Operationalising Coastal Resilience to Flood and Erosion Hazard: A Demonstration for England

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Abstract

Resilience is widely seen as an important attribute of coastal systems and, as a concept, is increasingly prominent in policy documents. However, there are conflicting ideas on what constitutes resilience and its operationalisation as an overarching principle of coastal management remains limited. In this paper, we show how resilience to coastal flood and erosion hazard could be measured and applied within policy processes, using England as a case study. We define resilience pragmatically, in economic, environmental and social terms, integrating what is presently a disparate set of policy objectives for coastal areas. Our definition includes several dimensions of resilience and we develop a set of composite indicators for each of these, grounded empirically with reference to national geospatial datasets. A prototype model has been developed, which generates a quantitative resilience index for a given geographical unit (England's coastal hazard zone being represented at a high spatial resolution, about 8,000 areal units). A range of different stakeholder perspectives are captured using relative indicator weightings. The illustrative results presented here demonstrate the practicality of formalising and quantifying resilience, and the insights obtained mainly concern this process of operationalisation. To re-focus national policy around the stated desire of enhancing resilience to coastal flooding and erosion would require firm commitment from government to develop an approach to monitor progress towards resilience, extending the present risk-based approach. This requires a consensus methodology in which stakeholder values are explicitly considered, and also requires incentives for coastal managers to engage with and apply this new approach. Such a transition would challenge existing governance arrangements at national and local levels, requiring more integration and inter-agency cooperation. However, it could provide a robust evidence-based framework for achieving more sustainable, equitable and societally acceptable adaptive responses to climate change at the coast.

Keywords

Adaptation pathways, policy, management, resilient communities, socio-economic resource allocation

1. Introduction

There are at least two perspectives on resilience, one deriving from dynamic system theory and another a conceptual framework for system management. Resilience is widely viewed as an important attribute of natural systems (Holling, 1973; Pimm, 1991; Walker and Salt, 2006), including those at the coast (Klein et al., 1998; Bernhardt and Leslie, 2013; Masselink and Lazarus, 2019), where it is starting to emerge as an overarching policy goal of strategic management and planning (Rosati et al., 2015; Sheaves et al., 2016). Resilience is also well established as a framework for managing socio-ecological systems (Paton et al., 2000; Adger et al., 2005). Examples include disaster management and emergency planning, as exemplified by the development of resilience-based coastal management programmes focusing on major disasters (Kim et al., 2014; USACE, 2014; Kress et al., 2016). Increasing interest in resilience also reflects the need for more holistic perspectives that capture the complexity of climate change impacts on coupled ecological, geomorphic, socio-economic and engineered infrastructural systems (Park et al., 2011; Sheaves et al., 2016). However, operationalisation of resilience as a basis for strategic coastal management remains at an early stage.

The convoluted history of resilience as a concept (Alexander, 2013) has stimulated a lively academic discourse on inconsistencies in its definition (Klein et al., 2003; Haimes, 2009), the validity of some of the underlying assumptions regarding stability and equilibrium in ecological and geomorphic systems (Piégay et al., 2018; Masselink and Lazarus, 2019; Kombiadou et al., 2019), and their transferability from natural to human systems (Chaffin and Scown, 2018). It might also be argued that the development of quantitative resilience-based approaches to coastal management has been inhibited by the success of quantitative risk assessment (Linkov et al., 2013) and by the application of risk-related concepts in the realm of resilience (Park et al., 2013).

In this paper, we move beyond these debates to engage with the more pressing problem for coastal policymakers: how to quantify resilience in a way that is useful for strategic coastal management. The conceptual foundations for resilience predate widespread understanding of the environmental impact of humans, especially at the coast. Most analyses of coastal resilience have focused on a small number of state variables used to track the behaviour of specific ecological or geomorphic systems (e.g. French, 2006; Orford and Anthony, 2011; Houser et al., 2015; Chambers et al., 2019). Quantifying the resilience of complex systems that incorporate a multitude of physical, biotic, social and economic components and behaviours presents a greater challenge (Haimes, 2009). Using England as a case study, we demonstrate a practical method of measuring resilience for use in coastal management. This has the potential to inform policy processes at multiple space and time scales. Any measure of resilience will incorporate a subjective element given that the conceptualisation of the systems and the choice of individual indicators will vary, according to the goal or process that managers set. We show that this can be turned into an advantage by using the relative weightings of a set of indicators to represent different stakeholder perspectives in a transparent way, while acknowledging that these weightings may differ according to different stakeholder views.

2. Current Coastal Management in England

In England, strategic coastal management for erosion and flooding emerged in the 1990s with the adoption of a shoreline management approach to coastal flood and erosion risk in the context of regional-scale coastal processes (Nicholls et al., 2013). Shoreline Management Plans (SMPs) select from a small set of mutually exclusive high-level policy options for risk management focusing on coastal defence. These have changed over time; the current set of options are: Hold the Line (maintain the present shoreline); No Active Intervention (take no further action to actively manage the coast); Managed Realignment (actively allow coastal retreat and often promoting the return of nature to coastal areas); and Advance the Line (actively move the current shoreline seaward). In the 1990s, the first generation of 44 SMPs were produced for the coast of England and Wales. In the second iteration, these were consolidated to 22 SMPs covering the entire coast of England and Wales (Nicholls et al., 2013). The SMPs continue to be reviewed and updated with the third and latest “refresh” ongoing at the time of writing to accommodate changes that have arisen since their production, and to consider: adaptation on dynamic and eroding coasts, links to land use planning (e.g., DEFRA, 2012; 2018), and the challenges this raises (e.g., Fisher and Goodliffe, 2020).

Climate change, particularly sea-level rise, is increasing the pressures at the coast and is already driving policy change. An investigation by the UK Committee for Climate Change (CCC, 2018) found that some coastal communities and infrastructure will almost certainly become unviable in their current form and that the policy options envisaged in the current SMPs will become unaffordable over current planning horizons. In particular, substantial lengths of coastal frontage will be undefendable at any reasonable cost and 71% of management units (accounting for 29% of the English coastline) with a policy of 'Hold the Line' will achieve a cost-benefit ratio well below the current funding threshold over this timescale. Major transitions in policy will be needed and one of the biggest challenges is to develop a strategy that is sustainable, equitable and addresses societal pressures as well as natural system perturbations (Bostick et al., 2017).

