette et al. 2002; Anderson et al. 2007; Gray 2008), little attention was devoted to structuring the decision processes of multiple actors as they debate and potentially resolve complex problems together or even overcome social dilemmas within their local contexts. Social dilemmas entail actors being locked into sub-optimal outcomes, often through a lack of information, limited communication, and a dearth of collaboration (Janssen et al. 2019). Nowadays, collaborative and co-creative approaches are receiving increasing attention (Sanders and Stappers 2008; Montero and Kapinga 2019; Ranjan and Read 2021; Nunes et al. 2021), although only a few authors evaluate such interventions (see McEvoy 2020; Vreugdenhil et al. 2022) or explore value co-creation (Pera et al. 2016; Ketonen-Oksi and Valkokari 2019).

In this paper we will focus on a standardized 'game-structuring' approach, comprising common analytical (game) elements embedded within a participatory approach (Voinov and Bousquet 2010), as developed by Cunningham et al. (2014) and applied in South Africa (Slinger et al. 2014). The first step in this generic six-step process involves identifying the players. According to Hermans and Cunningham (2013) this step is equivalent to describing the arena of the problem, and includes determining the purpose of the intervention. Purposes can range from initiating joint action, to engendering learning, or defining technical requirements. The second step involves analyzing the system and its context, and usually forms the major focus of problem structuring efforts (Enserink et al. 2022). The third step involves the description of possible strategic futures (see Howard 1987; Ramalingam and Jones 2007; Rodgers et al. 2020). In this approach, such future outcomes are not defined by first focusing on the range of possible actions, nor on changes in the context. Instead, a planning approach is adopted (see Bertolini 2010) in which outcomes are envisaged first and actions are considered later (in step 5). The outcomes should include the status quo outcome, that is the future that would resulting from persisting with present policies and management. In the fourth step the stakeholder-specific valuations of the future outcomes are solicited and analyzed. Step five then involves evaluating all the outcomes to determine a set of possible and/or necessary actions for each player to achieve the outcomes. This does not imply that any actor would necessarily wish to take the action concerned. Finally, the sixth step involves integrative negotiation (Thompson 2011; Kim et al.

2015) or mediation with analysts indicating the space of possible win–win solutions and facilitators seeking to enhance communication about potential actions, particularly potentially beneficial joint actions that align with the purpose of the intervention.

Informed by problem-based and authentic learning pedagogies (Barrows 1985, 1992; Schmidt 1993; Nicaise et al. 2000; Herrington et al. 2014; Yew and Goh 2016), this game-structuring approach was later adapted to form an eight-step transdisciplinary collaborative (co-)design workshop-method for multi-disciplinary teaching on nature-based flood defence (Klaassen et al. 2021; Slinger and Kothuis 2022). The Houston–Galveston Bay application represented an evolution of the original approach, incorporating slight modifications (Fig. 1), namely:

- An initial step was added in which the participants became acquainted,
- Game theory-based terms were phrased more understandably, and
- A facilitated discussion of the set of possible and/or necessary actions for each player to achieve the outcomes was undertaken together with the discussion on commitment to (joint) action. This combination of the original steps 5 and 6 above was based on the analysis of the stakeholder-specific valuations undertaken by the research team.

3 Method

When designing a participatory risk management intervention, the following factors are considered by the TU Delft team: (i) access to the local context, (ii) the contextual embedding of the intervention, (iii) the participants, (iv) the co-design workshop, and (v) the exit strategy. Any constraining factors and the related choices are explained hereafter for the application to Houston–Galveston Bay.

3.1 Access to the local context

The suitability of an intervention method for a local context is influenced by the manner in which access is achieved to the local context. Where there are significant power differences or contestation exists, care must be taken to not appear to be on one side of the issue or simply a representative of one power base or party. In our case, access to the Galveston-Houston Bay issue came about in a convoluted fashion. A key professor from the University of Texas A&M Galveston had arranged for various dignitaries and

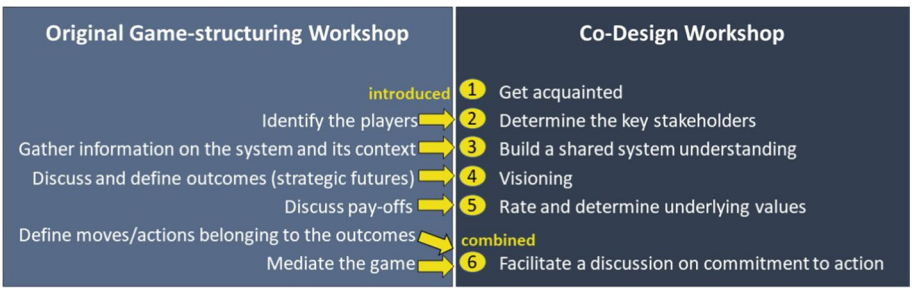

Fig. 1 Evolution of the original game-structuring workshop steps (Cunningham et al. 2014; Slinger et al. 2014) into the transdisciplinary co-design workshop method

colleagues from Texas to travel to the Netherlands on a number of occasions, usually timed to coincide with the annual closure of the Maeslant Flood Defence. The flood gates of this large infrastructure, located at the access channel from the North Sea to the harbor of Rotterdam, are closed once per year to check that they are working. The delegation routinely visited the Delft University of Technology (TU Delft) on these occasions to meet Dutch experts and discuss innovations in flood risk management. In 2014 a professor from Rice University in Texas visited the TU Delft to discuss the ecological implications of proposed flood protection measures for the Houston–Galveston Bay area (Fig. 2) a few months later. The discussion covered the potential for nature-based solutions rather than conventional hydraulic structures alone and the need to involve a wide range of local stakeholders in such discussions.

