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A Framework for Cloud to Coast Adaptation: Maturity and Experiences from across the North Sea

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Abstract: The low-lying coastal areas of the countries around the North Sea are exposed to flooding and the influence of sea level rise. The countries in the North Sea Region need to continue to adapt if the associated risk is to be well-managed into the future. In addition to reducing flood risk, adaptation measures can bring development opportunities for those same places. These opportunities, however, are unlikely to be achieved through a 'defence only' paradigm, and instead a new approach is needed that simultaneously reduces risk and promotes liveable places, ecosystem health and social well-being. The building blocks of this new approach are promoted here and are based on an adaptation process that is collaborative and takes a whole-system, long-term perspective. The approach developed through the Interreg funded project, C5a, brings together governments, practitioners and researchers from across the North Sea to share policies, practices and the emerging science of climate change adaptation and enabling sustainable development. The new approach reflects a Cloud to Coast management paradigm and emerged through a combination of knowledge exchange and peer-to-peer learning across seven case studies. Central to the case studies was a maturity analysis of existing capabilities across the North Sea countries and their ability to adopt the new approach. This paper presents the results of this analysis, including the common challenges that emerged and the methods and examples of good practice to overcome them. Building upon these findings, the paper concludes by presenting four priority policy directions to support the uptake of the Cloud to Coast approach.

Keywords: climate change adaptation; coastal protection; flood risk management; maturity analysis; resilience; sustainable development; systems approach

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1. Introduction

Across Europe, the annual number of people affected by fluvial flooding is projected to reach 359,000 by the 2080s (currently 167,000) and by coastal flooding 40,000 up to 425,000 (currently 10,000) [1]. The annual damage from river flooding is projected to reach 97.9 billion by the 2080s (currently 5.5 billion) and from coastal flooding 17.4 up to 25.4 billion (currently 1.9 billion) [1]. Flood risk, however, varies considerably across the territories of Europe. Evidence of this distribution and territorial patterns of flood risk is getting stronger (for example, through the Territorial Impacts of Natural Disasters (ESPON-TITAN) project) [2]. This evidence suggests that, in economic terms, the coastal areas of the North Sea tend to be more affected by windstorms and storm surges than most of the rest of Europe's territories. The concentration of property and infrastructure in these areas can mean their impact is particularly significant. Many of the coastal areas, particularly low-lying areas, also experience river flooding. This implies flood risk cannot be effectively managed through a single action (addressing coastal flood hazards, for example). A more broad approach is needed to develop place-based measures that address all sources of flooding and enable the economy, people and nature to thrive.

The need for place-based measures, supported by cooperation and coordinated policies, is emphasised by the EU Territorial Agenda 2030 [3]. This framework provides the political agreement of EU Member States around the key objectives of spatial development. The agreement is based on two pillars: a '*just Europe*', which offers prospects for all places and people, and a '*green Europe*', which protects the environment and marks a social change. In doing so, the agenda helps translate the principles of sustainable development into tangible goals, the Sustainable Development Goals (SDGs) for Europe. Collective action is seen as essential (across sectors, policies, governance levels, places and societal groups) to achieve these objectives, and, in turn, adaptation choices are central. The choices around how to adapt to climate change provide an opportunity to develop liveable places that are both safe and thriving [4], whilst also contributing to the achievement of SDGs [5,6] (including food security, the circular economy, tourism and social cohesion).

The conventional response to managing flood risk has been to deliver project-based infrastructure responses, focusing on levees and dikes. However, a local 'defence only' paradigm is unlikely to manage flood risk over the short to long term and promote liveable places, ecosystem health and social well-being [7]. There is a general acceptance that adaptation and sustainable development can only be addressed successfully through collective action that integrates natural and built infrastructure. The continued evolution of the approach to managing flood risks is needed based on an adaptation process that is collaborative and takes a whole-system, long-term view.

This paper presents insights from the Interreg NSR project C5a in support of this evolution. The approach presented brings together policymakers, practitioners and researchers around seven case study areas across the North Sea as a way of co-creating knowledge for better adaptation to climate change and sustainable development [8]. The C5a project team has explored and developed the basis of a new 'Cloud to Coast' approach through a combination of knowledge exchange and seven case studies. This approach builds upon the outcomes of seven founding Interreg NSR projects, BEGIN, Building with Nature, CATCH, CANAPE, FAIR, FRAMES and Topsoil [9], along with other national and international partnerships. Although these projects have partially been successful in their approach, an initial survey among the partners confirmed that several barriers to progress persist (see Table 1). The Cloud to Coast approach offers practical benefits in that it enables collaborative processes to overcome these barriers.

Table 1. Barriers that emerged from the initial survey among the C5a partnership.

Barriers to Progress
Institutions are often fragmented with little incentive for collaboration, which is hindered by capacity barriers and siloed programme and delivery targets.
Co-funding that goes beyond support or contributory funding is difficult to achieve as it raises leadership ambiguity and benefit attribution.
Strategic planning and operational processes are often misaligned within and between various organisations.
Although it is accepted that the future is uncertain, few decisions embrace this complexity and often choosing sectoral precautionary with little ability to trade outcomes across sectors.
A reluctance to embrace innovation and accept the inevitable increase in risk for return for the potential opportunity.

