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Problems in applying Soft OR methods to climate actions: lessons from two cases of governmental use

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The field of Soft Operational Research (Soft OR) has emerged from the attempt to address contextually rich, multi-actor 'wicked' problems that are not amenable to traditional 'hard' operational research techniques, which often rely on mathematical modelling. This study assesses the use of Soft OR techniques in climate change policymaking. Since climate change problems are classical wicked problems, many assume that Soft OR would be in high demand in developing climate change policy. And the review of the use of these techniques conducted here does find that in the cases where Soft OR methods have been used by academics and other non-governmental actors, they have consistently provided useful results for policymaking. It is puzzling therefore that there is little evidence of governments using Soft OR application in this area. We study two cases of explicit (in Bristol UK) and implicit use (Rhode Island, US) of such techniques by governments to explain why this is so. We argue that notwithstanding the challenges the two cases reveal in their application, Soft OR nevertheless has much to offer policymakers in the arena of climate change policymaking and deserve more attention and use.

INTRODUCTION: SOFT OR AND WICKED POLICY PROBLEMS

Conditions of well-intentioned and well-informed governments and decision makers and accommodating policy targets are often assumed to be the starting point for policy design, but in fact, are often sorely lacking in practice[1,2]. Not only are many government decisions undertaken under conditions of great uncertainty[3], but designs must also deal with self-interested and self-centred behaviour on the part of both policymakers and policytakers which can lead to poor or ineffective policy outcomes[4].

These dimensions of the 'wickedness' of policy problems[5,6] have also been captured in the field of operational research (OR), which proposes to apply advanced analytical problem-solving methods to aid decision making in such difficult cases. In the late 1970s and early 1980s, traditional forms of OR (Hard OR) developed and were applied in many fields such as manufacturing and linear programming in order to help deal with uncertainty in those fields. In other more fluid areas such as social and political science, however, it became apparent that Hard OR techniques were 'mathematically sophisticated but contextually naive'[7] and fell short of addressing many of the practical problems encountered in these fields. In order to deal with these kinds of 'messy' and 'wicked' organisational problems, the field of 'Soft OR' emerged[8,9].

'Soft OR' techniques developed on the assumption that problems are perceived differently by different stakeholders based on their social, cultural and psychological constructs and thus these techniques have focused their efforts on better 'problem structuring' in order to promote solutions. Rather than attempt to counter the ambiguity of wicked problems by using sophisticated, mathematically grounded solutions[7], the focus of Soft OR lies on managing the root 'cause' of 'wickedness': that is, the diverse, ever-changing and often conflicting perspectives held by various stakeholders in complex problem contexts such as dealing with global carbon emissions, poverty alleviation or ecosystem management. Thus, in contrast to 'Hard OR', Soft OR advocates assume that defining and framing a problem is itself a part of the problem-solving process that requires care and rigour in analysis[10]. In contrast with 'hard' operational research (Hard OR) methods, Soft OR methods are less mathematically grounded, more likely to embrace diversity in stakeholder perspectives, and to promote stakeholder participation in the problem modelling process.

In particular, Soft OR involves the development of a suite of possible 'Problem Structuring Methods' (PSM) intended to help policymakers deal with the conflicting perspectives held by stakeholders which make it difficult to precisely define a problem and thus to identify a 'correct solution'. They are thus designed to handle problems that are significantly more ambiguous than those addressable through Hard OR techniques. Importantly, unlike with Hard OR techniques, Soft OR methods are not meant to find an 'optimal' solution to a problem. Rather, they are used by practitioners to explore the problem space and develop mutually agreeable solutions with stakeholders and other affected parties[8,10,11].

Soft OR methods are quite flexible and some applications are explicit while others are more implicit. Practitioners, for example, need not apply any single method but can adapt the methods to circumstances or even combine different Soft OR methods to suit the purposes of their work. For instance, a modified version of soft systems methodology which incorporated more self-reflection exercises[12] was used by Martin and O'Meara[13] in their study of stakeholder perspectives towards community paramedicine services in Australia's rural areas. Other examples include Rodriguez-Ulloa and Paucar-Caceres[14], who combined soft systems methodology with systems dynamics to identify plausible solutions for resolving interpersonal conflicts within a company and Lousada et al.[15], who combined systems dynamics with cognitive maps to examine the causes of urban blight.

Despite much work on such techniques, however, it is not clear if policymakers are using these methods or, if they are, if they are using them appropriately. This paper reviews multiple cases of

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Table 1. Summary of some of the major soft OR methods.