At that time, a first version of a game-structuring, co-design method had been developed and applied in South Africa (Cunningham et al 2014; Slinger et al. 2014). The idea of applying the method in Houston–Galveston Bay area arose. The high degree of contestation between parties supporting the construction of an Ike Dike extending along the Bolivar Peninsula and beyond the San Luis passage in the southwest (Merrel 2011), and others suggesting different locations for flood barriers, or more nature-based solutions (see Brody et al. 2022) was explained. With the provision that key protagonists would not attend the workshop, but would facilitate access to a wide variety of local stakeholders, even those with whom there was disagreement regarding proposed flood risk management interventions, the TU Delft team agreed to undertake such a transdisciplinary intervention.

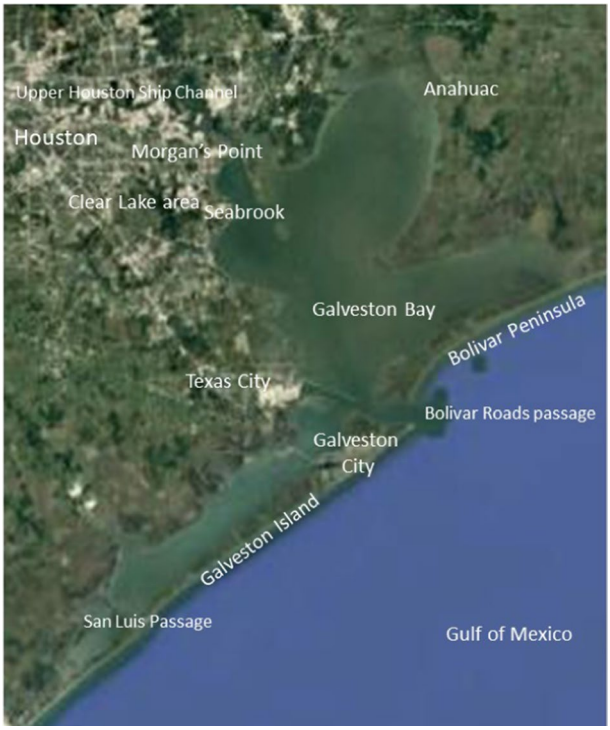

Fig. 2 Map of the Houston–Galveston Bay area; the proposed Ike Dike extended along the Bolivar Peninsula and beyond the San Luis passage in the southwest

3.2 Contextual embedding of the intervention

The 3-person Dutch team comprised experts in participative problem structuring and flood risk management from the Policy Analysis section of the TU Delft. Members of the team arrived 6 to 9 days in advance of the workshop to familiarize themselves with the Houston–Galveston Bay area and meet many of the stakeholders involved in the flood protection discourse (Table 1). The Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center in Houston were their hosts. Excursions around Galveston Bay were planned in advance, but many other meetings were arranged on the spot as the Dutch team learned about the Bay and her people. For instance, the need to include stakeholders with knowledge of the economic interests of the Houston–Galveston Bay area was identified, leading to a meeting with the Bay Area Houston Economic Partnership (BAHEP) and the attendance of the workshop by a BAHEP representative.

3.3 Participants

The workshop was attended by 14 participants in total, including representatives from local authorities, emergency services, the port authority, a federal agency, engineering and environmental consultancies, an economic association, interest groups, scientists and students (Table 1). Care was taken to ensure a spread in representation between people from Galveston Island and Houston.

3.4 The co-design workshop

The workshop took place on 16 and 17 October 2014. It was facilitated by the TU Delft research team (the authors) and spanned 1,5 days. The first day took place at Rice University in Houston, while the venue for the second day was the City Hall of Seabrook. The results of model simulations of flood risk reduction measures were not used to support discussions in the workshop on the first or second day as they were the subject of controversy. The first day closed with the rating of a wide range of utopic and dystopic futures generated by the participants. The analytical step of determining the underlying values from the ratings was undertaken overnight by the research team who then presented the results of this step on the morning of the second day. The workshop culminated with the final, sixth step in which the participants explored the implications of the outcomes for the Houston–Galveston Bay area, their living environment, and moved towards agreements on appropriate follow-up actions.

The six-steps in the game-structuring workshop undertaken for Houston–Galveston Bay are listed in Fig. 1. The steps were also explained as addressing the questions (1) Who are we? (2) Who cares? (3) Why we care? (4) What do we care about? (5) What do we value? (6) What can we do jointly?

3.5 Exit strategy

As agreed at the workshop, the report of the proceedings and the analysis of underlying values was circulated to all participants within a fortnight (Kothuis et al. 2014). Contact

details for the TU Delft researchers were provided so that any participant who has a query or wished to withdraw their permission for data sharing could do so. In addition, the contact details of SSPEED were provided to participants.

4 Results

Following Thissen and Twaalfhoven (2001), Slinger et al. (2014), McEvoy et al. (2018; 2020) and McEvoy (2019), the results of the workshop are described in terms of the process and outcomes per step.

