CHAPTER 8

What Insights Can the Programme Share on Developing Decision Support Tools?

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Abstract

- The definition of decision support tools in the context of climate change and adaptation is explored, highlighting the variation in approaches to design and form of tools.
- Several challenges are identified that have impeded the successful development of decision support tools, including financial restrictions, time constraints and meaningful stakeholder engagement.

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- We highlight a number of potential areas for future research, including work to address the challenges of scaling up decision support tools and stronger frameworks for guiding stakeholder engagement.

Keywords Decision support tools · Climate hazard · Adaptation · Stakeholder engagement

1 Introduction

To minimise the risk from the impacts of climate change, both mitigation and adaptation strategies will be required, hence decision-makers—such as government departments, local councils and private businesses—are increasingly interested in potential options to reduce their exposure to climate-related risks. Key enabling tools here are decision support tools (DSTs).

The UK Climate Resilience Programme (UKCR) funded several projects that focused on developing DSTs, where a DST allows users to derive critical information-such as climate hazard to subsequent risk—to make informed decisions. This could be a synthesis of large datasets (making data more digestible), or an interactive tool that displays

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climate hazard information alongside associated impacts and mitigation/adaptation options. DSTs take a multitude of forms, from integrated assessment frameworks to visualisation platforms. This paper will focus on the science-user interface and how information to inform decisions is presented.

In broad terms, a DST can be defined as a tool or knowledge resource to support the decision making process, by facilitating a comparison of different climate futures or adaptation options [1, 2] or by enabling information awareness at spatial scales [3]. The way in which this is interpreted allows for the generation of non-uniform, heterogeneous tools, which have been designed for specific use cases and stakeholders. Consequently, the definition of DSTs varies among the climate resilience community, with different expectations among user communities.

In what follows, we discuss some of the key findings with respect to the development of DSTs from across the UKCR programme, including challenges and gaps in understanding to inform future work. This chapter complements other chapters in this collection, including but (not limited to) chapters 11, 7 and 3.

2 Survey and Review of Decision Support Tools

A series of surveys and reviews of projects funded through the UKCR programme were conducted, focusing on projects where an output was regarded as a decision support tool. In total, nine structured interviews were conducted (each 30–60 minutes in length) with project leads. A summary of the DSTs and key stakeholders is provided in Table 1.

2.1 Web-Based Interactive Tools

At a local scale, the UKCR project 'Catchment Erosion Resilience' designed a pilot web-based interactive DST to illustrate changes in erosion risk within rivers under UKCP18 projected extreme rainfall events. Focusing on a single river, the pilot demonstrated the change in erosion risk to critical infrastructure, including roads, bridges, water and waste treatment structures and electricity transmission towers as well as agricultural land. Similarly, to assess future heat risk across a city, part two of the 'Heat Service' (Meeting Urban User Needs) project combined heat hazard information with socioeconomic data to develop a heat vulnerability index (HVI) for Belfast and Hull. This was delivered to users through a web-based ArcGIS StoryMap, allowing users to interact with

Table 1 A summary of the projects interviewed for the survey of UKCR decision support tools, including a description of each tool, the spatial scale it operates on and the stakeholders directly involved in its development

Title of project	*Decision support tool*	*Platform*	*Scale*	*Key stakeholders*
Climate Risk Indicators	Interactive website allowing visualisation of climate risk indicators across the UK at varying spatial scales and allowing download of data. Primary aim is to assist in raising awareness of potential climate changes	Interactive web tool (https://uk-cri.org/)	National, with varying reporting spatial scales	Wide range of users, including Environment Agency and The Wildlife Trusts
Catchment Erosion Resilience	Interactive visualisation of flood and erosion risks, and associated economic damage to infrastructure, for different rainfall events under UKCP18 climate change scenarios	Interactive web tool (pilot) (https://arcoes-dst.liverpool.ac.uk/EHRC/bootleaf-master3/index_DST_F2.php?map_no=9)	Local	Water companies, electricity transmission and erosion control industry
Risk Assessment Frameworks	Interactive web tool to develop the capability to use climate data in open-source risk assessment framework software, to quantify future climate risk in the UK, explore adaptation option appraisals and assess sensitivities [4]	Interactive web tool—R Shiny (proposed)	National	Department for Education, Ministry of Justice
Once Upon a Time	Interactive web tool exploring changing temperatures for different climate scenarios	Interactive web tool (Northern Ireland Rural Heat Map) (https://akaresearch.shinyapps.io/ruralheat/)	Regional	Climate Northern Ireland, Dale Farm dairy cooperative and Ulster Farmers' Union