The approach continues to build upon existing and emerging approaches. Within the water sector, integrated coastal zone management (ICZM) [10,11] and integrated water resources management (IWRM) [12,13] approaches have both emerged in an attempt to enable integration. Such approaches tend to focus on the management process (rather than outcome) [14]. In doing so, such approaches fail to address future uncertainty, and limited methodological support is given as to how to meaningfully address the issues of adaptation and sustainable development. More recently, strategic approaches have been developed that accept the complexity and uncertainty of current and future decision-making and provide a more practical long-term focus to address the highly uncertain issue of climate change [15–17]. These emergent approaches also more explicitly promote the integration of nature-based solutions into climate adaptation, as these offer more flexible long-term solutions with multiple benefits, including flood protection [18]. Nature-based solutions have gained increasing prominence in applications for river systems since the impacts of flood control areas with riverine vegetation stand unchanged [19]. Similar impacts on flood mitigation occur in urban areas populated by trees and green roofs. Zolch et al. [20] found an increase in water storage capacities can be achieved through a strategically planned green infrastructure network with features designed to deliver runoff regulation.

While ICZM and IWRM plans have evolved to include adaptation mechanisms and phased decision-making, this has been implemented only on a case-by-case basis. A benefit of the Cloud to Coast approach is that it more explicitly connects whole-system and multi-scale approaches to undertaking adaptation. Due to this broad emphasis, the approach gives less consideration to specific aspects such as monitoring arrangements. Another benefit lies in the alignment of policies and supporting governance systems across sectors, which is encouraged by the Cloud to Coast approach. This aspect is often neglected by existing approaches, in that these tend to presume perfect alignment of sectoral strategies and plans and the organisations that deliver them.

The new approach has been built and tested in case studies. The first case studies, Dordrecht (NL), Het Zwin (BE) and Klarälven (SE), helped to build the Cloud to Coast framework and make the step from 'concept to approach'. In the full set of case studies, with the addition of Esens-Harlingerland (DE), Kent (UK), Ringkøbing-Skjern (DK) and Weijerswold (NL), the Cloud to Coast approach was tested and refined, so that it was co-created with the partners. The experiences of the case studies were captured by a maturity analysis of the involved partners. From the maturity analysis, a set of common challenges emerged for evolving existing approaches. These challenges are presented, along with good practice examples from the case studies to overcome them. Building upon these examples, the paper ends with a discussion of four priority directions to support the uptake and transfer of the Cloud to Coast approach in policy and practice.

2. Materials and Methods

2.1. Conceptual Framework: Four Main Pillars of Cloud to Coast Adaptation

The conceptual framework for Cloud to Coast adaptation brings about a whole-system understanding (across catchment, coasts, cities, infrastructure networks) through an inclusive process and enables a continuous dialogue that delivers sustainable, integrated and multifunctional adaptation measures. The early concepts underlying this framework were derived from the initial survey of partners involved with the founding Interreg NSR projects and an additional literature review of the systems approach [21–24] and related concepts. Across these projects, four main pillars of the planning process are increasingly recognised as prerequisites for adapting to climate change and enabling sustainable development. These main pillars help the development of a strategy or investment plan to deliver a resilient outcome and are themselves enabled or confounded by policy structures within which these strategies and plans are made and implemented.

The main four pillars encompassed within the Cloud to Coast framework are (see Figure 1):

- **A whole-system response:** A whole-system response requires us to challenge our own 'silo' and become 'system thinkers'. To aid this process, the Interreg NSR project FAIR promoted the use of the source–pathway–receptor (SPR) framework [25]. This framework provides a practical means of separating the basic components of environmental risk into its constituent components [26]. Adopting a whole-system perspective within the Cloud to Coast framework has similar reasoning to other frameworks, such as 'source to sea' [27] and 'ridge to reef' [28]. The key difference between these frameworks is the outcome of interest, which can be environmental risk (for cloud-to-coast), ecosystem service flow (for source to sea) or suspended particulate matter flow (for ridge to reef). The SPR framework helps explore the 'whole system' that influences flood probability, the probability that flood waters will reach a particular location and the consequences for the affected system. This structured understanding of the system enables interactions to be understood, and the way risk may cascade and escalate through systems. Practical questions include: Is there agreement on what is an appropriate whole system in the context of the decisions being made? Is there a common understanding of the physical extent of the system? What are the time boundaries of the analysis? Are these spatial and temporal boundaries right? For example, if there are significant interactions across boundaries, these may need to be reconsidered.

- **An inclusive process:** An inclusive process is much more than simply 'including' stakeholders in discussions on adaptation measures. Governmental authorities should invest in 'a process of dynamic, collective learning involving those for whom an issue is of particular concern' [29]. This process should support the role of 'concerned groups' in not only problem-solving and analysis but, more importantly, meaningful participation in the decision-making process. Inclusive climate change adaptation clearly values a citizen-science process. This process should value local wisdom and public knowledge as a credible sources of expertise. Practical questions include: Are all those that may be impacted by a decision or have a role to play in the future management of flood risk (either their own or others) appropriately involved? Is their involvement purposeful and meaningful, both to the stakeholders and to the decision-maker?
- **An adaptive approach:** Developing 'adaptive capacity' is increasingly recognised as a central response to any uncertain future (associated with climate change, development and funding etc.). Various approaches to decision-making under conditions of uncertainty have emerged to support this response [30–32]. All these framings of adaptation share common attributes: they all promote a continuous process of monitoring and action that reinvigorates the classical engineering control loop of data acquisition, decision-making, intervention and monitoring. Recent decision-oriented adaptation approaches are framed within a 'pathways' metaphor to emphasise the processes change and intertemporal complexity [33–36]. However, adaptation pathways approaches applied to date mostly focus on contexts with clearly identified decision-makers, such as a governmental agency or infrastructure provider, and well-defined and unchanging goals. As a result, they generally constrain the type of responses to those that are largely in control of the defined decision-makers and hence often fail to provide the multi-actor adaptation that may be necessary to provide a whole-system response. This broader conceptualisation, recognised as pathways thinking [37], is an approach that recognises interactions between sectoral adaptation plans, vested interests and situations where values, interests or institutions constrain societal responses to change. Practical questions are: How might the future be different from today? What are the opportunities and risks? How do we reduce the risks and realise the opportunities? Where and when are the key decision points? Is innovation being given space to flourish?
- **A continuous dialogue:** Adaptive plans and priorities change in unexpected ways. Mutual learning and an iterative process of deliberation to evolve priorities and actions are central to the success of continuing to maintain societal resilience. During the continuous dialogue, the complexity and behaviour of the whole system are discussed by the stakeholders. Stakeholders will also share their respective knowledge and explore the barriers and opportunities for a resilient future. Practical questions are: How will future choices be made; who will make them? Which foundations have been laid for those future choices to remain under review, as stakeholders, preferences and experiences change?