Step 1 Getting Acquainted

In this step, participants gathered around a large hand-drawn map of the Houston–Galveston Bay area and were asked to indicate areas for which they had a particular affinity. For instance, because they lived there, worked there, or were interested in or had done research on a particular feature. Knowing that underlying tensions could be present, this casual format was chosen above more usual formal introductions to encourage an open atmosphere from the outset.

The outcome was that participants shared some personal anecdotes, but were careful in choosing which colored pen they used in drawing on the map. Upon inquiry by the Dutch team, the colors were revealed to allude to the university they had attended with blue representing Rice University and the maroon and yellow colors representing the maroon of Texas A&M. This confirmed that the workshop intervention was being held in a situation characterized by contestation.

Table 1 Eight-day sequence of activities (9 to 17 October 2014) and participants in which the game-structuring co-design workshop (shaded) was embedded

Oct	Activity	Participants
9th	Attendance of Coastal Resilience Conference 2014. 'Living on the edge. Strategies for Building and preserving resilient Coastal Communities' at Texas A&M, Galveston	BK from TU Delft, SSPEED Center host. Many participants – contact made with representatives from Texas A&M Galveston, U.S. Army Corps of Engineers (USACE) Galveston District, University of Texas San Antonio, Louisiana State University, Green Nexus Consulting
	Meeting at Texas A&M, Galveston to discuss the workshop intervention, issue invitation to attend.	Key Texas A&M Galveston researchers (x2), BK from TU Delft
12th	Excursion around Galveston Bay (310 miles). Ship Channel area, Chambers County, Bolivar Island, Bolivar Roads, Galveston Island, Brazoria County.	SSPEED Center (Rice University) host, WUR, TU Delft
	Meeting at Bolivar Island on effects of Hurricane Ike for Bolivar Island residents. Discussions on environmental health of Galveston Bay and its importance for birds. Experiences of a prawn fisher.	Houston Audubon Society representative, Vietnamese fisher, SSPEED Center (Rice University) host, WUR, TU Delft
13th	Research meeting at Rice University, Houston. Explanation of TU Delft research groups, the Multifunctional Flood Defence research programme, Game-structuring workshop as policy intervention, and a presentation on salt marsh as an element in flood defence.	Key SSPEED Center (Rice University) researchers (x3), Fugro representative, Walter P Moore representative, Wageningen University (WUR) researcher, TU Delft researchers, Rice University students (x3)
	Excursion Houston Ship Channel and Clear Lake area (100 miles). Fred Hartmann Bridge, Bay shore cities of Baytown, LaPorte, Seabrook, Kemah, Morgan's Point, Clear Lake area, State Highway 46, Houston Ship Channel, Port of Houston.	SSPEED Center (Rice University) host, WUR, TU Delft
14th	Meeting at Clear Lake about businesses in cities along Galveston Bay, the Ship Channel and the Texas City petro-chemical industries. Shared BAHEP knowledge of the economic system. The workshop approach was explained, so that he could join on Day 2.	Bay Area Houston Economic Partnership (BAHEP) representative who joined Day 2 of the workshop, TU Delft, Introduction by SSPEED Center (Rice University) host
	Meeting at Friendswood on the forthcoming workshop to explain the approach. Discussion on the Coastal Spine concept and the NSF- PIRE Proposal.	Key Texas A&M Galveston researcher (travelling on date of workshop, so could not attend), TU Delft
15th	SSPEED Center Modelling Meeting at Rice University, Houston – presentations and discussion of results from ADCIRC and SWAN modeling	Representatives from USACE Galveston, Texas A&M Galveston, Six Counties Surge District, Houston Endowment, Dannenbaum, Arcadis USA, Energy Transfer, Houston Galveston Area Council (HGAC), SSPEED Center (Rice University), WUR, TU Delft
	Discussion over dinner in Houston - reflecting on SSPEED Center research results presented at earlier workshop.	SSPEED Center researchers (x3), WUR, TU Delft
16th	**Workshop Day 1** at Rice University, Houston	Representatives from Houston City Council, City of Baytown, Seabrook emergency services, Port of Houston, National Oceanic and Atmospheric Administration, WorleyParsons, Coastal Solutions, BAHEP, Galveston Bay Coastal Protection Association, Houston Galveston Bay Foundation, Citizen Advisory Panel – Ship Channel Area, Citizen Advisory Panel – Bay Area, University of Texas A&M Galveston, Rice University
17th	**Workshop Day 2** at City Hall, Seabrook	
	City of Seabrook at the Community offices. Presentation and discussion of Hurricane Ike impact on Seabrook – infrastructural damage and recovery process	Mayor of Seabrook, Seabrook emergency services, TU Delft
	Meeting at Texas A&M Galveston to deepen understanding of the bay system and the Coastal Spine initiative, and to discuss the Dutch Building with Nature approach.	Key representative of Texas A&M Galveston
	Reflective discussion over dinner in Houston	SSPEED Center (Rice University) host, WUR, TU Delft

Details of the contextual embedding of the workshop (bold) are provided to illustrate of the type of activities and range of participants that are necessary for appropriate application of the co-design workshop method

In addition, the mapping exercise revealed that there were no participants from Anahuac or the eastern shore of Galveston Bay (Chambers County), nor was the Bolivar Peninsula represented (Fig. 2).