Resilience as an overarching goal is increasingly prominent in English policy documents (notably Defra, 2015, 2018; HMG, 2016; EA, 2019). Unlike the USA, where coastal management is now founded on a clear and pragmatic definition that embraces multiple facets of resilience (Rosati et al., 2015), national policy statements on coastal resilience in England are far less clear. Resilience is defined inconsistently and with variable clarity and, as noted more generally by Pimm et al. (2019), has all the hallmarks of an 'ideology' rather than a robust framework based on rigorous theory and quantitative evidence. A content analysis of recent policy documents for England (Supplementary Material S1 and Table S1) lends support to this view.

3. Reframing resilience for coastal management: a pragmatic approach

Like sustainability, resilience is an elusive concept, albeit one that is attractive to policymakers (Sidle et al., 2013; Fekete et al., 2019). We have adopted a pragmatic approach to measuring resilience, and draw on recent work by the US Army Corps of Engineers (USACE) and others (Linkov et al., 2014; Rosati et al., 2015; Kress et al., 2016; USACE, 2018) that frames resilience-based management at national, regional and local project levels.

In formulating our approach, we acknowledge that there can be no absolute notion of coastal resilience as it crosses diverse knowledge domains and traditions and objective single metrics are not possible (Haimes, 2009). Instead, we sought a broad definition that encompasses some of the traditional elements of resilience such as the ability of a system to rebound following a shock, as well as aspects of resistance that underpin risk-based coastal management (which emphasises protection against external flood and erosion hazards). Other definitions are clearly possible, and there is much scope for variation in the detail. There is also potentially an inherent conflict within any system, where a gain in resilience for some part(s) may result in a loss of resilience for others. Resilience seeks to optimise the processes that sustain the system and this requires balancing social gains and losses, ideally through consideration of multiple societal preferences (Adger, 2000; Kim and Marcouiller, 2020). Accordingly, we argue that it is not the precise definition that matters, but that a clear, pragmatic and consistent process is followed throughout an analysis. The context is important here and it is essential that the conceptual definition adopted should be framed by the questions ‘resilience against what?’ and ‘resilience for whom?’

For these reasons we adopt the USACE definition (Rosati et al., 2015). This defines resilience as “the ability of a system to prepare, resist, recover, and adapt to disturbances in order to achieve successful functioning through time”. In the context of coastal hazards, this draws upon the conceptualisation of Linkov et al. (2014) (Figure 1a) as a cyclical sequence of actions catalysed by successive ‘events’. This view of resilience incorporates the protective actions that have traditionally underpinned coastal engineering approaches to erosion and flood risk management as well as more dynamic adaptive responses to evolving hazards and is therefore well-suited to our purpose.

Delivering resilience in practice requires a transition from the present largely qualitative notion to a quantitative evidence-based framework. As Cai et al. (2014) observe, a minority of disaster resilience studies are founded on quantitative measures, and only a subset of those attempt any empirical validation of those metrics. The coastal systems of interest here extend beyond individual geomorphological and ecological systems to a complex interplay between landform systems and their associated ecosystems, socio-economic systems and engineered infrastructural systems. The principal hazards are also compound in nature, dominated by flooding and erosion phenomena that interact, but also exhibit different spatial and temporal footprints. We thus must capture the state of a set of coupled sub-systems that are typically described in different ways and from fundamentally different perspectives. The challenge of how best to adapt to climate change and evolving hazards at the coast can thus be viewed as a ‘wicked problem’ in the sense of Rittel and Webber (1973) and Brown et al. (2014). Whilst this is already acknowledged in existing coastal management decision-making processes to some extent, it does greatly complicate the operationalisation of a quantitative resilience-based approach.

Returning to the questions concerning ‘resilience against what’ and ‘for whom’, we reason that the coast has a state of resilience that depends on a complex set of interactions. We do not seek, or need, to define this in any absolute sense. From a management, or policy, perspective we simply need to identify those actions that will enhance the state of resilience. For this we define a set of objectives, which encapsulate actions that maximise the capacity to cope or minimise the potential for loss. The objectives we have used are summarised in Figure 1b. As our context is coastal flooding and erosion, the objectives will have a different focus for these two forms of hazard. This translates into different measures to assess what is changing and appropriate responses for each hazard. For example, whilst it may be possible to protect assets from repeated flooding, it may only be possible to delay rather than halt erosion. Any framework to measure and use resilience to develop a policy response, therefore, needs to be flexible enough to encapsulate these differences.

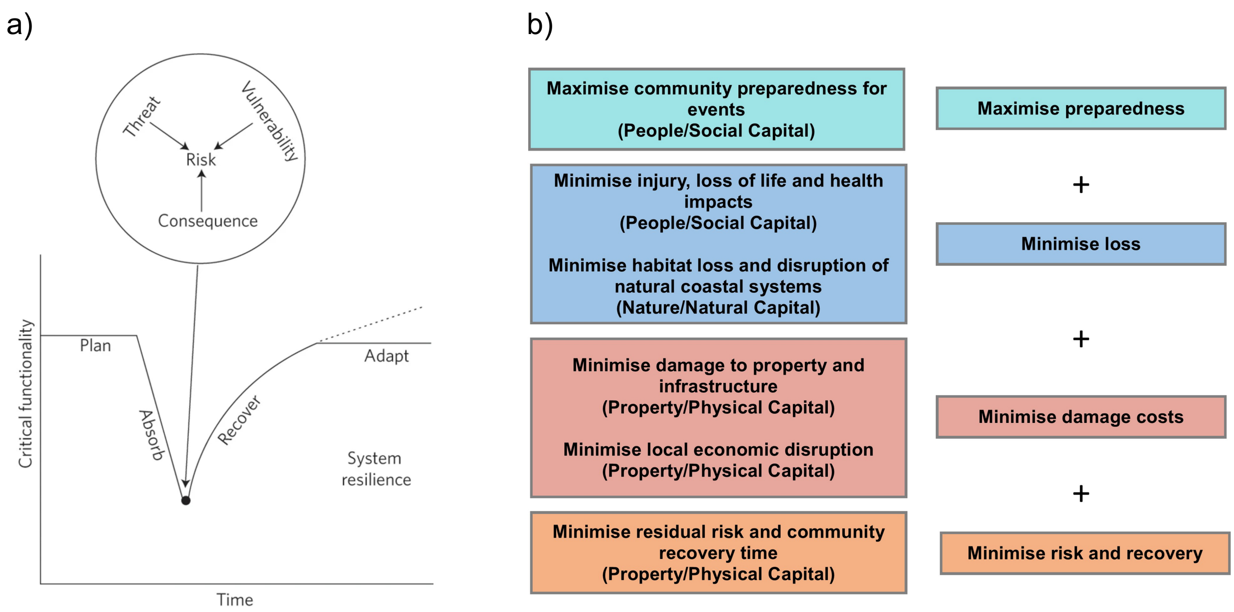

Figure 1: a) Generalised resilience management framework that includes risk analysis as a central component (reproduced from Linkov et al., 2014). The dashed line shows that a resilient system can adapt such that its functionality may improve with respect to its initial state, enhancing system resilience to future adverse events; b) Objectives that serve to enhance coastal resilience by maximizing the capacity to cope and minimizing the potential for loss.