Techniques/methods	Purpose and use	Theoretical underpinning	References
Cognitive mapping/ journey making	For graphical representation of a problematic situation	Developed by Colin Eden	Ackermann and Eden[45]
Soft systems methodology	To identify problem based on a 7 steps/ stages method	Developed by Checkland based on Systems Engineering	Checkland[46]
Strategic choice approach	To underpin priorities under uncertainty	Developed initially by Friend and Jessop[47] and later by Friend and Hickling[48]	Friend and Hickling[48]
Strategic assumption surfacing and testing	To uncover deep assumptions of the issues and challenge them	Churchman's dialectical approach	Mason[49]
Critical systems heuristics	To challenge boundaries and circumscribe the focus of planning or design	Churchman's dialectical approach	Mingers[11]
Hypergames, metagames and drama theory	Used in situations of competition and conflict, covers Soft Game Theory	Game theory	Mingers[11]
Robustness analysis	To identify and prioritise current commitments in response to robust and uncertain future	Decision analysis and planning methodologies	Rosenhead and Mingers[50]
Interactive planning	To help participants design a desired future	Pragmatism and systems theory	Ackoff[51]

Source: Leong and Howlett[52].

Soft OR use in the climate change case to answer these questions. We find that evidence of Soft OR application in this classically wicked problem area by governments is often at best implicit and indirect. Reviewing recent Soft OR applications relevant to climate change by both governmental and non-governmental actors, and examining two cases of explicit and implicit use of Soft OR techniques by governments, we suggest several popular Soft OR methods have consistently provided useful results for policy-making but also highlight the challenges that interested policy-makers should be mindful of in their consideration and application of these methods.

AN INVENTORY OF SOFT OR TECHNIQUES AND THEIR USE
In general Soft OR techniques have nine features. They are: (1) designed to lead to improvements in a problematic real-world situation, (2) involve applications of systems thinking ideas, (3) have been adapted to fit the particular problem situation, (4) yield methodological lessons, (5) acknowledge that problems are constructs of a person's mind and cannot exist independently of human thought, (6) are applied to a 'messy'/'wicked' problem, (7) involve a high level of interaction and iteration amongst stakeholders, (8) recognise that stakeholders can never remain neutral/remain separate from the issue and (9) are continuously refined to overcome methodological limitations[16].

Various specific Soft OR methods have been developed to aid problem structuring, each with its own unique processes and demands. For instance, some soft systems methodologies feature a CATWOE (Customer, Actor, Transformation, Weltanschauung, Owner and Environmental) framework for defining problems[17] while others such as Critical Systems Heuristics use 12 questions to make explicit the contexts (e.g., cognitive biases) through which stakeholders interpret a problem situation[18].

Table 1 provides an overview of the Soft OR methods that have been developed in recent years and their respective purposes, including problem representation, eliciting and challenging assumptions, promoting future-oriented visioning, and determining priorities. They are also expected to be employed in different problem situations such as competition, conflict, and uncertainty.

To date, the main users of such methods have been academic scholars who have engaged a variety of stakeholders, including government agencies and public communities in testing and refining these approaches.

For instance, as part of efforts to develop solutions for managing floods in the Adyar Watershed, India, Suriya and Mudgal[19] used soft system methodologies to identify issues faced by both policymakers and scholars and also to develop feasible solutions such as building waterways and bars, raising public awareness and improving maintenance of drainage facilities. The same Soft OR method was used by Saeedi et al.[20] to elicit and organise professional opinions (from policymakers, academics, consultants and contractors) in order to develop a conceptual model of green infrastructure development in Tehran. Soft OR methods have also been used in the decarbonisation of urban energy systems[21], to understand stakeholder (e.g., pier and harbour managers, coastal planners, local fishermen, tourist sector operatives) perceptions of climate vulnerability along the coasts of Ireland and Scotland[22], and the increased risks of climate change-induced natural hazards. Members of the North Shore Community Disaster Planning Committee from the North Shore of O'ahu, Hawaii, for example, have used fuzzy cognitive mapping to develop a tsunami disaster plan[23].

However, whether and how governments are using Soft OR remains little studied and poorly understood. Given that Soft OR was developed to address wicked problems, a problem type common in climate change policy[24], many would assume that Soft OR methods would also be often deployed by governments charged with dealing with such problems. Whether or not this is the case and why or why not such techniques are deployed, and how, however, remain outstanding research questions. To address these issues, this paper utilises a bibliometric review of Soft OR use to examine the prevalence of specific Soft OR techniques applied by governments in climate change policymaking.