(continued)

Table 1 (continued)

Title of project	*Decision support tool*	*Platform*	*Scale*	*Key stakeholders*
CoastalRes	Prototype methods to assess coastal resilience to erosion and flooding under climate change scenarios at local to national (England) scales [5]	Result datasets, reports, interactive educational web tool (https://coastalresilience.uk/crm/)	Varying spatial scales	Environment Agency and maritime local authorities who manage coastal flood and erosion hazards in England, plus other stakeholders interested in shoreline management planning (e.g. Natural England)
OpenCLIM	An integrated cross-sectoral assessment tool for climate impacts and adaptation options, including hazards such as heat, flooding and water supply, and impacts on people, property, agriculture and biodiversity to support national climate risk assessment as exemplified by the UK's third Climate Change Risk Assessment (CCRA3). The tool is critically underpinned by an open modelling framework which allows for production of new results and updating of workflows and models	Result datasets, modelling framework, interactive web tool (proposed)	National	Department for Environment, Food and Rural Affairs (Defra), Climate Change Committee (CCC) Environment Agency, Climate Ready Clyde, Natural England, Norfolk Broads National Park Authority and many more

(continued)

Table 1 (continued)

Title of project	*Decision support tool*	*Platform*	*Scale*	*Key stakeholders*
Coastal Climate Services	Part one—A globally relocatable tool to provide regional sea-level projections rooted in the Coupled Model Intercomparison Project Phase 5 (CMIP5) model simulations and Monte Carlo approach, for the future emissions scenarios used in the Intergovernmental Panel on Climate Change's 5th Assessment Report (IPCC AR5). These are based on Representative Concentration Pathways (RCPs) [6, 7] Part two—A dataset of projected future still water Return Levels (RLs) at 2km spacing around the UK coastline, for the future emissions scenarios used in the IPCC AR5 and based on RCPs	Part one—Python-based tool[1] (will be made accessible on completion of the UKCR programme) Part two—Result dataset in GIS format (https://ukclimateprojectionsui.metoffice.gov.uk/products/form/MS4_ESL_Subset_01 and https://ukclimateprojectionsui.metoffice.gov.uk/products/form/MS4_ESL_Subset_02)	Part one: Local Part two: National	Environment Agency, Scottish Environment Protection Agency, National Resources Wales, Department for Infrastructure Rivers (Northern Ireland), flood risk practitioners and Institution of Mechanical Engineers

(continued)

[1] Stored as a GitHub repository of Python code.

Table 1 (continued)

Title of project	*Decision support tool*	*Platform*	*Scale*	*Key stakeholders*
Meeting Urban User Needs (City Packs)	Fact sheets and infographics that use probabilistic projections from UK Climate Projections alongside other information to help inform decision-makers about their climate risks	Infographics, PDF fact sheets	National	Local and city councils
Meeting Urban User Needs (Heat Service)	Part one—A set of factsheets building understanding of heat hazards and impacts in cities Part two—Heat vulnerability index combining climate, socioeconomic and built environment data to assess future heat risk across the city	Infographics, PDF fact sheets, GIS layers, GIS StoryMap	National	Local and city councils, emergency planning groups
Bristol Heat Resilience[2]	Heat Vulnerability Index to explore where heatwaves could have the biggest impact and a Heat Resilience Plan to support the development of green infrastructure strategies	Interactive web tool (https://bcc.maps.arcgis.com/apps/instant/portfolio/index.html?appid=986e3531099f48d393052fab91ceff51)	Local	Bristol City Council

the HVI maps. The tool allows for a narrative to be built around the data and generates maps to aid understanding.

Web tools at larger spatial scales have also been developed; the project 'Once Upon a Time' has enabled users in Northern Ireland to examine likely changes in temperature—and therefore temperature extremes—as shown in Fig. 1. This tool was designed in conjunction with Climate

[2] The Bristol Heat Resilience project has been included in the table for information but was not part of the nine interviews undertaken for this paper.