Formal evaluations of coastal resilience have typically relied on expert elicitation as a way of achieving a scientific consensus based on knowledgeable opinions (e.g. Thorne et al., 2015; Sanderson et al., 2016).

However, the growing availability of open geospatial datasets means that data-driven resilience assessments are now a practical possibility (Rumson et al., 2019; Shamaskin et al., 2020). Numerous studies have already applied statistical analyses to multivariate measures of exposure and vulnerability that can be considered indicative of resilience within coastal communities (e.g. Hummel et al., 2018) and infrastructure (e.g. Brown et al., 2018). However, resilience is a broader concept than vulnerability and risk and, as Linkov et al. (2013) argue, must be analysed with bespoke methods that are complementary to, but also distinct from, those developed for risk analysis. Cross-disciplinary exchanges of ideas can be extremely valuable and Linkov et al. (2013) draw on military theory to map four resilience 'domains' (physical; informatic; cognitive; social) onto a four-stage event management cycle (plan/prepare; absorb; recover; adapt). Essentially the same conceptualisation has subsequently been adopted by the USACE (Rosati et al., 2015). The 'cells' of this 4 x 4 matrix guide the specification of individual resilience metrics and the whole matrix provides a transparent connection between resilience policies and likely outcomes (Linkov et al., 2013).

In contrast, our concept of resilience (Figure 1b) is less tied to a disaster event management cycle but similarly defines an interface between the different resilience domains (natural, physical, social and economic capital) and key policy goals (maximisation of preparedness and minimisation of loss, damage costs, risk and recovery time). The next step is to operationalise this conceptual model of resilience and its associated policy options with a set of data-driven metrics. Multivariate geospatial datasets are already widely used in coastal vulnerability assessments (e.g. Ramieri et al., 2011; Christie et al., 2018), including those that explicitly cite resilience as a policy goal (e.g. Shamaskin et al., 2020). The extension of these analyses to encompass a wider range of resilience-related measures has become feasible with the growing availability of open datasets that provide insights into not just the geographical variation in hazards but also their consequences for coastal systems (Rumson et al., 2020).

4. Operationalising the Method

Although resilience has often been conceptualised with reference to systems in a single domain (e.g. ecosystems or infrastructure systems), coastal resilience is a composite property that emerges from the interplay of diverse natural and human systems. Quantitative resilience-based coastal management offers many advantages over more narrowly focused risk-based analyses of vulnerabilities and likely losses (Linkov et al., 2014), but operationalising it to support coastal management encounters the problem of reconciling measures defined for these very different domains. At one level, theoretical analyses imply that the overall resilience of complex and composite interacting systems subject to multiple, compounded, hazards is in principle unknowable (see, for example, Haimes, 2009). Moreover, there are many possible conceptual models of resilience, depending on how society chooses to define the system and the problem. Recognising these challenges, we have pursued an approach that is grounded in current capabilities, whilst acknowledging the shortcomings and hence potential to develop the approach further.

To implement a framework for decision making, we adopt a method that is supported by a model to quantify the current state of coastal resilience and how this might change over time. We first outline the steps needed to establish the framework, before detailing the model developed to provide a quantification of the state of coastal resilience.

4.1 Decision-making framework

The initial steps in developing a policy or decision-making framework revolve around clarity of purpose, identification of the options available for implementation, and clear performance measures. Therefore, the first steps needed to develop coastal resilience policies can be summarised as:

1. Establish the decision-making context (policy aims, decision-makers, key stakeholders).
2. Identify clear objectives that are specific, measurable, agreed, realistic and time dependent (i.e. SMART).
3. Define the available options that can realistically address the objective(s).
4. Design a method to evaluate likely outcomes and measure performance.

Table 1: Summary of objectives and sub-objectives.

High level agendas	Coastal Resilience Objectives	Sub-objectives
Human health	Maximise human health	Minimise (i) loss of life, (ii) injury, (iii) health impacts
Human assets	Minimise damage	Minimise damage to (i) property and (ii) infrastructure
Residual risk	Minimise response time	-
	Minimise recovery time	-
	Minimise displacement	Minimise for (i) flooding and (ii) erosion
Economy	Minimise damage to economy	Minimise (i) local and (ii) national damage (including supply chain impacts)
Natural assets	Minimise habitat loss	-
	Minimise disruption of natural systems	-
Community preparedness	Maximise preparedness	Use (i) warnings and awareness, (ii) monitoring and maintenance
	Minimise exposure to risk	Minimise exposure by (i) avoidance, (ii) protection, (iii) limiting residual risk, and (iv) limiting financial impact
	Maximise social acceptance	-

The context of coastal flood and erosion hazard in England was outlined in Section 2 and concerns the need to reduce overall risk, where possible, but where this is not possible, to adapt to enhance resilience. Within this context a set of illustrative objectives were defined. The starting point is the well-established objectives used for SMPs, which are intended to ensure the protection of people and property from flooding and coastal erosion, albeit with a range of supplementary concerns (e.g. relating to the environment and social deprivation). Whilst the focus remains on flooding and erosion, the objectives are broadened to consider not simply protection but a range of other objectives that contribute to greater resilience of the combined system of natural, built and social components. These objectives are presented in terms of system functions that need to be maximised or minimised in order to enhance resilience in Table 1. Each high-level objective relates to one or more coast-specific objective, each of which may be elaborated with sub-objectives.

Our emerging coastal resilience framework is not a substitute for risk management but can be explicitly aligned with existing coastal risk management policy options and related governmental priorities. To do this, we develop policy options that seek to encapsulate the wider scope required for adaptation. Table 2 summarises the current strategic policy options used for SMPs, and how these relate to a broader set of adaptation options (Defra, 2018) and resilience tools (EA, 2019), which are derived from work by Burton (1996) and Cimato and Mullen (2010). The Defra adaptation options are high level and generic but are generally consistent with the resilience principles defined in Figure 1b. The EA resilience tools cover a mix of specific (e.g. flood walls) and vague (e.g. innovation) approaches. The final column of Table 2 presents a set of resilience-focused policy options produced by the UK National Environmental Research Council (NERC) funded 'CoastalRes' project (Townend et al., 2020) that is the focus of this paper. These policy options are intended to integrate the current SMP options into a set of non-mutually exclusive policy options that, taken together, could be used to deliver the enhanced coastal resilience that is envisaged by current policy statements (CCC, 2018; EA, 2019). Crucially, the resultant set of strategic policy options are all framed around existing, well established, government agency activities.