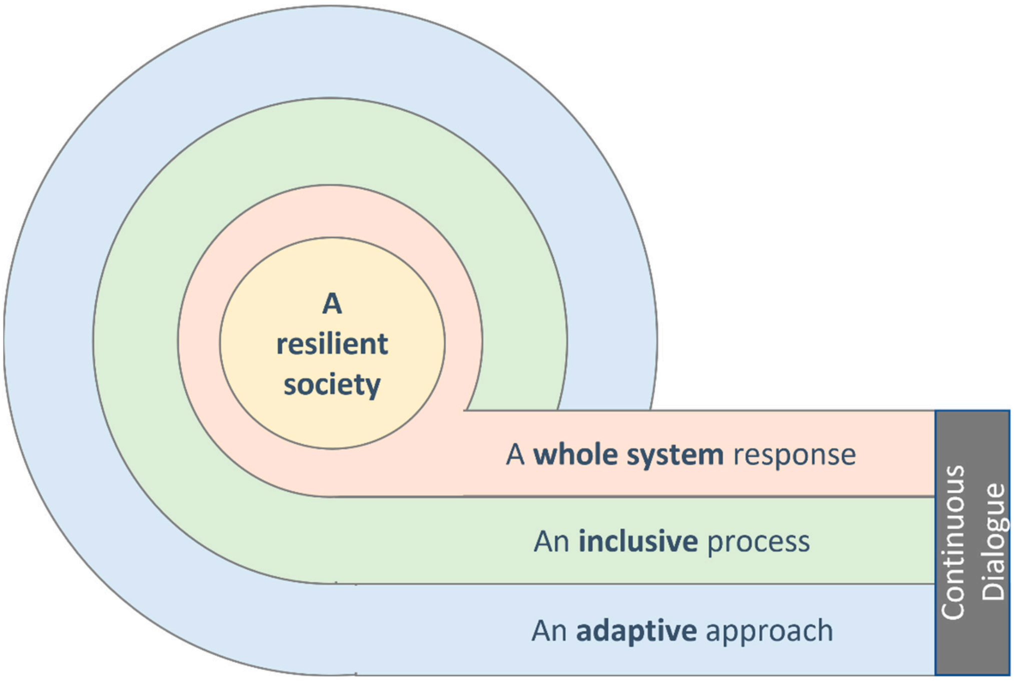

Figure 1. The four pillars of the Cloud to Coast framework to support the transition to a resilient society.

2.2. Maturity Analysis: A Tool to Measure Progress on the Four Main Pillars

The maturity of each governmental authority involved in the case studies in adopting a Cloud to Coast approach has been assessed using a maturity analysis. Maturity is a measurement of the ability of an organisation for continuous improvement in a particular discipline. One such discipline is infrastructure asset management (IAM) [38], including assets used for flood protection. Volker et al. [39] reviewed the use of maturity models in the context of IAM. They concluded that there are various types of models, but most were optimised for other domains and therefore unsuitable for IAM. Nevertheless, the maturity analysis concept has evolved from an appraisal method for software processes [40] to being widely used across a range of areas, including for IAM [41–44]. In the Interreg NSR project FAIR, the maturity analysis concept has been used by governmental authorities to consider best practices and competencies for IAM for flood protection and to understand the need for and effectiveness of the AM processes they use [45].

The C5a project has applied the maturity analysis concept to the four main pillars that underpin the Cloud to Coast concept. This application combines best practices and competences into a qualitative scale by which relative maturity of Cloud to Coast adaptation can be tested. The maturity levels for each main pillar have been defined by the researchers of the C5a project, using a five-point scale ranging from an ad hoc level to an optimised level of maturity (Figure 2). The ad hoc level represents limited experience and a reactive approach, whereas the optimised level means that an organisation is continually improving its best practices. The definitions in the Cloud to Coast maturity model are given in Table 2. These definitions are tentative and meant to be updated based on the feedback by the governmental authorities in C5a to reflect their local conditions.

The governmental authorities have evaluated their progress in evolving their existing approach to Cloud to Coast adaptation in conformity with the four main pillars to deliver a resilient society outcome. To obtain valuable insights, each authority carried out the self-assessment in an interactive session with two to four colleagues in various roles, such as a policy maker, spatial planner or community manager. This broad participation in the maturity analysis was important from the perspective of an organisation's shared responsibility for climate change adaptation.