BIBLIOMETRIC METHODS
To systematically examine the use of Soft OR techniques by governments in dealing with wicked problems, an online search (via Google Scholar and Elsevier) was conducted for papers concerning the use of Soft OR in climate change-related topics. The search terms/keywords for Soft OR include both the specific Soft OR methods listed in Table 1 and generic phrases such as the term Soft OR' itself. Likewise, keywords for climate change-related topics include specific words such as 'carbon emissions', 'floods', 'droughts' as well as the umbrella term, 'climate change'.

Relevant papers were then subject to another round of filtering where only papers that bear some direct relation to governments were shortlisted. Examples of government involvement include research that was funded by government bodies, research that involved the active participation of government officials and case

Table 2. Overview of soft or applications and government involvement.

Paper	Initiator of research	Description of Soft OR application	How was the government involved?	Outcomes
Gray et al.[22]	Academics	Fuzzy cognitive mapping was used to understand stakeholder perceptions of climate vulnerability along the coasts of Ireland (Tralee Bay) and Scotland (Outer Hebrides).	Government officials (the specific ministry was not mentioned) participated in surveys and interviews where their inputs served as data for building the cognitive map	The cognitive map helped to identify pertinent signals of climate change along the coasts and provided a structured communication platform for organising and integrating climate issues into future coastal management deliberation
Henly-Shepard et al.[23]	Non-profit disaster planning community	Fuzzy cognitive mapping was used by the North Shore of Oʻahu, Hawaii's non-profit community disaster planning community to better inform their community disaster planning in relation to the potential impacts of a tsunami	Government officials (the specific ministry was not mentioned) participated in the workshops	The cognitive map helped the community to better understand the impacts of various tsunami scenarios on their community and compare the pros and cons of various adaptation strategies
Martinez et al.[29]	Academics	Fuzzy cognitive mapping was used to understand the Water–Energy–Food (WEF) nexus of Andalusia, Spain	Government officials (the specific ministry was not provided) participated in a workshop where their inputs served as data for building the cognitive map. The workshop was hosted by the Regional Government of Agriculture, Fishing and Rural Development. The research was funded by the European Union's Horizon 2020	The cognitive map identified several factors that significantly impact the stability of Andalusia's WEF nexus, including climate change, water availability and environmental conservation
Meliadou et al.[27]	Academics	Fuzzy cognitive mapping was used to understand the objectives, priorities and perceptions of North Lebanon's coastal productive sectors with regard to coastal zone management	Government officials (the specific ministry was not provided) participated in roundtable discussions where their inputs served as data for building the cognitive map	Several factors perceived as affecting North Lebanon's coastal zone management were identified, along with common challenges, expectations and stakeholder objectives
Nguyen et al.[26]	Academics	Soft system methodology was applied to understand the challenges and solutions for managing the mangrove-aquaculture system in Kien Vang, Vietnam	Government officials from the Department of Environment and Natural Resources, An Giang Province and the Forest Department of Ca Mau Province participated in interviews where their inputs served as data for subsequent analyses. The research was funded by the UK Research and Innovation, a non-departmental public body sponsored by the Department for Business, Energy and Industrial Strategy	Several challenges (management difficulty, water pollution, low yield of aquaculture) and potential solutions (water control, yield maintenance, infrastructure investment) were identified
Olazabal and Pascual[21]	Academics	Fuzzy cognitive mapping was used to develop plausible policy scenarios that support the decarbonisation of the urban energy system of the city of Bilbao, Spain	Government officials (the specific ministry was not provided) participated in interviews where their inputs served as data for building the cognitive map. The research was funded by the European Science Foundation	Results suggest a combination of institutional and social action as the 'most conducive' for stimulating effective and sustainable changes to Bilbao's energy system
Reckien[25]	Academics	Fuzzy cognitive mapping was used to assess sensitivities to weather extremes (heatwaves, rainstorms) and for comparing the utility of various adaptation measures in Hyderabad, India	Government officials from the Hyderabad Metropolitan Development Authority participated in interviews where their inputs served as data for building the cognitive map. The research was partly funded by the German Ministry for Education and Research as well as the German Science Foundation	Results suggest rainstorms affect low-income residents more than heatwaves, while the opposite is true for medium-income respondents. The results also suggest that while the impacts might become increasingly severe due to climate change, investments in water infrastructure and management have the greatest mitigation potential
Saeedi et al.[20]	Academics	Soft systems methodology was used to understand stakeholder perceptions and challenges of green infrastructure development in Tehran, Iran	Government officials (the specific ministry was not provided) participated in interviews where their inputs served as data for subsequent analyses	Based on the challenges identified, 10 categories of actions were proposed