Table 2: Current strategic policy options used within the SMPs in England, separate sets of adaptation options (DEFRA, 2018) and resilience tools (EA, 2019), and a set of derived resilience–focused policy options that build on existing government agency activities.

SMP Policy Option	Defra Adaptation Options	EA Resilience Tools	CoastalRes Resilience Policy Options (applied in this paper)
• **Hold the line** • **Advance the line** • **Managed realignment** • **No active intervention**	• Preventing losses • Tolerating losses • Spreading or sharing losses • Changing use or activity • Changing location • Restoration and replacement	• Flood walls • Coastal infrastructure • Natural flood management • Property flood resilience • Flood forecasts and warning • Sustainable drainage systems • Evacuation • Recovery • Land management • Spatial planning • Innovation • Moving people to new places	• Land use planning • Catchment management planning • Coast protection (erosion and flooding) • Flood and storm proofing • Emergency planning • Storm forecasting, monitoring and warning services • Recovery and restoration • Habitat creation (space for water) • Socio-economic regeneration

4.2 Quantification of Coastal Resilience

The final step in the method outlined, step 4, involves the measurement of coastal resilience. This is needed to support planning, where likely outcomes need to be assessed, and during implementation, to measure ongoing performance. The focus is therefore on the state of the system at any point in time. This requires a conceptualisation of the system of interest in order to define relevant measures that contribute to the defined objectives (step 2). Integrating the various measures defines the present state of resilience, and projecting how the measures may change over time provides a forecast, or scenario testing, capability. This is the basic workflow used to establish the Coastal Resilience Model (CRM) (Figure 2), as elaborated in more detail below. In essence, we map the multi-variate performance measures over the flood and erosion hazard zone and combine these measures to create a resilience index. This defines a state of the system. To evaluate changes in time we use scenarios to model the impact of external drivers (e.g. climate change, land use, etc.) and the likely response to selected policy options (e.g. emergency planning, socio-economic regeneration, etc.). The process of integrating the various performance measures entails a subjective weighting and we use this to incorporate different stakeholder perspectives and thereby provide a more nuanced characterisation of the state of resilience that reflects the inherent heterogeneity of societal perspectives.

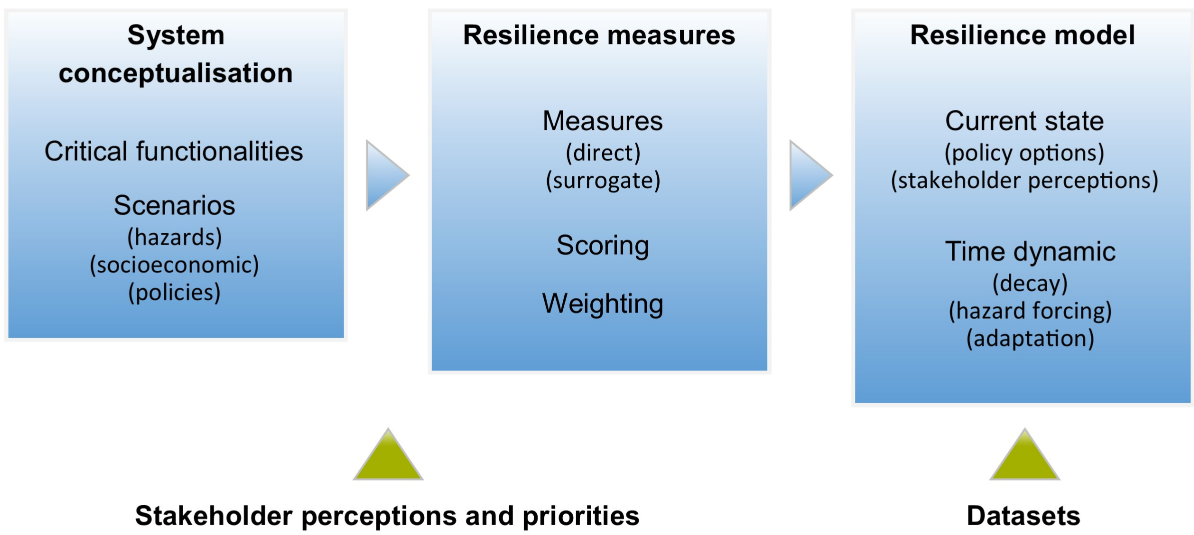

Figure 2: Workflow for development of the prototype Coastal Resilience Model (CRM) based on Multiple Criteria Analysis (MCA) with explicit representation of (i) stakeholder perceptions and priorities and (ii) timelines of change and pathways of adaptation.

Various approaches have been developed for the assimilation of inconsistently quantifiable multivariate data. Of these, Multiple Criteria Analysis (MCA) (Keeney and Raiffa, 1976) has proved especially useful as a way of supporting decision-making processes by considering multiple and diverse criteria within a structured methodology. Various forms of MCA have been applied in areas such as coastal vulnerability assessment (Viavattene et al., 2018., Sekovski et al., 2020) and management of evolving flood risk (e.g. Brouwer and van Ek, 2004; Levy, 2005; Ranger et al., 2013). MCA allows quantitative analysis of complex systems that are defined in terms of a set of variables, which may be measured in fundamentally different ways, including some that are only poorly quantifiable (Hajkowicz, 2008; Cinelli et al., 2014). It also provides an effective basis for incorporating stakeholder preferences into climate change adaptation strategies (e.g. Brown et al., 2001; Kim et al., 2017; Barquet and Cumiskey, 2018).

An MCA-based policy assessment typically involves defining the context, as described, and the following steps (DCLG, 2009):

(i) Identify criteria which measure progress towards the objectives, using performance measures which can characterise the current state and how this is likely to change.

(ii) Evaluate the provisional set of performance measures for, inter alia, completeness, redundancy, operability, independence, ability to resolve variation in performance over time, transparency and ease of communication to stakeholders.

(iii) Evaluate the performance of each option using the defined measures (e.g. with a performance matrix) via four sub-tasks:

   a. Acquire the data needed to define each performance measure;
   b. Apply scores and weights to reflect the relative importance of the performance measures;
   c. Evaluate the ability of the approach to identify realistic options;
   d. Apply sensitivity analysis to determine how different assumptions influence the outcome.