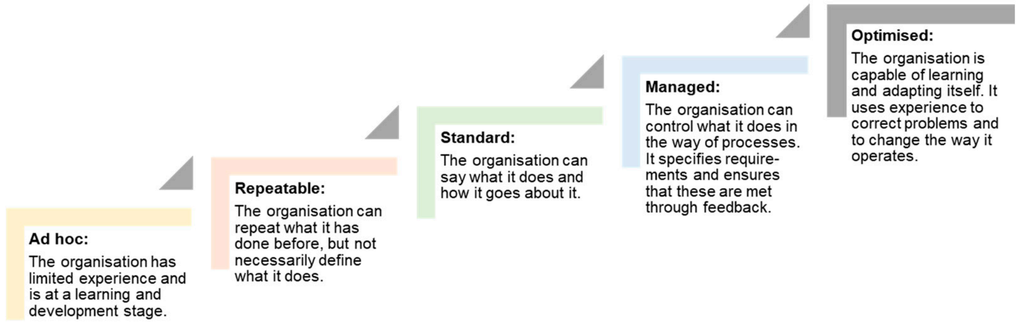

Figure 2. Five-point scale along which maturity can be increased incrementally (adapted from Williams et al. [46]).

Table 2. Cloud to Coast maturity model, using a five-point scale ranging from an optimised level (top row) to an ad hoc level (bottom row).

A Whole-System Response	An Inclusive Process	An Adaptive Approach	Continuous Dialogue
The study boundaries are adjusted—in time and space—to ensure present and future external (beyond the system) influences are limited and collaborative adaptations actively sought and implemented.	Collaborative participation and decision-making process from stakeholders and disadvantaged/vulnerable communities which facilitate collective learning, legitimacy and equitable impacts.	Multiple future uncertainties are considered and multiple adaptation pathways envisaged that maintain future optionality. The plan is updated dynamically.	New knowledge and understanding are acquired through mutual learning with other organisations in an adaptive process. The organisations involved are learning to improve the dialogue itself.
The study boundaries are adjusted—in time and space—to ensure present and future external (beyond the system) influences are limited and opportunities for adaptations by others promoted.	Participation and decision-making process that is not only from stakeholders but also from disadvantaged/vulnerable communities are representative and transparent.	Multiple future uncertainties are considered and multiple adaptation pathways envisaged that maintain future optionality. The plan is revised routinely and updated.	New knowledge and under-standing are acquired through mutual learning with other organisations, in an iterative process (that is repeated every X years).
The study boundaries are adjusted—in time and space—to ensure external influences are limited and effort made to understand the role of the adaptations by other actors.	Decision-making process from stakeholders is shared and discussed; however, the main decision is held by key stakeholders.	Climate uncertainty is represented in precautionary allowances and used to develop a single staged adaptation pathway and actions taken today to enable those stages. The plan is revised routinely and updated.	New knowledge and understanding are acquired through mutual learning with other organisations.
Potential interactions between the study area boundaries (in time and space) are discussed and recorded but little consideration given to completeness of management actions considered.	Decision-making process involves stakeholders that only offer one-way consultation to collect input, feedback and public enquiries	Climate uncertainty is represented in precautionary allowances and used to develop a single staged adaptation pathway. The plan is revised routinely and updated.	New knowledge and under-standing are acquired through learning within the organisation.
Little to no consideration is given to interactions at the boundaries of the study area or beyond the adopted time horizon. The completeness of management actions considered is not challenged.	Internal decision-making process from responsible authorities.	The future is reacted to as it happens.	New knowledge and understanding are acquired by chance.

2.3. Peer Learning Workshops: A Tool to Improve Current Practices

Despite the heterogeneity of the NSR, governmental authorities face common challenges that impede the translation of Cloud to Coast adaptation into policy and practice. Through its peer learning workshops (Figure 3), C5a created the opportunity for mutual learning between the governmental authorities. These workshops helped them to collectively identify and address the challenges for improving on the main pillars of Cloud to Coast adaptation. Peer learning offers many advantages as a tool to accelerate learning [47], some of which are relevant to co-creating the Cloud to Coast approach. For example, it can explicate systems principles—helping to separate 'the wood from the trees'. It also provides an environment for surfacing assumptions and exploring mental models outside of the normal experience of individual organisations—helping to prevent the 'not invented here' effect. However, the success in accelerated learning depends on issues such as trust building and network operating processes [47]. This requires skills around network brokerage, facilitation and benchmarking. In C5a, these skills were provided by the researchers, who took the lead in the preparation and facilitation of the peer learning workshops. For the first workshop, they collected, analysed and presented the results of the maturity analyses. This workshop hosted 19 participants (all online) from 10 organisations. It served as a validation step to ensure consistency in the interpretation of and judgement on maturity. The validated results were then used in the next peer learning workshops. By comparing the maturity per main pillar between governmental authorities, the opportunities for peer learning were identified. Accounting for mobility and travel restrictions posed by the COVID-19 pandemic, the workshops were organised online or in-person. The second workshop hosted 19 participants (of which five were online and 15 in-person) from 10 organisations and the third 13 participants from seven organisations. Each workshop started with the introduction of a prioritised learning question by the proposer, together with a good practice example presented by the responder. This was followed by a break-out session in which the involved experts had more in-depth discussions, thereby deepening the learning. This sometimes involved discussing another good practice example or showcasing a (software) tool relevant to a main pillar.