Table 2 continued

Paper	Initiator of research	Description of Soft OR application	How was the government involved?	Outcomes
Singh and Nair[30]	Academics	Fuzzy cognitive mapping was used to develop a livelihood vulnerability index due to climate variability and change for poor agro-pastoralists in Bhilwara, Western India	The research was funded by the Department of Science and Technology, Government of India and the International Development Research Centre, Canada	The results confirm that financial and natural assets are most susceptible while organisational and financial assets are more resilient against climate change. The results also suggest that livelihood vulnerability of agro-pastoralists lies in the range of being 'vulnerable' to climate change while varying across three seasons summer, winter, and rainfall
Suriya and Mudgal[19]	Academics	Soft systems methodology was used to understand the flood management issues in the Adyar Watershed and also to develop solutions	Government officials from various government agencies (Public Works Department, Institute for Water Studies, Chennai Metropolitan Development Authority, Institute for Hydraulics and Hydrology) participated in interviews where their inputs served as data for the soft systems methodology	Six categories of flood management issues were identified along with eight solutions, which were ranked in terms of how urgent these solutions need to be implemented

studies that described the use of Soft OR methods by government bodies. As the literature concerning Soft OR is quite recent, only papers within the past decade were used as source materials.

Some research papers use Soft OR techniques but do not explicitly state which Soft OR method was used (e.g., 'soft systems methodology'). When such an ambiguous approach is detailed, we relied on Yearworth and White's[16] framework (see above) to identify the extent to which a paper in fact used some form of Soft OR.

FINDINGS

Soft OR's explicit application by governments to address climate change issues

Table 2 shows that in general Soft OR techniques have only been infrequently applied to study climate change-related topics. Some Soft OR studies sought to understand local perceptions of climate vulnerability (e.g., refs. [22,25]) while others sought to develop climate adaptation measures (e.g., refs. [19,26]). Although infrequent, the results showed that the use of Soft OR methods did help researchers identify potential challenges posed by climate change to the economy (e.g., ref. [27]) and also enabled users to devise multiple solutions (e.g., use of water control, yield maintenance and infrastructural investments to manage Vietnam's mangrove-aquaculture system[26]) or combinations of solutions (e.g., ref. [21]) to address climate change-related issues.

Significantly, though, we found very few instances of governments explicitly initiating and applying specific Soft OR methods. An exception to this is Bristol city, a case which we shall later examine in full. The review shows that academic researchers are by far the dominant users of Soft OR techniques, largely for academic research purposes. Governments have, on the contrary, mainly participated in rather than initiated or controlled such efforts. For instance, government officials have served in expert panels, and/or participated in stakeholder discussions, interviews and workshops where their inputs serve as data (e.g., refs. [19,25,28]).

While governments only rarely initiated Soft OR exercises themselves, they clearly see value in such methods, as can be gathered from the fact that they have supported such research with funding (e.g., refs. [29,30]). For example, officials from India's Hyderabad Metropolitan Development Authority participated in Reckien's[25] cognitive mapping workshops where their input was used to assess Hyderabad's sensitivities to weather extremes (heatwaves, rainstorms) and for comparing the utility of various possible adaptation measures. The same study was also partly funded by the German Ministry for Education and Research as well as the German Science Foundation. As another example, officials from the Forest Department shared their opinions regarding the challenges and plausible solutions for managing the mangrove-aquaculture system in Kien Vang, Vietnam, which were used in Nguyen et al.'s[26] soft system methodology research. Here, trans-national funding of Soft OR work can also be seen at work, as Nguyen et al.'s research was financed by the UK Research and Innovation, a non-departmental public body sponsored by the Department for Business, Energy and Industrial Strategy.

While governments have not extensively utilised explicit Soft OR methods in climate change policymaking, however, signs of Soft OR elements being used implicitly to various extents by governments, can also be observed. We trace these in our review below, and will discuss one case in Rhode Island, US in full later on.