This is sufficient to characterise a static state. To extend the approach to dynamic systems, step (iii)a needs to be expanded to include data on future conditions such as climate change, demography, land use, etc. This will typically also require models that can capture the interaction between performance measures. Measuring the likely impact of one or more policy option similarly makes use of similar or additional data and models.

The range of measures and datasets that might conceivably relate to coastal resilience is very large. For example, Rumson et al. (2020) list 254 candidate measures and data sources and pragmatic choices are necessary. Our conceptualisation of resilience (Figure 1b) naturally unpacks into sub-sets of measures that relate to people, property and nature. Figure 3 presents a conceptual diagram that relates these facets of resilience to an illustrative suite of measures that either directly or indirectly relate to the various minimisation or maximisation objectives in Figure 1b. We acknowledge that subjective judgement is inevitably involved in the derivation of a composite resilience measure for a well-defined purpose and other conceptualisations are possible.

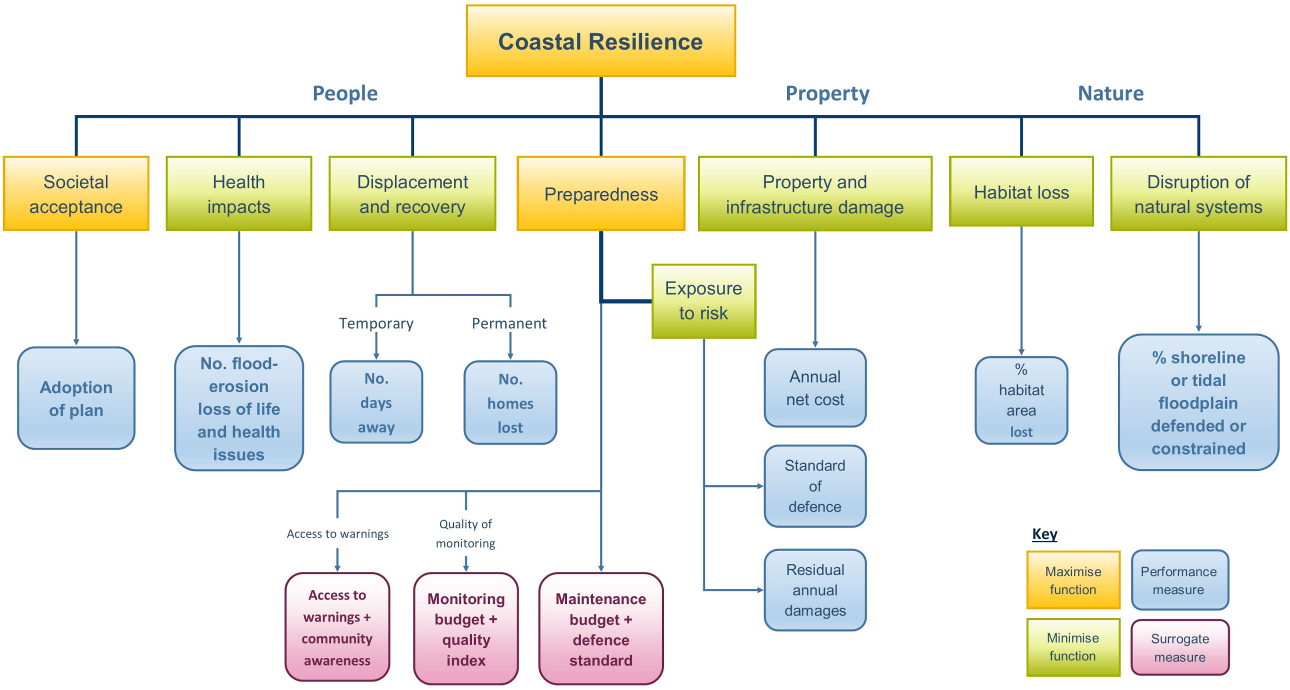

Figure 3: A set of objectives that need to be maximised or minimised, in order to enhance coastal resilience, and which can be quantified using indicators and associated data-driven metrics.

Some aspects of resilience, such as loss of life or certain economic damage costs, can be evidenced via direct measures. Others, such as those relating to the capacity for recovery following a hazard event, can presently only be approximated by surrogate or proxy measures (e.g. using a selected deprivation index). Surprisingly, there is no complete and consistently compiled national flood defence infrastructure dataset, or high spatial resolution data on insurance cover. Further details of the geospatial datasets used in the analysis presented below and the data processing workflow are provided in Carpenter and Hill (2020).

In our model to quantify coastal resilience, step (iii) is completed to determine the current state of the system, which includes geographical variation in resilience. From this baseline, time variations of key drivers (demography, sea level and storminess, national/international policy context, etc.) can be introduced to establish a set of future scenarios. Sets of policy options defined for each hazard zone may also include transitions between options and multiple pathways for adaptation (see also Ranger et al., 2013). Such transitions may well be linked to thresholds or trigger points, rather than being imposed at some fixed point in time. Quantification of the time evolution of overall coastal system resilience in this way provides a powerful approach for time-dependent decision management (Ranger et al., 2013) given the deep uncertainty that inevitably surrounds our understanding of future hazards (Walker et al., 2013).

We implemented an MCA-based determination of overall system resilience based on a suite of performance and component metrics, which were determined for areal units representing combined flood and erosion hazard zones. The basic workflow is summarised in Figure 2. First, each of the data-driven metrics was transformed to a common scale (0 to 100) to give a set of metric scores (s). Appropriate transformations range from simple linear functions, to non-linear or more complex (e.g. sigmoidal) functions, and these may be either positive or negative (according to whether the goal is to minimise or maximise the metric). For simplicity, we use two-part linear functions. Performance measures are typically defined from multiple metrics. This necessitates a two-stage process in which each of the broader performance measures ($P_{j,\ j=1 \dots N}$) are defined by the weighted combination of their constituent metric scores ($s_{i,\ i=1 \dots M}$). Thus:

$$P_j = \sum_{i=1}^{M} q_i \, s_i \qquad [1]$$

where $q_{i,\ i=1 \dots M}$ are weights assigned to the metric scores that combine to give P_j, where

$$\sum_{i=1}^{M} q_i = 1 \quad . \qquad [2]$$

A composite Resilience Index (RI), is then obtained as

$$RI = \sum_{j=1}^{N} w_j \, P_j \qquad [3]$$

where $w_{j,\ j=1 \dots N}$ are weights assigned to the performance measures. We found it more intuitive to define this second set of weights on a scale of 0 to 100 and then to convert them to a scale of 0 to 1, such that