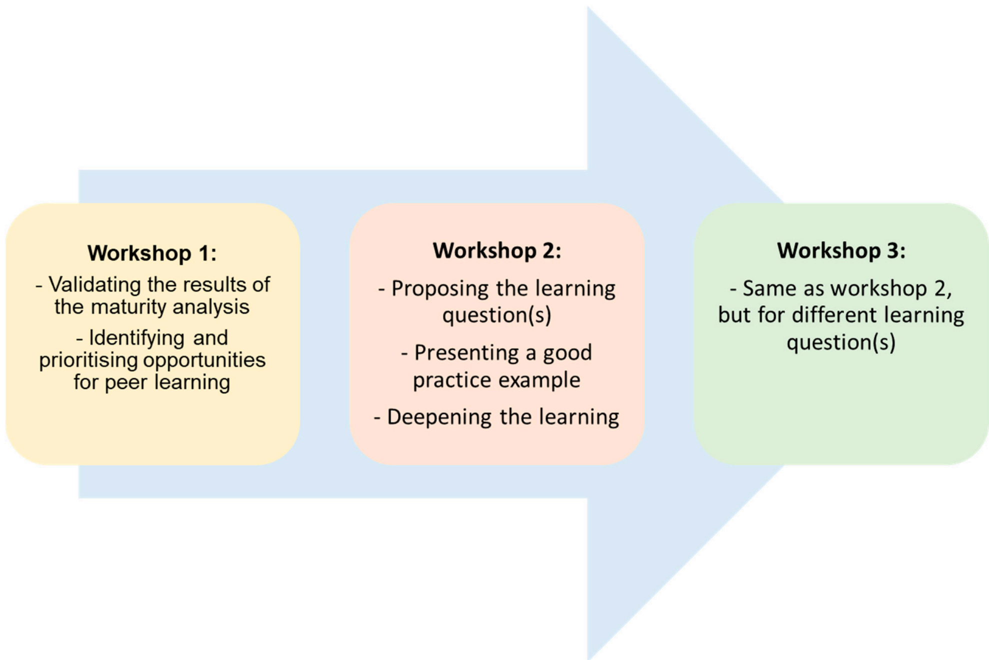

Figure 3. Design of the peer learning workshops.

3. Results

3.1. Results of the Maturity Analysis

Figures 4 and 5 show the results of the maturity analysis for the national and regional governmental authorities, respectively, involved in the C5a project. These spider diagrams illustrate the progress of evolving their existing approach to Cloud to Coast adaptation. Each diagram contains four axes for the main pillars of the approach, starting in the centre point. The distance from the centre point represents the maturity of a main pillar: the more distant from the centre, the more mature the governmental authority is on that main pillar. The extent of the coloured areas in the spider diagram represents the overall maturity of a governmental authority. The shape of the coloured areas gives some information about the potential for improvement on the main pillars.

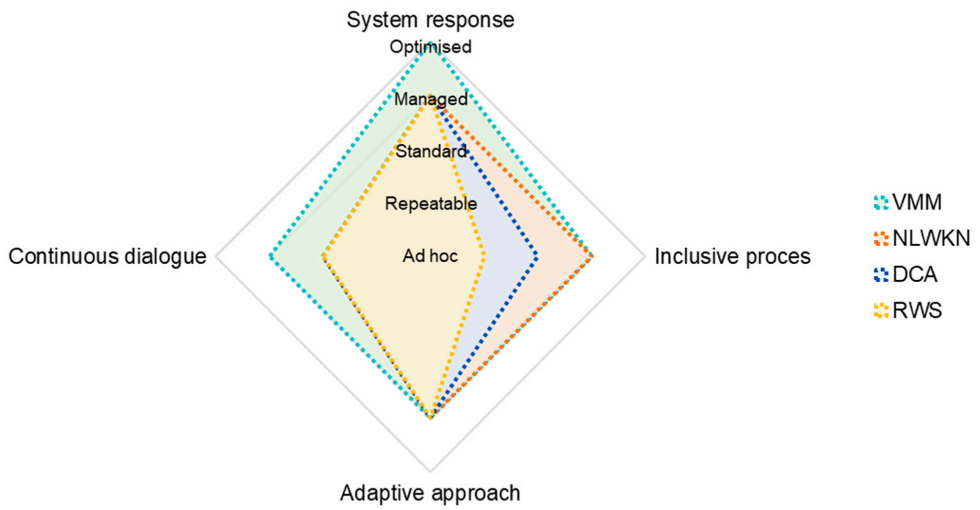

Figure 4. Spider diagrams of maturity of national and state governmental authorities.

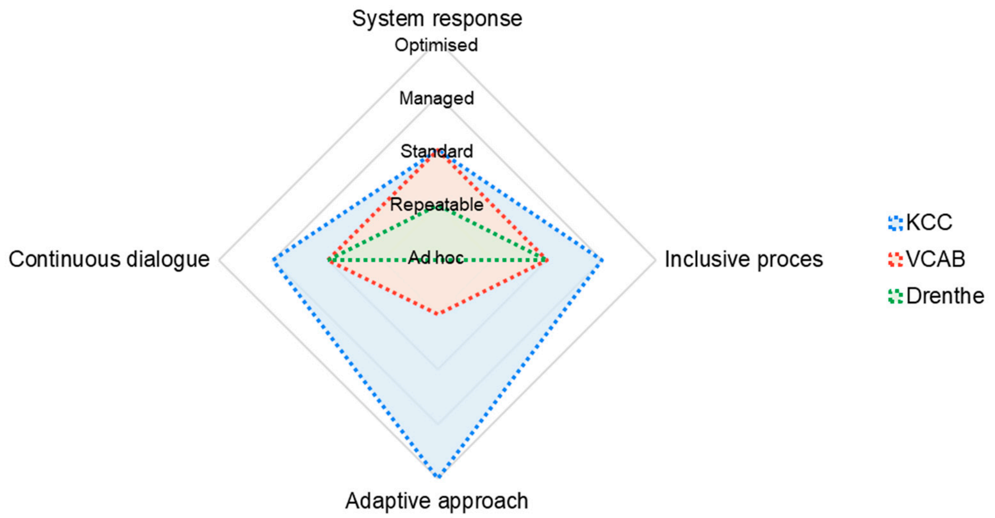

Figure 5. Spider diagrams of maturity of regional governmental authorities.