The Bristol case

Given the possible benefits of the application of Soft OR, the fact that few governments explicitly initiate such efforts is puzzling. Some of the reasons can be discerned from one of the few cases of explicit government-led Soft OR use: that of municipal sustainability planning in Bristol, England.
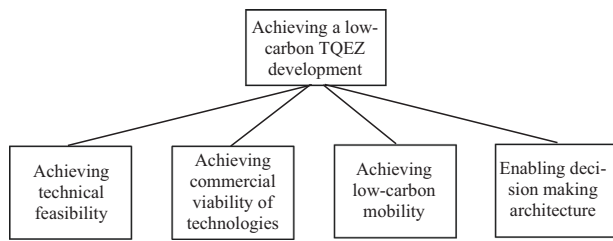
Fig. 1 The STEEP project's hierarchical process model. Achieving a low-carbon TQEZ development. Source: Adapted from Freeman and Yearworth[38].

Fig. 2 Overview of the STEEP methodology. Source: Yearworth et al.[55].

Bristol is a 'green' city—it won England's first 'cycling city' title in 2008[31], and the UK's first European Green Capital award[32]. In terms of its energy consumption, the Bristol City Council has committed to helping the city become carbon neutral by 2030[33], and has policies to reduce energy inefficiencies as part of its climate adaptation plans. However, these policies were often sector-specific, meaning that energy efficiencies achieved in one sector can potentially have negative impacts on other sectors[34].

An opportunity for inter-sector cooperation in energy policy-making occurred in 2012, when Bristol's Temple Quarter was slated for redevelopment into an Enterprise Zone[35]. The initiative was part of Bristol's attempts to regenerate 130 hectares of brownfield in Temple Quarter area to create 10,000 homes, 22,000 jobs and attract £1.6 billion in income annually to the city's economy[36]. Funded by the European Commission's 7th Framework Programme[34], four organisations were primarily involved in developing the Temple Quarter Enterprise Zone (TQEZ): the Local Enterprise Partnership (a regional job creation organisation), the British City Council (Bristol's local authority), the Network Rail (operates railways within the TQEZ) and a central government agency (which owns several plots of land in the TQEZ).

Developing the TQEZ involved balancing two objectives[37]. First, to stimulate economic growth (e.g., job creation, infrastructural investments) and second to safeguard the environment, including to mitigate and adapt to climate change, the use of renewable and low-carbon energy, sustainable building policies and flood mitigation plans.

To achieve these objectives, a 2-year Systems Thinking for Efficient Energy Planning (STEEP) project was commissioned to develop a low-carbon, energy-efficient masterplan for the TQEZ[38].

The project involved the explicit use of Soft OR systems thinking to develop models for energy master planning. It was an inter-sectoral effort jointly conducted by the Bristol City Council, the University of Bristol, a building engineering consultancy and a sustainable planning consultancy. Using the STEEP methodology —a modified version of hierarchical process modelling[39] (a technique that involves breaking down a large ambiguous process into smaller, more manageable parts providing stakeholders with a detailed understanding of the challenges involved in a task[38]) that integrates several Soft OR methods—several problem structuring processes were undertaken. Figure 1 showcases an example of a hierarchical model comprising a 'top-level' process (achieving a low-carbon development) and its corresponding 'bottom-level' processes.

In the STEEP project's context, the re-structuring of problems into a hierarchical model was further supported by three other explicit Soft OR methods[40]. Stakeholders began with defining the 'top-level' process (i.e., the project's purpose; to develop a low-carbon energy masterplan) in the hierarchical model using soft system methodology. To help stakeholders evaluate their model, dialogue mapping was used to provide a visual representation of the key stakeholders' ideas. Lastly, issue-based information system was applied to structure discussions[41–43] whenever stakeholders encountered a sub-process that was either difficult to evaluate
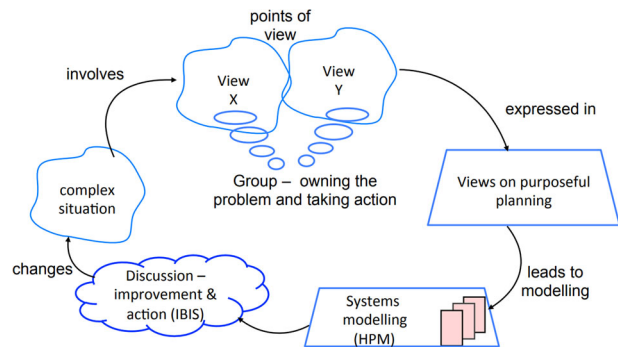
(due to a lack of information) or poorly performing. Figure 2 provides a summary of the STEEP methodology.