Northern Ireland and others (e.g. agricultural associations) so that more informed decisions can be made.

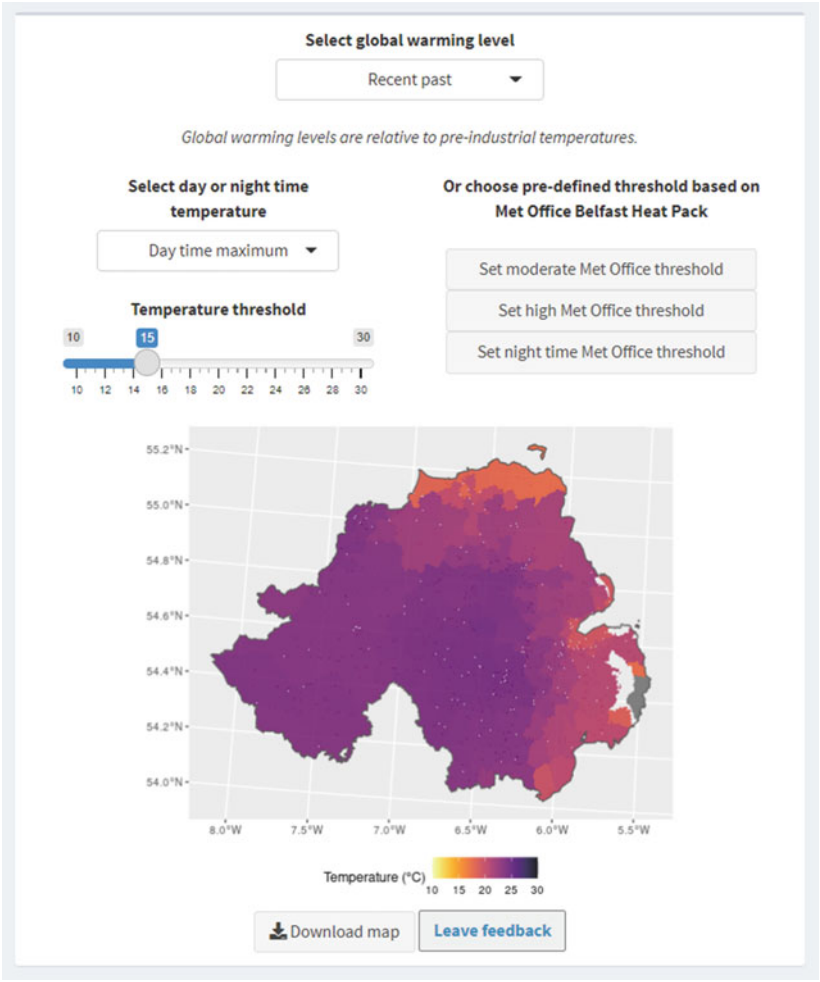

Fig. 1 From the UKCR project 'Once Upon a Time', an example of an interactive DST, which allows users to explore the changes in temperature rise across Northern Ireland over time (*Source* https://akaresearch.shinyapps.io/ruralheat/)

Finally, 'Climate Risk Indicators' developed a web-based interactive DST to provide information on climate risk indicators across the UK at spatial scales ranging from local to national. The indicators cover a range of sectors and are calculated from the latest UK Climate Projections (UKCP18).

2.2 Infographics and Climate Hazard Information

The 'City Packs' (Meeting Urban User Needs) project used the UKCP probabilistic projections to create static fact sheets, using infographics, to raise awareness of the headline messages on climate hazards (such as temperature, rainfall and sea-level rise) likely to affect the given city or region. They were co-developed with relevant authorities to explain the science and the results in a simple, easy to understand format that could be easily distributed.

Based on this success, part one of the 'Heat Service' (Meeting Urban User Needs) project also developed a set of factsheets focusing on heat hazards and associated impacts in cities, to support local and city councils in their decision making around climate change adaptation and to inform planning for future heat events (see example in Fig. 2). Although not interactive, they are highly visual and meet users' needs by providing information on climate specific themes in an accessible and policy-relevant manner.