National or state governmental authorities that performed the self-assessment include the Danish Coastal Authority (DCA), Flemish Environment Agency (VMM), Lower Saxony Water Management Coastal Defence and Nature Conservation Agency (NLWKN) and Rijkswaterstaat (RWS), and the regional authorities are Värmland County Administrative Board (VCAB), Province of Drenthe (Drenthe) and Kent County Council (KCC). The results of maturity analysis highlight both the areas of complacency with the Cloud to Coast approach and the areas that are less developed and a focus for improvement. None of the governmental authorities in C5a assessed their existing approach to Cloud to Coast adaptation as fully mature. Some governmental authorities (KCC, NLWKN and VMM), though, did perceive themselves as fully mature on (maximum) one of the main pillars of the Cloud to Coast approach. KCC, NLWKN, RWS and VMM perceived themselves as well-managed (or higher) on at least two of the four main pillars. VCAB and Drenthe have the lowest overall perceived maturity levels.

3.2. Results of the Peer Learning Workshops

Four common challenges for improving on the main pillars of Cloud to Coast emerged from peer learning workshops, in which the results of the maturity analysis were discussed and taken forward. It should be noted that there is no direct overlap between the four challenges and the four pillars of the Cloud to Coast approach. Rather, each challenge encompasses more than one pillar. Other key outcomes from the workshops were the good practice examples from across the case studies. These good practices point to promising ways to address the associated challenges that hamper progress on Cloud to Coast adaptation. Below we describe each challenge and present a good practice example that shows the way forward.

3.2.1. Overcoming Challenge #1: Creating Liveable and Resilient Places

Managing flood risk is central to a resilient society, but it is not the only goal. A shift away from the local 'defence only' paradigm is needed to break the tendency to treat flood resilience and liveability as rivals. In the new paradigm, nature-based solutions and sustainability will be at the centre of flood risk management. Nature-based solutions not only mitigate flood impacts and improve adaptation to climate change but also improve the quality and living conditions of urban environments in terms of thermal comfort, biodiversity and air quality. By doing so, initiatives for climate change adaptation can become a driver to add value to public and green spaces.

- **Example #1: Creating liveable and resilient places:** In Denmark, local municipalities take the lead on spatial planning, but the landowners are responsible for flood management. Without collaboration, development can fail to take account of the current or future flood risk. In Ringkøbing-Skjern municipality, a more collaborative approach is being adopted. This approach involves raising awareness of the sources of flood and the associated risk and sharing this information with spatial planners and residents. Present and future flood risks are explained through face-to-face and digital participation processes. The communication of risk is accompanied by information and engaging animations on how individual homeowners can modify their homes to reduce their risk. It also emphasises the need for and benefits of collective action to reduce flood risk to the community. Thereby the collaborative approach enables development that can deliver better places for the community and manage risk.

3.2.2. Overcoming Challenge #2: Flood Risk Is Dynamic in Space and Time

The spatial and temporal dynamics of flood risk respond not only to climate change but also to planning decisions across various sectors, such as urban planning, nature conservation and agriculture. Flood risk should therefore not be considered in isolation from other water management functions. Instead, it must be addressed within the wider framework of integrated water resource management. Under this framework, the catchment must be considered as a dynamic system in which the land, surface water and groundwater interact. There is a need for knowledge integration platforms to help understand these interactions.

- **Example #2: Recognising flood risk is dynamic in space and time:** In Klarälven (SE), the C5a workshops have brought stakeholders together to discuss their ambition and concerns in addressing climate change impacts on the river and the sectors that depend on the river. Through the workshops, stakeholders gained new knowledge on threats and opportunities and new insight into much of their work is connected. Tangible changes in perspective emerged from this collaborative process. There is now broad recognition of the advantages of using a whole-system approach. New types of multi-functional measures were identified and discussed for the first time. The stakeholders who participated in the C5a workshops testified to the benefits they observed from the process, particularly when it comes to social or governance aspects.

3.2.3. Overcoming Challenge #3: Confrontations May Lead to Overall Reduced Benefits

The policy sectors that relate to climate change adaptation, such as water, land use, agriculture and nature, start the dialogue from their sectoral perspective and often from a particular stakeholder perspective. A change of perspective and an understanding of other interests is necessary to acknowledge different interests as legitimate and to open space for compromises. In the adaptation dialogue, stakeholders should recognise that individually they may not be able to achieve all their original objectives. Otherwise, the dialogue could result in confrontations that may lead to overall reduced benefits.

- **Example #3: Recognising and addressing conflicts to increase overall benefits:** De Staart, a neighbourhood in Dordrecht (NL), can be developed as an attractive residential work area and a large-scale, self-sufficient shelter. The municipality organised meetings with stakeholders who have an interest in the future of De Staart. These meetings were structured according to the 'Green Circles' method. This starts with formulating a shared dream for the area: the future vision. This vision incorporates knowledge, wishes and interests of the parties in the circle, such as companies, residents and public and social organisations. The vision is then translated into projects that help to realise that dream. In addition, parties are identified who will benefit from the realisation of the future vision. It can be interesting for those parties to invest in projects. However, not all imaginable projects can be implemented in the short term. Therefore, the municipality wants to start with the quick-win projects, such as greening linked to sewer works, as a step towards an attractive and healthy neighbourhood. If these projects prove successful, they give positive energy to tackling subsequent (more expensive) projects.