$$\sum_{j=1}^{N} w_j = 1 \quad . \qquad [4]$$

The two sets of weights introduce subjective judgement to the process in that different sets of experts, stakeholders or decision makers are likely to assign values that reflect personal knowledge, perceptions and priorities. This has sometimes been highlighted as an inherent weakness of MCA (Garmendia et al., 2010; Estévez and Gelcich, 2015). However, in the context of resilience this subjective aspect encapsulates the variation in human values and views. This can be used advantageously to capture the knowledge and preferences of distinct stakeholder groups in a way that allows the effect of these on perceived resilience outcomes to be presented and communicated in a transparent way (Raymond et al., 2010). There are a range of formal methods for eliciting the preferences of stakeholders and decision makers, such as Deliberative Mapping (Burgess et al., 2007) and Analytic Hierarchy Process (ATP) (Saaty, 1980): ATP involves a pairwise comparison between every pair of options (Roy, 1968). We utilise weightings derived using a simple hierarchical ranking process. To simulate a stakeholder elicitation, the project team adopted different economic, social and environmental perspectives (Townend et al., 2020).

For operational use, any *RI* needs to be able to evaluate how the current state may vary over time (a) due to external drivers (e.g. climate change, land use etc.) and (b) in response to the implementation of one or more policy options (e.g. emergency planning, socio-economic regeneration etc.). To do this, we first define one or more scenarios to describe how conditions may change in the future. We then define a set of policy pathways. These set out how the various policy options might be used. Some options might be applied for the entire simulation period, whereas others may introduce changes either at a given time, or in response to triggers defined within an adaptive management framework (e.g. Ranger et al, 2013).

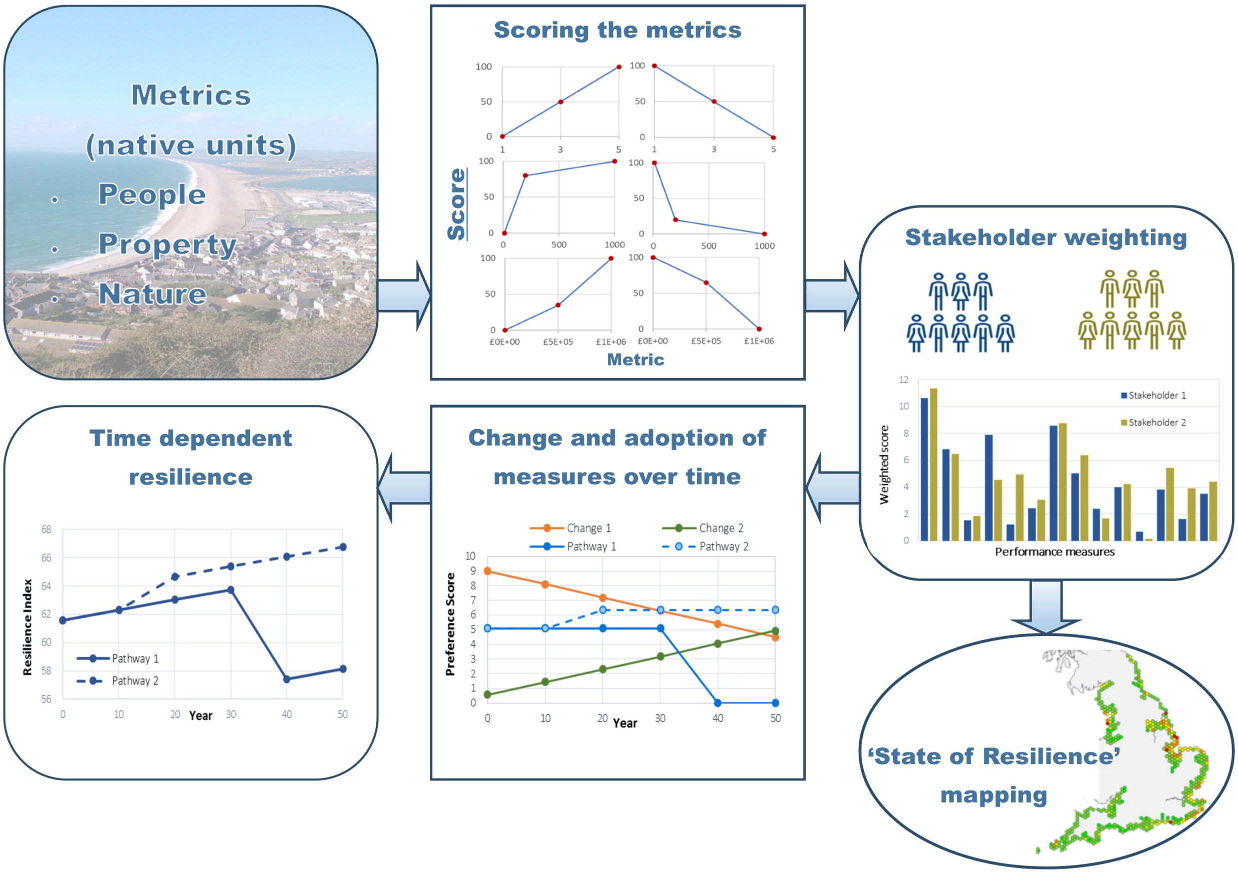

*Figure 4: Schematic of the derivation of the Resilience Index (*RI*). Metrics for the performance measures are converted to a common scale (e.g. 0-100) to give a score. Performance measures are weighted to reflect stakeholder preferences. These weighted scores combine to give the* RI *at a given point in time. This can be mapped spatially to reveal geographical variation in resilience. Applying predicted changes (social, economic and environmental) and adaptation pathway actions, generates a timeline for each performance measure. Summing the time dependent preference scores gives a timeline of the* RI *for each projected pathway.*

5. Illustrative local-scale studies

As a demonstration of our approach, we first present illustrative analysis using the CRM for the City of Portsmouth, supplemented with consideration of the rural north bank of the Outer Humber Estuary, east of Kingston-upon-Hull (Figure 5). We select these sites because they are both highly exposed to coastal hazards and yet represent contrasting urban and rural settings which test our resilience measures. First, we assess the current state of resilience (Figure 4) at a local scale. We then consider how resilience might evolve over time using scenario analysis. It is emphasised that these worked examples are illustrative demonstrations of the CRM; they would require further development for policy application and the insights reflect the method and approach rather than the outputs per se.