Step 2 Determining the key stakeholders

In this step, the participants were asked to identify stakeholders who care about or have an interest in Houston–Galveston Bay using the nominal group technique. Each participant was given a stack of post-its and a marker pen. After first writing down their ideas individually, they then gathered around a large empty table where they took turns to place a stakeholder post-it on the table and explain to the group why they considered the stakeholder relevant. By the third round, all participants had nominated the stakeholders they had listed on their Post-it's. The participants began to suggest that stakeholders with common interests were positioned close together during the second nomination round, anticipating upon the final instruction in this step to cluster the nominated stakeholders into groups.

The outcome was the identification of 8 clusters of key stakeholders. After some discussion, two groups were again grouped together (1a and 1b) as they represented a national level perspective on the Houston–Galveston Bay area. The final list of key stakeholders was:

1. National level key stakeholders
    a. Federal government & US Army Corps of Engineers & Flood insurance underwriting
    b. American people
2. Environment & Tourism
3. State and Local Government
4. Infrastructure & Emergency Response
5. Citizens on the Water Front
6. Citizens in the Surge Zone
7. Industry, Business and Ports

Step 3 Building a shared system understanding

In this step, participants were seated in a semi-circle facing a large whiteboard covering almost the whole of one side of the long rectangular room. The participants were asked to focus on the Houston–Galveston Bay system and its characteristics, describing why people care about the bay area and the associated flood risk. A moderator captured and systemized the suggestions of participants by writing terms or phrases on the whiteboard. The participants spoke freely and continued to volunteer additional information and perspectives on the system until the diagram in Fig. 3 was produced.

The participants found this an exciting exercise and liked the systematization of such a large range of issues. They had expected the economy, industry, the ecosystem and flooding to feature in their system description, but were particularly intrigued to note the family life and community aspects that came to light. One participant expressed a common view: 'Having it visualized like this makes you comprehend much better how much is at stake and how intricately it all connects.'

Step 4 Visioning

In this step, the participants generated a wide range of potential future outcomes for the Houston–Galveston Bay area drawing upon knowledge from the preceding step. This potentially difficult visioning step was undertaken in stages. First, the participants were divided into small groups of 2 or 3 people and attempted a trial run upon which they received feedback. Next, they proceeded to the actual task of developing at least one

dystopic outcome and one or possibly two utopic outcomes per group. The participants were asked to 'Describe potential outcomes for the Houston–Galveston Bay area, what it would look like (but not how to get there). Describe the state of the things that are cared about (positive and negative).' They were to generate system-feasible outcomes, but not be constrained by social acceptability nor by resource limitations. They were instructed to think in a divergent way, and told that there were no wrong answers. The setting for this step was informal with packed lunches provided and the groups working in clusters throughout the venue. Some enjoyed their lunch outside while working on the visioning task. The facilitators moved from one group to another, checking on progress, and offering support as needed.

After about 2 h, each group presented their potential future outcomes in plenary. The names and specification of the outcomes were captured on Flip-over sheets, which were then stuck on the wall where they were visible to all participants. Finding agreement within the teams was not always easy with two teams dividing the task and members developing outcomes apart from each other. Most groups came up with two outcomes, some with only one, but this was then very detailed.

Twelve potential future outcomes were identified and characterized (Table 2). Four of the outcomes were perceived by the group as positive or utopic and four were deemed negative or dystopic. Two outcomes exhibited both negative and positive features and two outcomes were viewed by different participants as the natural extension of present practices into the future or the 'status quo'. This divergence in opinions was retained by recording two 'status quo' outcomes for the Houston–Galveston Bay area.

The task of combining the 12 visions to a feasible number for further rating and analysis represents the last stage of this visioning step. It was undertaken with all the participants seated and facing the Flip-overs on the wall. The participants were asked to 'Combine outcomes (to a maximum total of 7 or 8) and give each group of outcomes a clear and descriptive name.' As reflected in the workshop proceedings (Kothuis et al. 2014), seven combined outcomes resulted (with the letters in brackets reflecting the labels from Table 2), namely:

1. Slow boat cabaret (FI)
2. Taken out (B)
3. Let the storm come (C)
4. Enhanced and rejuvenated relationship (CK1)
5. Self-reliant communities (EG)
6. Over-engineered solution (J)
7. Waiting for the next one (DHK2)

Despite signs of tiredness near the end of an intensive day, the participants still expressed enthusiastic amazement at the breadth and depth of the generated outcomes. Two participants indicated that they had found making the final combined outcomes particularly difficult.

Step 5 Determining underlying values

In this step, the participants assessed the extent to which the values of the eight key stakeholders were represented in the seven combined outcomes for the Houston–Galveston Bay area. The small groups were assigned roles as key stakeholder. One small group was assigned two roles, namely the Citizens of the Water Front and the Citizens in the Surge Zone. The facilitators took on the role of the Federal Government, and the American

People with the proviso that the entire group later checked and corrected the assigned ratings. Each group was provided with 8 green stickers and 4 orange stickers to rate the combined outcomes from the perspective of their key stakeholder. The green stickers represented positive rating of an outcome and the orange stickers represented negative rating of an outcome. No limit was placed on the number of stickers that could be allocated to a specific combined outcome, but a key stakeholder could not place both green and orange stickers on a single combined outcome.

Finally, each small group explained their key stakeholder ratings in plenary with each team presenting cogent arguments. Participants chose to spread their ratings over a number of combined outcomes with no team placing all their green or orange stickers on any one outcome. There was some dissent particularly within one team regarding their assigned ratings. Indeed, the participants indicated that they found distributing the stickers a difficult task, particularly because (as intended by the research team) the number of the stickers did not correlate easily with the seven combined outcomes. This completed the first day of the workshop.