From a broad, ambiguous goal of developing a sustainable, city-level energy masterplan, the application of an explicit Soft OR-based STEEP methodology helped the team reduce the wickedness or complex, intertwined nature of the task and arrive at a shared understanding of the current performance within each of the four processes.

The development of a low-carbon energy masterplan via the STEEP methodology, however, was hindered by three issues[38]. First, there was a lack of clarity on problem ownership. Since the sustainability aspect of TQEZ's vision was a job for BCC's Future Cities team, other stakeholders within the STEEP project team initially assumed that the entire energy masterplan belonged to the Bristol City Council itself. However, the city council does not have control over the financial and infrastructural decision making of the Local Enterprise Partnership and private property developers.

Secondly, there was a lack of interest amongst many stakeholders in realising a low-carbon energy masterplan. As a result, stakeholders' participation during the STEEP workshops was inconsistent. As the STEEP methodology relies on an iterative interactive process, such inconsistent participation distorted the hierarchical process model.

Lastly, and related to both the other issues above was an imbalance in stakeholders' power. Stakeholders with the most power to realise the energy masterplan (e.g., the property developers) tended to have the least amount of commitment and interest while those with the least decision-making power tended to be amongst the most committed and interested[38]. For example, the STEEP project team failed to set clear performance metrics because the city council did not have power to enforce measures of carbon emissions or measure such emissions in private properties within the TQEZ.

The case thus illustrates how a lack of clarity in the power relationships between the stakeholders and a poor incentive structure for stakeholders led to some problems in the use of Soft OR methods. This helps account for the low explicit usage of such methods among governments in general since all three problems are common in governance and policymaking contexts.

Soft OR's implicit application by governments to address climate change issues. At the same time, and despite these problems, the benefits of using Soft OR methods are clear and there is evidence (Table 3) of greater implicit use of soft OR's application by the government in climate policymaking.

Perry et al.'s[44] study of implicit Soft OR use in the development of coastal resource management planning in the eastern United States provides a good example of these kinds of efforts and illustrates some of the advantages to the government of implicit rather than explicit use.

Table 3. Case studies of climate change policymaking with elements of soft OR.

Paper	Context	Yearworth and White[16] criteria	Soft OR elements observed?	Analysis
Jacobs et al.[53]	The researchers sought to develop a climate adaptation planning tool in conjunction with the New South Wales National Parks and Wildlife Service (NPWS)	Improvement activity	Yes	The methods 'successfully elicited tacit knowledge of agency staff about the range of interventions available, the need for management practices to evolve, and of discontinuities in management pathways'
		Systemic approach	Yes	Workshops were held for problem-scoping, visualising (via causal diagrams) the impacts of climate change, understanding current park management measures (via assessment matrices). The adaptation planning tool was developed by incorporating the above with a comprehensive list of management options
		Creativity	Yes	The systemic approach involved the integration of several methodologies such as the use of causal diagrams, adaptive pathways and risk assessment matrices
		Methodological lessons	No	The adaptation planning tool developed was disseminated to regional NPWS staff who were taught how to apply it in their work in a top-down manner
		Worldviews	Yes	Efforts were taken to ensure that the development process involved stakeholders across different 'functional areas' of the NPWS
		Wicked problem	Yes	'the complexity of NPWS's organisational structure and the breadth of its functions coupled to uncertainty surrounding the onset and severity of climate impacts across operational geographies have impeded whole-of-agency strategic planning for climate change. These issues often elicit a collective view that the task is 'too big to tackle"
		Interactive	Yes	The adaptation tool development first involved input from the functional area workshops, which was further refined via discussions during the regional workshops
		Subjectivity	Yes	The stakeholders are directly involved in the problem of park management under climate change
		Limitations	Yes	Anticipating that stakeholders may have trouble understanding some statistical concepts used in the methodology, the authors developed a qualitative risk matrix that relied on heuristics rather than statistical properties
Perry et al.[44]	The Rhode Island Coastal Resources Management Council (RICRMC) was trying to restore a drowning salt marsh due to sea level rise by working with local stakeholders such as the Town of Charlestown, Salt Ponds Coalition	Improvement activity	Yes	The large diversity of stakeholders was able to work together for a common goal of restoring the salt marshes
		Systemic approach	No	While there was a general framework governing how stakeholders communicate and resolve issues, there were no specific systems ideas /theoretical bases through which the framework was developed
		Creativity	No	While there were many opportunities for stakeholders to interact, there were no attempts to structure stakeholder communications by adapting or combining different methodologies
		Methodological lessons	Yes	Restoration plans and monitoring methods were constantly revised based on the field conditions
		Worldviews	Yes	The stakeholders were aware that the restoration project required expertise from several disciplines (engineering, ecology, public management, etc.) and that close collaboration was integral to ensuring these different 'schools of thought' worked together for the project's success
		Wicked problem	No	The restoration of the salt marsh was more of an engineering problem with an obvious, optimal solution: sediment enhancement
		Interactive	Yes	There were constant opportunities to voice concerns, share results and negotiate towards a mutually agreeable action amongst stakeholders
		Subjectivity	Yes	The stakeholders are representing organisations that are directly involved in the salt marsh restoration project
		Limitations	Yes	The authors recognise that their adaptive management approach required deep collaborations across stakeholders, which they overcome by providing many opportunities for open communications