2.3 Data Outputs

'OpenCLIM' developed a large set of data outputs, covering a range of climate hazards and associated impacts, such as heatwaves, drought and flooding, providing a large resource for information-driven decision making. Additionally, the modelling framework is open and usable for stakeholders, given appropriate training. The output data will allow users to explore these varied hazards and the effects of different adaptation scenarios.

The dataset compiled in part two of the project 'Coastal Climate Services' allows users to explore and download larger datasets of extreme water levels to derive their own understandings of risk, as well as the potential implications of different policy or planning decisions (where applicable data is available). Similarly, the underlying data and spatial outputs in 'Climate Risk Indicators', and the shapefiles produced for the

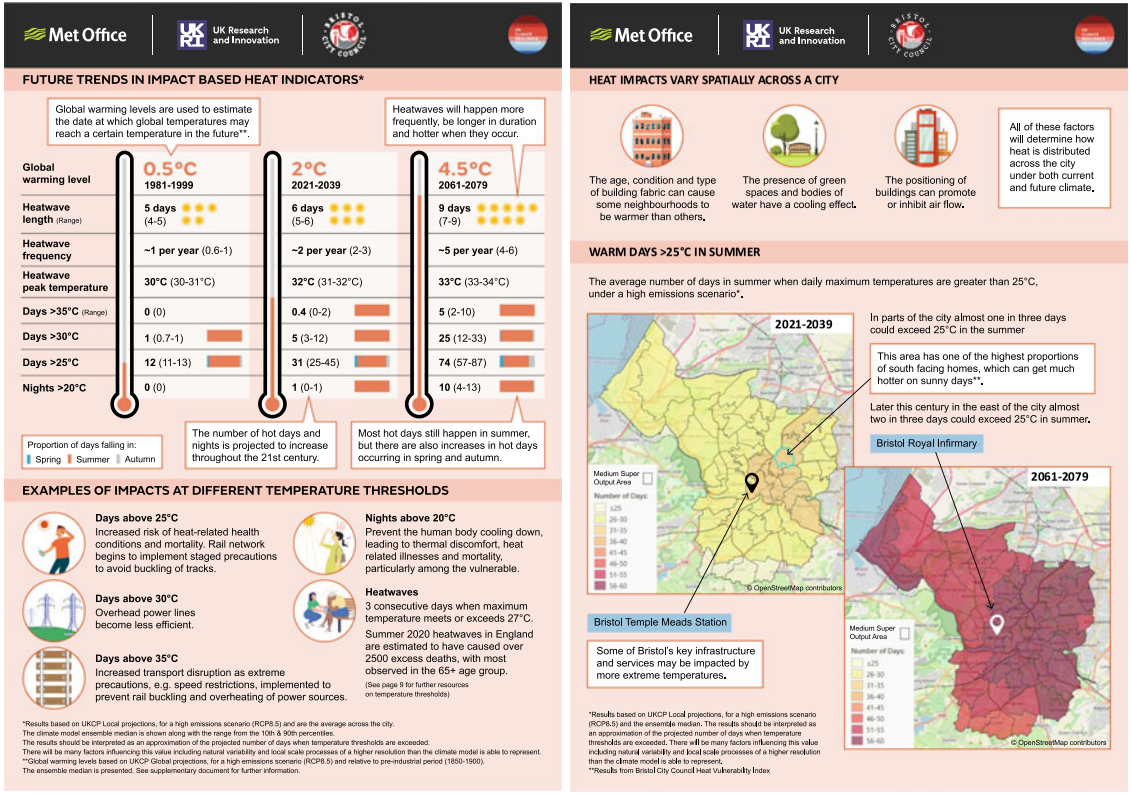

Fig. 2 Example pages from the Heat Pack for Bristol, one of the products of the 'Heat Service' (Meeting Urban User Needs) project. These PDFs are designed to inform stakeholders on possible effects of climate change to help inform decision making (*Source* https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/spf/ukcr_heat_pack_bristol.pdf)

heat mapping element of 'Heat Service' (Meeting Urban User Needs) are available for users to download and integrate into internal GIS systems or other software. These approaches allow users to explore the datasets in detail but require an in-depth scientific knowledge for successful application.