The research team then re-scaled the ratings of the participants to lie between zero and 100% per key stakeholder group (Table 3). Then (ratings of) the outcomes were compared with one another and the dominated outcomes were identified. For instance, the 'Enhanced and rejuvenated relationship (CK1)' outcome dominated over 'Slow boat cabaret (FI)' because it was rated more highly by each key stakeholder group. Similarly, the 'Enhanced and rejuvenated relationship (CK1)' outcome dominated over 'Taken out (B)' and 'Let the storm come (C)'. The dominated outcomes were eliminated from further analysis as they were not located on the Pareto front. The 'Self-reliant communities (EG)' outcome weakly dominated the 'Over-engineered solution (J)', as it was equally valued by the key stakeholder 'Infrastructure and Emergency Services'. The outcome was not eliminated from further consideration. In the three outcomes identified as win-wins all key stakeholders win, but some key stakeholders win more than others. These four combined outcomes were all located near, or on, the Pareto optimal front, and can be termed efficient combined

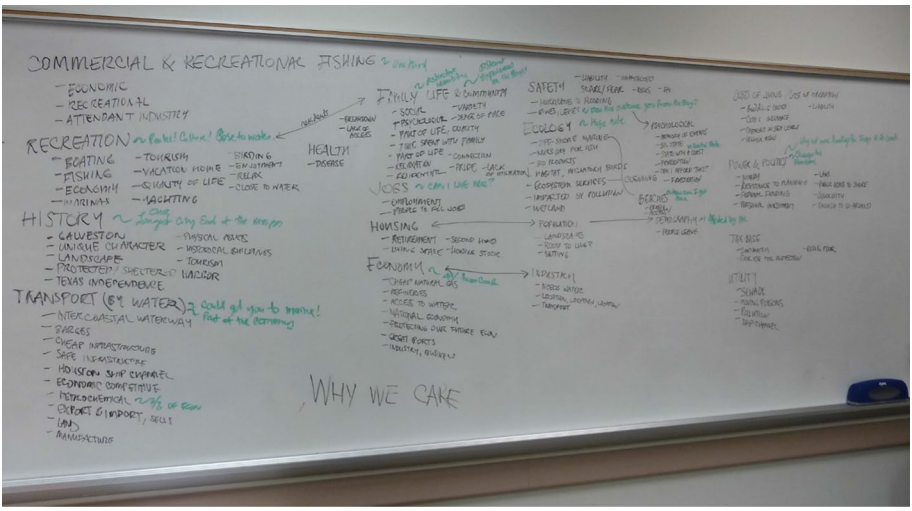

Fig. 3 System characterization of the Houston–Galveston Bay area

outcomes (Fig. 4). The 'Enhanced and rejuvenated relationship (CK1)' outcome received the highest total rating and so in game theory terms is identified as the Hicks Optimum.

Next, the ratings were explored to identify whether there were key stakeholders who consistently preferred the same outcomes, so that potential coalitions could be identified. Three potential coalitions were identified, namely (i) All in it for the Bay (everyone except Industry, Business & Ports), (ii) American Economic Prosperity (Industry, Business & Ports, State & Local Government, American People), and (iii) Infrastructure Planners (Infrastructure & Emergency Response, Federal Government).

The outcomes which, under prevailing circumstances, potentially offered the most value for the most stakeholders, were identified next. A lack of clarity was identified regarding the 'status quo', that is the health and performance of the Bay, and how this would develop if the present policies were to persist. This was consistent with the two versions of the status quo identified by participants in step 4 on the first day of the workshop.

Step 6 Facilitating a discussion on commitment to action

After a welcome to the City of Seabrook by the mayor, the second day of the workshop commenced. The proceedings and associated artefacts of the previous day were summarized by the facilitators. The list of key stakeholders and the outcomes from steps 4 and 5 were stuck onto the walls of the Seabrook City Hall so that the participants could refer to them. Then the information needed to initiate a discussion on commitment to action was presented. This included (i) the identification of the four outcomes at, or near, the Pareto front, (ii) the 3 potential coalitions, and (iii) the uncertainty associated with the status quo.

The four relevant combined outcomes are:

- Enhanced and rejuvenated relationship (CK1)
- Self-reliant communities (EG)
- Over-engineered solution (J)
- Waiting for the next one (DHK2)

The three potential coalitions comprise:

- All in it for the Bay (everyone except Industry, Business & Ports)
- American Economic Prosperity (Industry, Business & Ports, State & Local Government, American People)
- Infrastructure Planners (Infrastructure & Emergency Response, Federal Government)

The facilitators pointed out that lack of lack of clarity on the status quo can be resolved by undertaking monitoring of ecosystem health and human impact on the Bay and can be determined scientifically using environmental science methods, so is for the most part not a value-based issue. If the status quo were the 'Slow boat cabaret (FI)', this would preclude all other outcomes except a mixture of 'Enhanced and rejuvenated relationship (CK1)' and 'Self-reliant communities (EG)', because anything else would make some key stakeholder group worse off than they are under 'Slow boat cabaret (FI)'. However, if the status quo is 'Waiting for the next one (DHK2)', then the coalition of American Economic Prosperity would demand protection of the ship channel (protecting investments, as well as continued operation) and that port and industry workers get back to work after a hurricane (continued port operation). This potentially excludes environmental interests, local communities and Galveston Island. To bring such a broad coalition to the negotiation table, it would be necessary to generate an outcome that would cause them to do much better than they would do under the status quo of 'Waiting for the next one (DHK2)'.