Table 3 continued

Paper	Context	Yearworth and White[16] criteria	Soft OR elements observed?	Analysis
Barton et al.[54]	Creating a regional Climate Change Adaptation Plan for the Regional Government of the Metropolitan Region of Santiago de Chile and the Ministry of Environment	Improvement activity	Yes	Prior to each roundtable meeting, stakeholders were presented with relevant briefing papers to 'establish a common framework of understanding'. The roundtables were also organised systematically: the problem of climate change was defined; existing solutions were shared; new solutions were proposed, evaluated and selected and finally, a climate adaptation plan was put together
		Systemic approach	Yes	Problem structuring methods such as scenario planning were integral for communicating scientific findings to stakeholders during the roundtable meetings
		Creativity	No	No evidence was reported in the paper
		Methodological lessons	Probably	Solutions to overcome challenges (both anticipated and unanticipated) were incorporated into the workshops. For instance, to ensure stakeholders remain interested and committed, facilitators used a technique called 'making the case' to convince participants of the urgency of developing climate adaptation plans
		Worldviews	Yes	Beyond the core public stakeholders, participants from the roundtable include members of the private sector and academia. There was considerable diversity within these domains too (e.g., some participants are experts in healthcare, some are authorities on water and others in building and construction)
		Wicked problem	Yes	The roundtables were intended for developing adaptation plans for climate change
		Interactive	Yes	Development of the adaptation plan was a continuous learning process. Participants shared and evaluated their ideas during the roundtables and also continued reviewing information through briefs and working papers made available before each meeting
		Subjectivity	Yes	Most stakeholders are residing/representing organisations in Santiago; the same location where their climate adaptation plan will be implemented
		Limitations	No	The team noted that maintaining stakeholder interests and commitment was an issue and acknowledged that the large funding required for their methodology can make its applications 'a significant challenge'. However, no attempts were made to overcome these limitations

The Rhode Island Coastal Resource Management Council (RICRMC) case

The RICRMC case involved an attempt to restore a drowning salt marsh due to sea level rise. While it was immediately clear to the governments involved that restoring the salt marsh would require the use of technical sediment enhancement methods with their key challenge being to get stakeholders to work together on this project. Key stakeholders included the government/initiator of the project, the RICRMC; residents from the Town of Charlestown where the salt marsh was situated; the state-designated watershed council for RI coastal ponds, Salt Ponds Coalition; and the engineering company which conducted the sediment enhancement process, the J. F. Brennan Company.

To overcome potential challenges arising from disagreements amongst the stakeholders, a series of processes termed 'adaptive management strategies' was practised. These strategies embodied Soft OR techniques but without explicitly naming them.

An initial step of CRMC's adaptive management strategies was to ensure all stakeholders shared a common goal, by being forthcoming about each stakeholder's role in the restoration project. Next, in developing the marsh restoration plan, stakeholders took pains to ensure there were clear metrics and targets to assess the progress of the salt marsh restoration. CRMC also conducted several meetings and presentations to ensure stakeholders had opportunities to provide feedback and refine the marsh restoration process. Finally, to maintain public involvement in the project, data concerning the progress of the salt marsh restoration project was also made available online while the RICRMC routinely conducted regional presentations as well as site visits with the community and regional agencies.