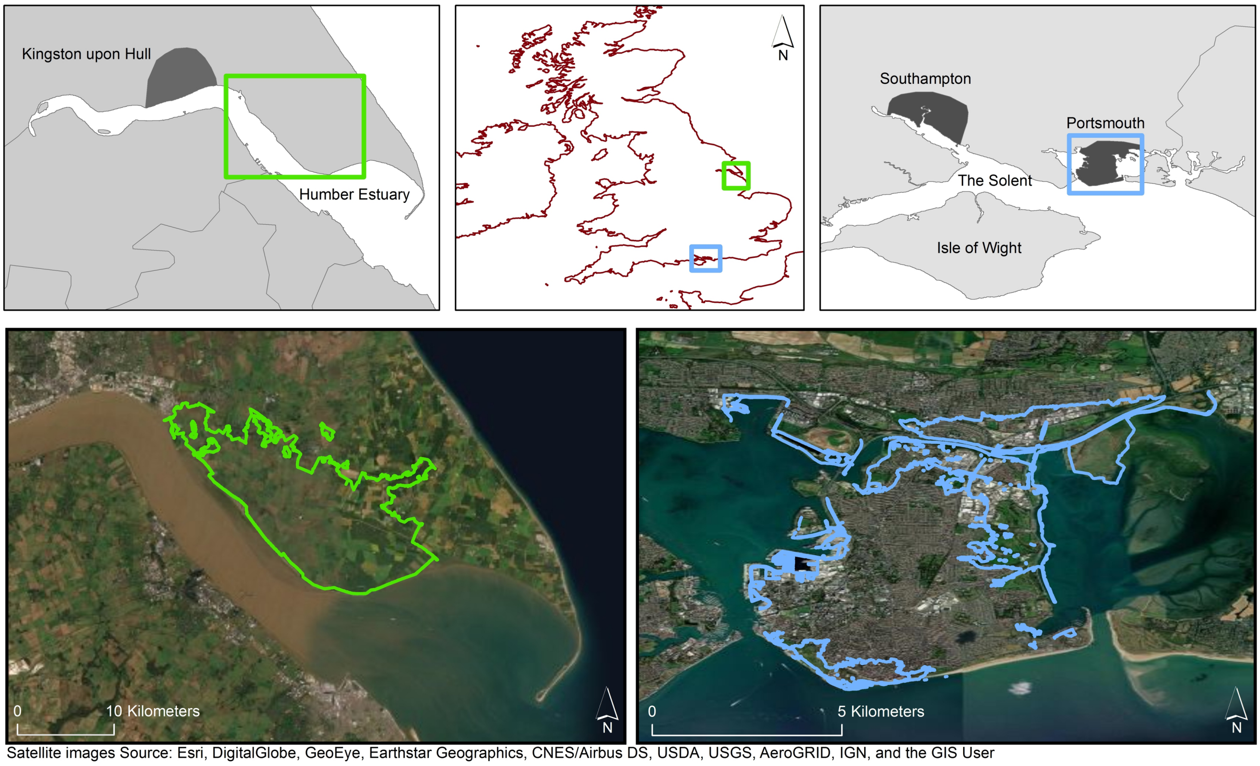

Figure 5: Location of Portsmouth and Humber case studies. The erosion and flood prone areas analysed are indicated.

Portsmouth combines urban estuary and open coast settings and is one of the most densely populated cities in England, with an historic core and more recent expansion (Stevens et al., 2015). It includes an important commercial port and an historic naval dockyard. Portsea Island is surrounded by the diverse and biologically rich coastal and marine environments of Portsmouth Harbour, Langstone Harbour and the Solent, including internationally designated habitats and species (Cope et al., 2007). The city has many heritage assets, including several Scheduled Ancient Monuments. The city is low-lying and Wadey et al., (2012) estimate that more than 14,000 properties are situated in the 1 in 200-year coastal flood plain. Coastal flooding during storms and high tides is a regular threat and this is being enhanced by sea-level rise (Haigh et al., 2011). As a result, a substantial proportion of the defences at Portsmouth are being upgraded including an allowance for sea-level rise. While this greatly reduces the risk of flooding, residual risk in the unlikely event of failure must still be considered, as in all flood prone areas.

In contrast, the north bank of the Outer Humber Estuary is an extensive low-lying area of rural land, which was claimed from the estuary by enclosure several hundred years ago. The area is predominantly fertile agricultural land but is now lower than the highest tides because it no longer receives sediment from the estuary. Until recently the entire area was defended with embankments but short lengths of defence are now being removed to create new wetland areas and, thereby, offset intertidal losses due to coastal squeeze elsewhere in the estuary (Winn et al., 2003; Turner et al., 2007). There is a small rural community and the area to seaward of the defences is ecologically important and protected under several conservation designations.

First, we focus on Portsmouth. The current status of the performance measures for Portsmouth is illustrated in Figure 6. These vary significantly according to the simulated stakeholder weightings derived to illustrate the different overarching perspectives (Figure 6). The measures sum to give the RI values shown. The different values reflect the different weightings, such as a social perspective putting more weight on human health, response time, recovery time, possible displacement of people, warnings and evacuation and insurance. In contrast, the economic perspective emphasises the avoidance of damage to assets and economy, and the environmental perspective prioritises coastal habitat and, perhaps surprisingly, social acceptance.

Looking to the future, we consider two stylised pathways to illustrate how resilience might evolve over a 50-year period. Pathway 1 (P1) assumes some loss of defence standard due to accelerated sea-level rise, thereby increasing the residual risk over time. Pathway 2 (P2) focuses on ensuring that the emergency services have a well-rehearsed response plan, the public have an increased level of awareness and the provision of flood proofing increases with time. With new defences in place, a careful public awareness campaign is required to strike a balance between recognition of the risk and acknowledgement of the high standard of defences in place.