Table 2 Characteristics of the 12 potential future outcomes envisioned for the Houston–Galveston Bay area, as reported in the workshop proceedings (Kothuis et al. 2014)

Letter	Outcomes as named by the participants	Characteristics
A (±)	Let the storm come	Benefits of the storm; Loss of housing stock; Better built, more reliable homes; Impetus to improve infrastructure; Better waste water
B (−)	Taken out	Petrochemical plant taken out – Exxon; National problem; Move to Baton Rouge; Everything on stilts; (Unclear)
C (+)	Rebuild wetlands and oyster reefs	Enhanced relationship; No negative impacts from solutions—healthy bay!; 50,000 acres of oyster reefs; Use dredged material for fringing wetlands—restore wetlands; Bad for home owners – less open water; Better access to the bay; Improved consensus on the healthy, restored bay; Building a trail system; More valuable asset
D (−)	Lose your first defense	Lose barrier islands; Moves inwards and inwards; We fail to do things; Inter-coastal waterway affected; Ship channel affected
E (+)	Community focus	A focus on what we can do on a community level; What is best for Galveston?; Why focus on Ship Channel?; Increased appreciation of Galveston; So much relies on Galveston and its Seawall; We want this for Galveston; Help the community
F (−)	Slow boat cabaret	In-fighting among agencies; NOT sustainable long-term; NOT full public support; Down sides—big; Denial of what's right there in your face; 'Life is wonderful'; Tremendous effect; No economy; Environmental catastrophe; U.S.A. has to resolve; World is also affected
G (±)	Yo-Yo Houston	Political infighting; Squabbles between all interested parties; If you don't work together you will lose what you value; No illusion making; Surge solution – affordable, environmental friendly, sustainable, long term, get public support; Self-reliance
H (sq_1)	Waiting for the next one	Do nothing – neutral; Spiral down ecological; Costs and benefits; Sitting and waiting; More development in flood zone; Houston development direct beneficiary, everyone else loses; Contractors win
I (sq_2)	Slow boat	Less subsidence; We can dredge less; We are making construction change today; More sustainable harvest; Less use of shells from the bay; Using limestone; Could we do more?
J (−)	Over-engineered solution	Regional focus; More drought, water table affected up to Dallas; Cost of freshwater to Bay; Over-engineered in the Bay; Deplete the health; Cut-off water; Nothing flushes; Lots of mosquitos; Smell!; Everyone negatively affects each other; Second order problems; Engineering which creates new problems
K1 (+)	Rejuvenate the Bay	Strengthen the integrity; Strengthen the ecology; Improve the access; Back to the natural integrity; Principal access, public waterfront protected; Needed for sea-level rise; Preferred ideal depends upon starting position (pragmatic approach)
K2 (+)	Houston for Houston	Protect Ship Channel; Centennial Gate

Each outcome is denoted by a letter from A to H or K1 or K2. The utopic (+), dystopic (−) or status quo (sq) appellations assigned by the participants to each outcome are indicated in the brackets

Six possible approaches, based upon the participants acknowledging the present unclear situation, and choosing to take (collective) actions, were then presented for discussion. The first four approaches involved forming broad coalitions, whereas approaches 5 and 6 were most effective if forming a broad coalition proved impossible, or was not desired by some.

1. *Retain Useful Ambiguity* Instead of clarifying the status quo using empirical scientific research, this approach retained uncertainty about the status quo. Ambiguity was explicitly retained and a combination of the outcomes a combination of the outcomes Self-reliant local communities, Enhanced and rejuvenated relationship, and Waiting for the next one, was pursued.

   The value of this approach was highest if the status quo happened to lie closer to 'Waiting for the next one', as it kept negotiation open and retained the possibility of a collaborative outcome incorporating the environment, communities and economic interests.

2. *Clarify and Inform* This approach aimed to resolve the uncertainty about the status quo through empirical research (socio-economic, ecological health, stakeholder consultation etc.) and the sharing of newly acquired and existing information. People would be no worse off than they were, and perhaps better off. The common understanding of the Houston–Galveston Bay area would increase.
3. *Establish Different Status Quo* This approach explored whether a status quo different from those already identified might exist. It aimed to inform stakeholders if such a 'new' status quo existed, simultaneously changing the existing situation and opening up new opportunities. As the new opportunities became clear, collective action would be taken to move towards them if so desired.
4. *Consider and Include Other Stakeholders* This approach focused on coalition building, trying to increase the number and range of stakeholders involved. Despite the increased complexity, it also meant better-arbitrated outcomes and the avoidance of surprises, e.g. additional requirements from previously unheard stakeholders. Through such an expanded network additional issues can be raised at an early stage. It is also possible to acquire additional resources, and new capabilities to argue and defend your interests, by widening the group of stakeholders you include.
5. *Prepare for Continued Dispute* This approach focused on gaining capabilities and resources for a particular group by forming action coalitions. Action coalitions are stakeholders with a common interest who have joined together with a commitment to, and capabilities for, action. This approach enhanced your ability to recognize your potential friends and allies, and can be viewed as using resources to act for what YOU want, and creating alignments for YOUR cause. The approach is not oriented to collective action for the common good, but seeks to fragment and then align for the good of the action coalition.
6. *Supply Information* This approach combined the outcome of 'Self-reliant communities' and 'Enhanced and rejuvenated relationships' by detailing the values embraced and the situation arising from combining these outcomes. The detailed combined outcome was then used when talking to engineers, contractors, state, local and national government about the future of the Houston–Galveston Bay Area. This approach could generate a groundswell, and create a vision of a future for the Bay. Such bottom-up vision creation

can act to alter the negotiation game and open up new possible outcomes. It can be a game changer.