Although there was no explicit mention of Soft OR, the RICRMC's adaptation strategies satisfied a number of Yearworth and White's[16] criteria for defining Soft OR methods (see Table 3). First, the adaptation strategies can be considered an 'Improvement activity' as their methods steered different stakeholders towards a common goal. Second, the adaptation strategies satisfy the 'Methodological lessons' criteria as stakeholders' were constantly revising their marsh restoration plans based on feedback (e.g., placing of signages and designation of alternative recreational space). Third, the 'Worldview' criteria were also met, since stakeholders in the restoration project came from diverse backgrounds ranging from policymaking (RICRMC) to engineering (J. F. Brennan Company). Fourth and most clearly, the adaptation strategies were definitely 'Interactive', given the numerous opportunities for stakeholders to communicate their goals and concerns. Fifth, the strategies may also qualify for the 'Subjectivity' criteria, since participants in the project all had a stake in the salt marsh restoration, ensuring that the stakeholders were not separate from the issue. Sixth, the strategies satisfy the 'Limitations' criteria. This is because the authors recognised that their adaptive management approach required deep collaborations across stakeholders and took steps to overcome this methodological limitation by providing many opportunities for open communications. Lastly, the strategies also qualify for the 'Wicked Problems' criteria since they were developed to address potential conflicts arising from stakeholder disagreements towards the marsh restoration project.

It must be noted that RICRMC's adaptation strategies did not fulfil all the formal elements of Soft OR elements established by Yearworth and White[16]. First, while there was a general framework governing how stakeholders communicated and resolved issues, there were no specific systems ideas/theoretical bases through which a framework was developed. Second, although RICRMC took measures to ensure stakeholders had many opportunities to interact, there were no attempts to structure these communications by adapting or combining different methodologies.

Overall though, the team achieved high collaboration, overcoming various obstacles with 'compromise, frequent and open communication with partners, and guided, productive monitoring and project meetings' which the explicit use in Bristol could not acheive. The partners were able to establish and hold similar goals, which led to accountability, commitment, and timely follow-up and overcame rigidities introduced in more explicit uses which constrained and discouraged actors and emphasised power differentials. Overall, researchers felt that Rhode Island's use of what was termed an 'adaptive management strategy' was effective and it continues to influence future decision and policymaking on coastal marsh restoration in the Northeast USA and beyond.

DISCUSSION AND CONCLUSION

Soft OR is a field developed to manage wicked problems and one in which it could be expected that there would be widespread use of its methods to handle such problems. The potential policy impact of successful Soft OR techniques is clear and manifested in many academic studies such as Gray et al.'s[22] use of cognitive maps helping to identify key indicators of coastal climate change, providing a 'structured communication platform' for organising and integrating climate issues into future coastal management deliberation; Martinez et al.'s[29] use of fuzzy cognitive mapping helping to identify factors that can significantly impact the stability of Andalusia's Water–Energy–Food nexus and Saeedi et al.'s[20] deployment of soft systems methodology research to detail ten useful categories of action to develop green infrastructure in Tehran, including management reforms, new regulatory controls and the enhancement of stakeholder interactions and relations.

Through a comprehensive review of the recent literature, however, we found that governments have only rarely used Soft OR methods explicitly in their climate change policymaking. Rather than being active practitioners, officials' involvement in explicit Soft OR applications has largely been passive, mainly through serving as participants or involved in a supportive role through financing research. The Bristol case study provided some possible reasons for this, related to the need to the difficulties explicit Soft OR techniques encountered in structuring actors' interactions within a context in which power differentials and distrust existed which discouraged needed collaboration between and among governments and stakeholders. This point is also made by Suriya and Mudgal[19] study of the use of soft systems methodology to understand Chennai's flood management policies.

At least part of these problems related to explicitly practising Soft OR on the ground revealed by the Bristol case involved the need to teach Soft OR methods to stakeholders. It is unlikely that facilitators with Soft OR expertise will always be present to guide actors. And until Soft OR is more widely applied explicitly in policymaking, a reliable pool of Soft OR practitioners or consultants will continue to be difficult to develop and deploy.

Despite these issues with explicit use, the review, however, did show that implicit use of Soft OR techniques is indeed becoming more common. The Rhode Island case suggests that it is more practical for policymakers to adapt implicit Soft OR methods to suit their policymaking purposes rather than to cleave to a formal and specific method, reducing the educational problems cited above and defusing possible stakeholder tensions involved in a way in which more formal applications cannot.

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COMPETING INTERESTS

The authors declare no competing interests.

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