3.2.4. Overcoming Challenge #4: Adequate Decision Support Is Rarely in Place

Delivering a resilient society requires more than simply an ambition. The multilevel character of decisions must be supported not only by knowledge, evidence and tools but also by adequate planning, legal and financial frameworks to enable implementation. This, however, is rarely in place. Planning typically lacks the latest climate science, and investment rules fail to support more contemporary approaches to flood management. Moreover, it increases governance complexity and the likelihood of negative interplay, where actions taken in one policy sector hinder those in another. For citizens, it may become difficult to assume responsibility when being part of overlapping areas of decision-making.

- **Example #4: Providing meaningful decision support for flood risk changes and influence:** Within Kent (UK), the Future Flood Explorer (FFE) [48] provides a window into present day flood risk, including not only economic damage but also social vulnerability [49], and how these risks may change with 2 and 4 °C rises in global mean surface temperature, low and high socioeconomic growth projections and the benefits and costs associated with alternative adaptation portfolios. By exploring a wide range of alternative adaptation portfolios (including a continuation of current policies as well as an enhanced and reduced adaptation effort), the FFE enables a portfolio-based optimisation of investment, taking into account how the risks and the benefits of adaptation vary across Kent (Figure 6). In doing so, the Kent Future Flood Explorer illustrates how robust adaptation choices can be made that work well across multiple futures. It helps provide the 'push' to action by providing evidence on the present and future flood risk given alternative pathways.

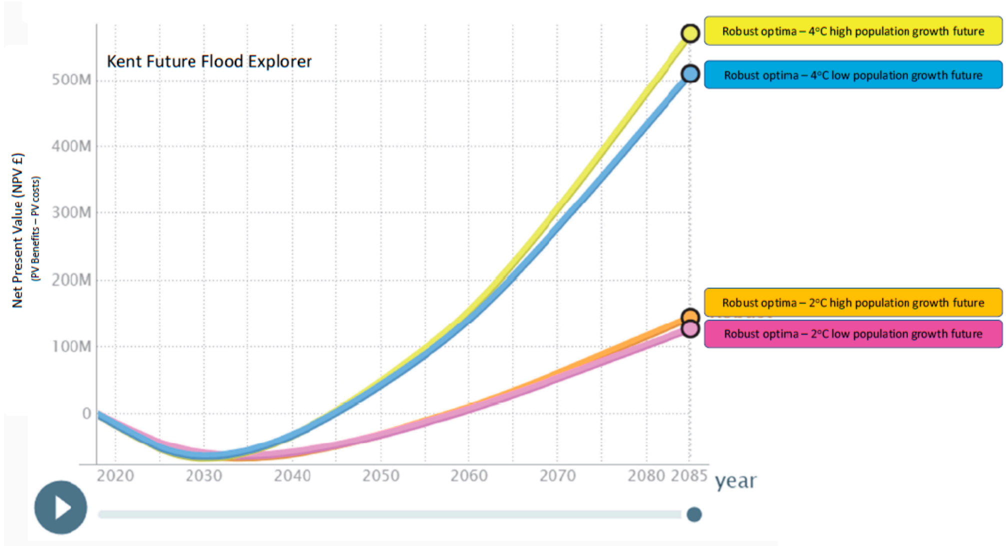

Figure 6. Robust optimisation of alternative flood risk management adaptation portfolios in Kent using the Kent Future Flood Explorer. Note: An optimisation of the net present value through to 2085 based on the identification of the adaptation portfolios delivering the greatest minimum NPV across all alternative futures.

4. Discussion

4.1. Reflection on the Cloud to Coast Framework

The Cloud to Coast approach promotes the adoption of a whole-system and long-term perspective on climate change adaptation and is purposeful, collaborative and builds on the principles of social justice and ecosystem health. The approach provides an 'actionable framework' to identify adaptation pathways to managing flood risk and creating a sustainable environment. The framework is flexible and can be readily adapted to reflect a particular context. Central to this flexibility is the use of a risk-based approach [25]; risk provides a common framework that can be interpreted and translated to any decision context. Similarly, a Cloud to Coast framework has utility for all those involved in the management of the flood risks by encouraging a common approach—rather than providing a prescriptive procedure or (software) tool. This does not imply that Cloud to Coast requires no supporting (software or guidance) tools or evidence; it does. Such tools can be bespoke to the decision at hand without compromising the Cloud to Coast framework. The Cloud to Coast framework also helps to guide interactions between sectors, organisations and processes involved with managing the flood risks. This is reinforced through the recognition of the need for a continuous dialogue between all those involved with climate change adaptation and the guidance provided on how to facilitate this.

4.2. Reflection on the Cloud to Coast Maturity Model

Although the four pillars of the Cloud to Coast approach were developed through co-creation, the public authorities found it difficult at first to apply the pillars in the context of their case studies. To overcome this difficulty, the maturity model was developed to accompany the approach. The definitions of each main pillar helped the authorities to consider best practices and competencies for that pillar. Moreover, their involvement in refining the definitions pushed them to critically reflect on their own practices. The results (i.e., the spider diagrams) of the maturity analyses highlighted that there were clear differences in current approaches to Cloud to Coast adaptation. This has helped to inform the opportunities for mutual learning between governmental authorities, which is a significant benefit of the maturity model. Notwithstanding this particular benefit, a critical observation should be made about the observed differences in maturity. That is, the results necessarily give a perception of maturity, which may or may not reflect reality. These perceptions are subject to the pitfall of governmental authorities '*not knowing that* *they did not know*' [50]. Given this (methodological) limitation, the real value of the results for driving improvements in Cloud to Coast adaptation lies in the intercomparison of maturity on the four main pillars for a given governmental authority. This intercomparison allows that authority to understand where there may be grounds for improvement in their current approaches.