After some clarifying questions, the participants discussed the lack of leadership in the Houston Galveston Bay area in coming to a shared approach regarding flooding, primarily to avoid 'continued dispute'. The group of participants identified a lack of political leadership as a major source of their problematic situation. They characterized their situation as contentious with no joint plan of action to address the risk of flooding in the bay area owing to hurricanes. This was most symptomatic of approach 5. The need for leadership was explicated in by the question "Who will drive the train?" and the statement "There is no leader right now". There were many suggestions for such leadership. Some suggested a legislative committee as lead, yet others stated a "Harris County Judge has to lead", others the Six County Surge District and yet others the Bay Area Houston Economic Partnership (BAHEP).

BAHEP was viewed as central to a shared approach, as was the Six County Surge District. This was created by the governor, following Hurricane Ike. The County judges and three other representatives of citizens and industries (Moody, Dow Freeport, Beaumont/Port Arthur) sit on the Board of the Six County Surge District. Whatever the leadership, the Surge district would need to ensure that a study of flooding risk in the Houston–Galveston Bay area was undertaken, but would not have to conduct all the studies themselves. The Surge District was deemed not very powerful politically. However, in an alliance with the General Land Office, which controls the coastline, there was potential for a workable match. Other qualifiers on the potential leader were that their vision

Table 3 Rating of the 7 combined outcomes (rows) from the perspectives of the 8 key stakeholders (columns)

Federal Government		American People		Environment & Tourism		State and Local Government		Infrastructure & Emergency Response		Citizens on the Water Front		Citizens in the Surge Zone		Industry, Business & Ports	
Slow boat cabaret (FI)															
-2	0	-1	0	-1	0	-1	0	-1	0	0	16,7	0	28,6	-1	0
Taken out (B)															
1	50	-1	0	-1	0	-1	0	-1	0	-1	0	-2	0	-1	0
Let the storm come (C)															
1	50	0	33,3	2	75	1	40	0	25	0	16,7	3	71,4	-1	0
Enhanced and rejuvenated relationship (CK1)															
2	66,7	2	100	3	100	3	80	2	75	5	100	5	100	1	40
Self-reliant communities (EG)															
4	100	2	100	2	75	4	100	3	100	3	66,7	0	28,6	2	60
Over-engineered solution (J)															
1	50	-1	0	0	25	-1	0	3	100	0	16,7	-2	0	0	20
Waiting for the next one (DHK2)															
-1	16,7	2	100	-1	0	0	20	-1	0	-1	0	0	28,6	4	100

Per column, the left-hand figures indicate the number of stickers received (positive for green stickers, negative for orange/red stickers). The right-hand figures represent the rescaling of the ratings to lie between 0 and 100% for each key stakeholder group

should not be too parochial, but more regional, and that it was possible to be too political. Such a leader needs to be above politics, which was why there was overarching support for BAHEP taking a key role.

The discussion ranged over the need for a local groundswell and that the federal government was waiting for a proposal for a shared and supported solution. Sound information, not necessarily collated in understandable form, can create a groundswell. The report cards

for the Bay form a very good example of such information. Indeed, Texas A & M and Rice University were undertaking system analyses and the University of Texas, Houston, was undertaking the requisite model simulations. There was agreement that a common knowledge base and respect for different opinions are prerequisites for committing to joint action.

The discussion then moved onto the possible approaches. An insightful comment was made that it was possible to combine approaches 1 and 6. Embracing Ambiguity meant agreeing on assumptions and proceeding from there to create the information that could change the situation by allowing self-reliant communities to evolve. The participant group responded very positively to this suggestion, favoring 'Self-reliant communities' and the 'Enhanced and rejuvenated relationship' outcomes, while still considering that the economic interests should be borne in mind. They indicated a desire to pursue this option by meeting together in future.

The workshop then closed with participants providing positive feedback on the intervention method and their experiences of the workshop.

5 Discussion

The game-structuring co-design intervention took place within the context of a highly polarized discourse on flood defence in the Houston–Galveston Bay area (See Brody et al. 2022). The discourse focused on the rival merits of a range of technical and infrastructure options such as the Ike Dike, a more comprehensive Coastal Spine or the Houston Ship Channel Centennial Gate and many others. The focus on these infrastructures represented attempts on the part of the protagonists to ensure a desired 'safe future' by what