3 Development of Decision Support Tools

Developing DSTs requires a level of stakeholder engagement or co-production if they are to be successful [8]. Decision support tool development varied across the UKCR projects, with approaches falling into two broad categories: (1) science-led, where the tool was initially developed prior to engaging with stakeholders to create a bespoke version; and (2) user-led, where stakeholders were engaged from the outset and at predefined intervals throughout the development process.

The 'Risk Assessment Frameworks' project initially developed the DST as a natural next step in the climate risk assessment framework, using the quantified risk to compare adaptation options. Discussions with stakeholders subsequently helped shape the framework beyond a simple cost-benefit analysis tool, to incorporate analyses such as how much a given adaptation action meets organisational objectives. Similarly, 'Climate Risk Indicators' produced a web platform primarily to disseminate project results, with its form and functionality informed by discussions with stakeholders. 'Coastal Climate Services' developed its sea-level tool informed by published literature, with a view to improving its capability and usability following a user engagement workshop (October 2022).

In contrast, the 'City Packs' and 'Heat Service' (Meeting Urban User Needs) discussed the overarching aims and the objectives of the project through larger workshops and smaller meetings, plus follow-up questionnaires. Furthermore, the 'OpenCLIM' project ran workshops both on a regional and per-sector basis to establish stakeholder needs across different groups, from administrative area policymakers to sector experts, through online interactive discussion sessions.

Both science- and user-led approaches to DST development can be successful, leading to purposeful engagement with and uptake of tools. The main advantage of science-led DSTs is that the climate change information is scientifically traceable and robust; however, they do not always filter through to local impacts, possible adaptation options or decision making. The perceived level of success of a DST will depend on

what the user need is. For example, if a user requires spatial hazard information for their own impact models such as that provided in the 'Coastal Climate Services' project then this approach can be considered successful; however, if they require additional adaptation information then this approach may not meet the user demand.

A user-led approach has the advantage that the resulting DST is understandable and appropriate for the decision in question, thereby increasing the likelihood of stakeholder uptake. However, the level of scientific rigour can sometimes be called into question when aspects are tailored to suit the user requirements rather than the science. Furthermore, there are issues with workshops which tend towards a broad audience, with a wide range of conflicting thoughts, ideas and interests and so diluting potential learning and beneficial outcomes. Much of the research across the UKCR programme highlights the benefits of co-production over consultation in this regard.

4 Usability of Decision Support Tools

DSTs have maximum impact and effectiveness when designed in collaboration with stakeholders [9, 10], specifically when they are demand-driven rather than science-driven [11], though the design of interactions with stakeholders must be considered otherwise DSTs can still prove to be ineffective [3, 12, 13]. Many of the UKCR-derived tools have been developed through engagement with stakeholders to ensure the DST meets their needs and can inform decision making processes. These tools have been developed in collaboration with groups such as interested local authorities ('City Packs'), government departments ('Climate Risk Indicators', 'Coastal Climate Services') and industry associations ('Once Upon a Time').

An important aspect of usability is fitness for purpose of the DST. For example, the 'Coastal Climate Services' project provides regional sea-level projections, which could help inform investment strategies based on the comparative risk to different regions. However, the information would not be sufficient for making infrastructure development plans, because additional site-specific information would be required to complete a detailed risk assessment, using for example a hydrodynamic model.

The success of DSTs in the context of the UKCR programme can be measured via their continued use, plus their influence on the development of new or existing climate change policies. Reporting of this

nature is weak or hard to identify, however. Within the time frame of the UKCR programme, success of DSTs is difficult to measure because many of the projects have only recently been completed. A longer-term assessment, which records evidence from stakeholders where tools have directly influenced policy changes, would allow for more useful evaluation. Certainly, there are several examples where this is anticipated, such as the 'Heat Service' (Meeting Urban User Needs) project, which will be used to update severe weather plans for heat risk in Belfast, as well as the city's climate change risk assessment. Further evidence can be gathered from emerging follow-on projects; for example, 'Catchment Erosion Resilience' produced a pilot tool for examining future river erosion impacts, which has led to other projects with infrastructure providers (e.g. Welsh Water and the National Grid).