4.3. Reflection on the Peer Learning Workshops

Through the maturity analysis, the participating authorities identified the areas for improving their own adaptation practices using the Cloud to Coast approach.

Peer-to-peer learning workshops facilitated this process in several ways. First, the interpretation of the maturity analysis of each authority was validated by discussing them with other authorities. Second, a transnational knowledge exchange took place on the similarities and differences between the maturity levels, which led to the identification of common challenges and good practice examples. Third, the examples and other practical insights on maturity levels provided opportunities for mutual learning between governmental authorities. Despite the mobility and travel restrictions and other disruptions caused by the COVID-19 pandemic, most of the project partners were able to join the online or in-person workshops. While the resilience of partners in maintaining their participation is acknowledged, peer learning could be enhanced by in-person discussions.

4.4. Future Directions for Policy, Practice and Science to Enable Cloud to Coast Adaptation

Setting the future direction is essential to support the transfer of the Cloud to Coast approach to policy and practice. Drawing upon the peer-to-peer learning workshops, the pilot applications and evidence from the support Interreg Programmes (including the FAIR policy brief [51]), key insights have emerged to advance progress. The four policy directions are outlined below (Figure 7), and each will need to be continuously evolved as scientific advances are made, and practice is monitored.

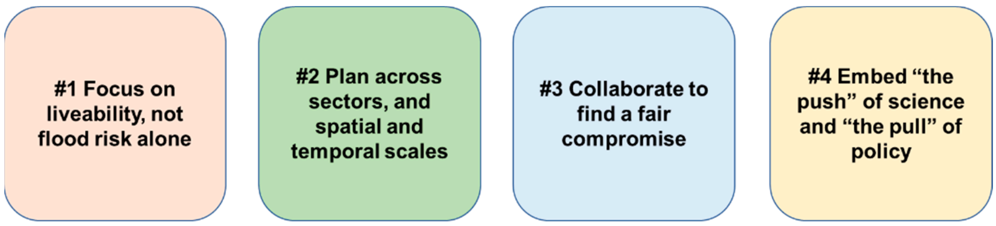

Figure 7. The four policy directions to support the adoption of a Cloud to Coast approach.

4.4.1. Direction #1: Focus on Liveability, Not Flood Risk Alone

Adaptation efforts should utilise place-making responsibilities to drive the work for people and nature in the short and long term. Successful adaptation brings together issues of place-making through spatial planning, investment, aesthetics, acceptable risks and more. Place-making involves transforming public spaces to strengthen the connections between people, places and nature. It is centred on people and their needs, desires and visions. Though often not a priority for people, flood management can be a positive force in creating liveable and resilient places that provide multiple functions.

4.4.2. Direction #2: Plan across Sectors and Spatial and Temporal Scales

Resilient society outcomes are best supported by collaborative approaches that contribute across sectoral perspectives, link upstream and downstream actions and connect the short term with the long-term. Emphasis should be on proactively reaching out across sectors to seek solutions that provide benefits to meet multiple needs and can be adapted as the reality of the future becomes known. Whole-system shared models and open platforms to share objectives, concerns and ideas are necessary to enable organisations to span conventional disciplinary boundaries and sectors and seek innovative solutions that deliver multiple benefits. They provide key support in finding solutions spanning multiple sectors.

4.4.3. Direction #3: Collaborate to Find a Fair Comprise

Consensus building is necessary to achieve the bigger goal of an adaptive system. In this mode, the stakeholders seek to make mutually advantageous compromises for adaptation. They co-create solutions that go beyond individual objectives. This solution has added value because it fulfils most individual interests when win-win outcomes are not possible. With this comes the need to ensure that decision frameworks and funding arrangements enable fair compromises between the involved stakeholders.

4.4.4. Direction #4: Embed 'the Push' of Science and 'the Pull' of Policy

Science and evolving policy goals at community and regional levels should jointly drive the widespread implementation of flood resilience. Future policy needs to enable multilevel governance mechanisms of mainstreaming flood resilience. Enabling flood resilience is always context-specific, which requires interconnectedness across spatial and temporal scales of climate risks. This can present complex challenges and requires advances in science and policy to co-evolve. Bringing forward innovations rapidly into practice is needed to respond to goals of social and economic equity and enable and encourage community-led solutions. To do so, a proactive effort is needed to enable the collaboration between the 'push' of the science and the 'pull' of the policy.

5. Conclusions

The combination of research, good practice and peer-to-peer learning explored through this paper highlights 'resilience' as an outcome; an emergent property of the system that is appropriately prepared and protected and capable of adapting and transforming our social and physical geographies to the future change. Successfully enabling 'resilience' requires a change in our approach to the management of flood risk, one that is more than simply a rebranding of conventional concepts and approaches. The Cloud to Coast framework offers guidance to support the transition towards a new approach.

Based on experience across the North Sea Region, four core attributes of the planning process are highlighted as central to making progress, namely: A whole-system response requires us to challenge our own 'silo' and become 'system thinkers'; the adoption of an inclusive approach that includes more than 'including' stakeholders in discussions, engaging and prioritising the outcomes for the most vulnerable; the adaptation of an adaptive approach that requires us to explore an uncertain future and to develop plans that make sense given that future; and the maintenance of continuous dialogue to adaptive plans and priorities as our understanding develops.

To mainstream the framework into practice, the paper sets out four 'directions' that present the change in perspective (applicable to any decision) that, if adopted, is necessary (although not sufficient alone) to reset the framing of flood risk management towards a more strategic Cloud to Coast approach.

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