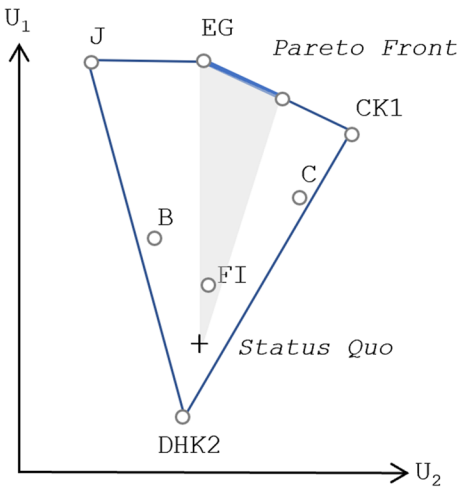

Fig. 4 The figure represents a low-dimensional representation of Table 3. The seven outcomes are positioned according to their respective appeal for the eight key stakeholders. The units of the axes are "utils" and represent the combined interests of stakeholders in the form of an aggregate utility score for two coalitions of stakeholder interests. The status quo is placed midway between outcomes DHK2 and FI. The available Pareto front is quite narrow, and reaches between outcomes EG and CK1, with the industry group presenting the strongest constraint on possible future outcomes. The shape of the space of welfare preserving improvements is distorted by the low dimensional projection of these data

they considered achievable actions. This intervention workshop allowed the participants to discover that they had more in common than they thought or that the prevailing discourse had led them to believe. They all valued a healthy, restored and functioning Bay ecosystem with resilient communities around it. They also realized that none of the highly positively valued futures featured the Ike Dike, as it was then envisaged. So, on the one hand a shared desirable future that included nature-based solutions now seemed potentially possible and on the other hand the spectre of having to prepare for continued dispute seemed very realistic. This meant that many of the participants chose to meet with the BAHEP representative again in the days following the workshop. And, although we cannot attribute this directly to the workshop, we note that representatives from Texas A&M University, the SSPEED Center at Rice University, and the Gulf Coast Community Protection and Recovery District, met in a panel discussion hosted by the Houston–Galveston Area Council on November 11, 2014. They expressed to be committed to collaborate 'to try to find the best solution for the region' and planned two meetings to discuss a memorandum of agreement and share data (Guidry News 2014).

The Dutch research team had anticipated that the transdisciplinary intervention would facilitate local environmental and experiential knowledge becoming available for inclusion in infrastructural design options for Houston–Galveston Bay–to supplement existing technical engineering knowledge. Despite the participants having such knowledge, the shared discussion focused more on the participants' values about the Bay and their shared love of the open water. This meant that the type of local knowledge that was drawn into the design process was social more than ecological – truly game-structuring, and truly driven by the participants themselves. Coalition building formed a central issue in the workshop discussions so that joint actions could be taken with an increased chance of success. The strong community base of Texan society came to the fore and the commitment that people felt to their communities meant that there was a willingness to engage and to stay involved.

Although the participants had not previously been extensively involved in flood defence design, planning and decision making, they were well acquainted with citizen participation in their society. In contrast, in Dutch society at the time, the direct involvement of citizens in flood risk management was not widespread, nor legally required. A number of public engagement processes has been initiated at national level, e.g., Room for the River, and were well underway. However, most Dutch citizens simply elected their water board representatives and left them to do the job. Only when proposed infrastructural measures directly affected them, e.g., land expropriation for raising the dikes, would they protest and take action (see Cuppen 2012). In 2015, the law was changed to place a duty of care on the water boards, requiring them to undertake participatory engagement with stakeholders in the execution of their flood risk management responsibilities (MinIenM 2015).

So, in some ways the participants in the Houston–Galveston Bay game-structuring co-design intervention were frontrunners in the manner in which they used the insights they acquired in the workshop. They tried to influence the choice of which type of flood defence infrastructure should be considered, not by engaging in debates on technical requirements, but by aligning with others sharing a love of the Bay.

Methodologically, the fact that the co-design workshop worked in this local context served to affirm the generic nature of the steps in the intervention. These steps were originally derived from a study of problem- structuring and game-structuring literature (see Cunningham et al. 2014) and only slightly modified for application in the Houston–Galveston Bay situation. However, an application of the workshop method alone without the brief, but deep immersion in the local context undertaken by the facilitators may not have succeeded as well. The diversity in the problem perceptions of the participants would have

been difficult to appreciate without having visited different areas of the bay, while allegiances to different prevailing opinions in the contested situation could potentially have been misunderstood if the meetings and workshops prior to the workshop had not occurred. Accordingly, we can infer that the steps of the co-design method are generically applicable when sufficient attention is given to understanding and learning about the intricacies of the local context.

6 Conclusion

A 6-step co-design workshop was undertaken on the flood defence of the Houston–Galveston Bay area in October 2014. At that time there was strong contestation surrounding the proposed Ike Dike with alternative combinations of nature-based and smaller conventional engineering solutions being proposed. The transdisciplinary intervention workshop was undertaken to explore whether we could include the lived experience of people in the design of nature-based solutions for their locality and how effective this would be. The results indicate that participants were able to generate a wide range of future outcomes for the bay and were able to use the insights on nature-based solutions and the social contacts that they acquired at the workshop to mobilize commitment to joint action. The action focused on collaboration rather than the determination of technical or infrastructural requirements and was instrumental in initiating more open discourse on flood defence options for the Houston–Galveston Bay area.

This reflected a resilient community-based choice for engagement in flood defence discussions in contrast to the national or regional focus of Dutch engagement processes related to nature-based solutions at that time. It also indicated that the co-design workshop method functioned as a participatory disaster risk reduction intervention for a context entirely different from its original context. However, its generic applicability is potentially limited by the need to contextualise the stakeholder-supplied information within the transdisciplinary workshop. In other words, to apply the co-design intervention method effectively in an unfamiliar locality, one needs to spend time in advance of the workshop becoming familiar with the local context–an intrinsic generic-contextual dilemma.

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Declarations

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