5 Barriers in Decision Support Tool Development

Several difficulties have arisen in the UKCR programme for those projects developing DSTs, commonly with respect to user engagement. Firstly, knowing who to approach within potential stakeholder organisations or groups to initialise engagement. Secondly, knowing which method of user engagement is appropriate for the desired outcome (large workshops can garner initial interest, while smaller, more targeted meetings are beneficial when refining the final product). Finally, knowing how to maintain purposeful engagement and manage expectations. To some extent, involving the right users begins to address this, although the relationship needs to be carefully managed to avoid stakeholder fatigue. The recent increase in the use of technology for virtual meetings has made engagement easier, but a balance needs to be maintained between user and developer expectations. Clear frameworks around managing expectations and engagement methods need to be made apparent from the outset of the process to ensure all parties benefit from the engagement, and no one party is left disappointed or frustrated.

Another recognised issue for DSTs is securing legacy access for stakeholders through online portals. Given the amount of resource invested in the development of these useful and usable tools, ensuring DSTs remain available beyond the funding window is especially important. Similarly, ongoing web support and updates are often not possible and knowledge loss may occur when the original project team moves on. This remains a

widespread issue affecting how tools remain available and supported for users. Overcoming this is a particular challenge but could be limited in some instances through extensive and detailed levels of co-production, or by ensuring some degree of handover of developed tools to others who are interested in their long-term availability—such as partners or larger central bodies who may have more flexible resources and may want to ensure invested resources, knowledge and technical advancement is not lost from the domain.

6 Conclusions

Several key insights have been learned with respect to DSTs across the UKCR projects. Firstly, DSTs vary in form, based on factors such as the 'decision' they were intended to address, the resources available and the amount of stakeholder engagement. They can be information only or a more complex interactive tool. Secondly, user engagement is often a challenge, despite the pivotal role it plays in DST design. Throughout the UKCR programme, user engagement for the development of DSTs has taken various forms, from targeted meetings to large workshops. Ensuring a suitable and diverse mix of stakeholders is crucial (see chapter 3 for further discussion on co-production and user engagement).

Further, DSTs can be science- or research-led, although fundamentally are dependent on the available science and thus data. Conveying the science is ultimately the role of a DST, although time and rigour is required from a science perspective to achieve this, which is not always fully recognised by stakeholders in the early stages of DST development. Lastly, key barriers to developing DSTs remain, namely funding, skills and legacy planning. Developing effective DST tools requires expertise across the science, usability and visualisation domains, yet few projects have the available resources or skills to do so. Ensuring legacy is an enduring issue.

Along with these insights, we suggest a number of areas of further research to help address key areas of understanding which could be improved in the context of DSTs and climate resilience. As discussed throughout, stakeholder engagement remains a challenge and the development of frameworks which can support this critical activity are essential to smooth this process for researchers, developers and stakeholders alike. These frameworks should consider many elements of the development process, but a further recognised gap that may aid this process is the potential for more consistent visualisation methods for climate-based

DSTs and in particular visualisations of uncertainties in data. Forming a common platform, or set of methods, such as for the visualisation of uncertainty common in climate-based modelling, may reduce time required for stakeholders to understand datasets and thus maximise the time that can be focused on other elements of DSTs and engagement. While some work has been done in this area (e.g. UKCR-funded studies [14, 15]), none of the DSTs reviewed here incorporated existing best practice or consulted visualisation experts to help convey the uncertainties.

Upscaling regional- or city-scale DSTs poses several challenges: from the underlying data potentially being limited geographically, whether due to licensing or because of the devolved management of datasets in the UK (e.g. 'OpenCLIM'); to the increasing data volumes becoming an issue for storage and processing methods; to analysis models being specific to an area (e.g. 'City Packs'). Some UKCR-funded work on addressing the challenges of upscaling has been undertaken through the project 'Upscaling Climate Service Pilots' (see chapter 7), though further work to gauge success regarding DSTs is required. Finally, throughout this review, being able to quantify the success of DSTs has been a consistent challenge given the various forms of tools, intended use and the diversity of stakeholders. The development of approaches to better capture the success and failures of current DSTs would enable future projects to learn from this and subsequently implement changes in their user engagement process and development of such tools.

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