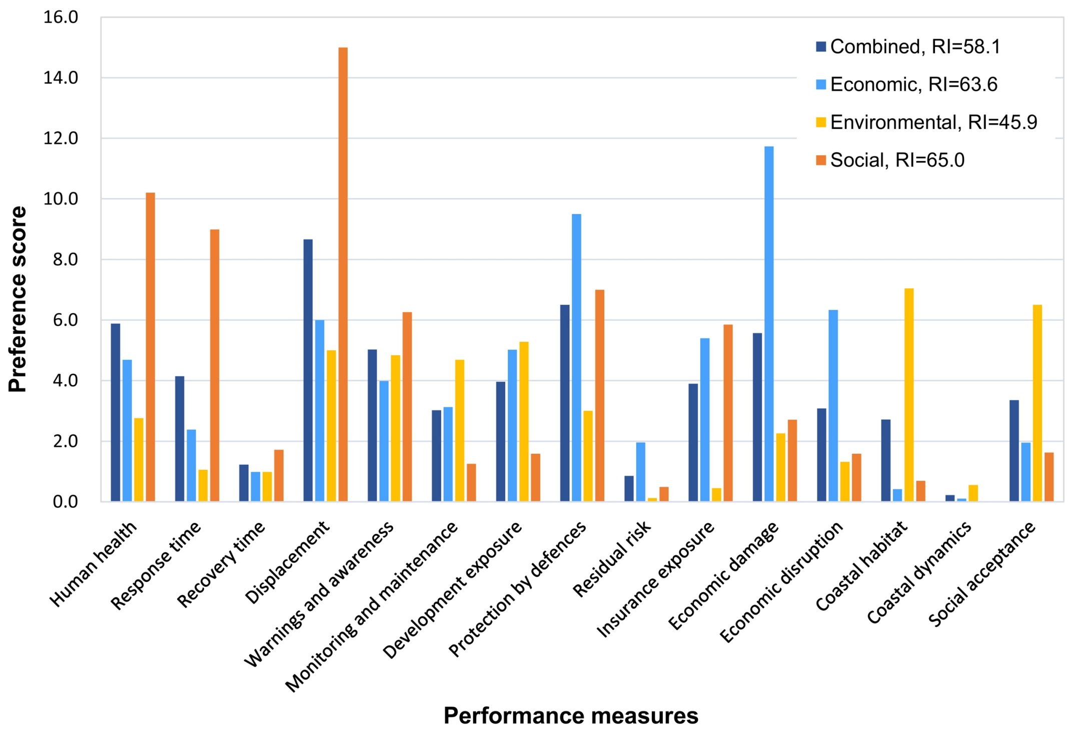

Figure 6: Current preference scores for Portsmouth using weights allocated according to social, economic and environmental perspectives, and the combined perspective.

The performance measures under the two pathways show a clear difference after 50 years under all three stakeholder perspectives and the combined viewpoint (Figure 7a and 7b). The *RI* is higher under P2 than P1 under all perspectives. This type of plot provides a “signature” of the resilience state that enables inter-comparison of different perspectives, times in the projection and sites (although the latter needs particular caution because of the influence of local conditions). These resilience signatures (Figures 6 and 7) are a key aid when interpreting both the degree and the nature of resilience, both locally and nationally. As such, they could enable constructive dialogue with stakeholders on the selection of policy pathways.

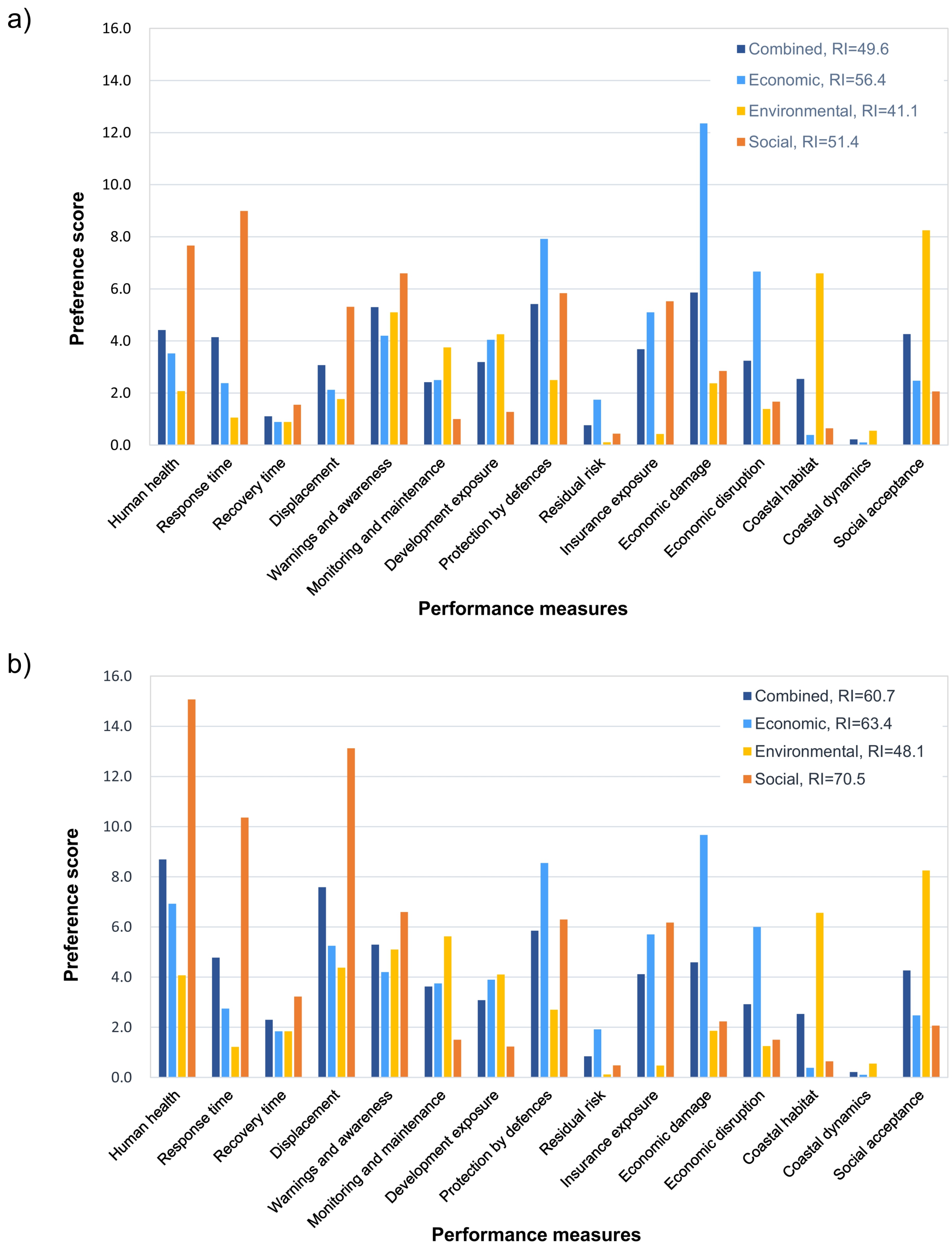

Figure 7: 50-year projection for the preference scores of individual performance measures in Portsmouth for a) Pathway 1; b) Pathway 2.

As well as snapshots, the evolution of *RI* over time under the two pathways can be assessed (Figure 8). The distinction between the three perspectives for *RI* is again highlighted, as is the marked difference in outcome after 50 years between the pathways, regardless of the stakeholder perspective that is considered. The evolution of performance measure under P1 and P2 is shown in Figures 9a and 9b, respectively. In these illustrative analyses, the future scenario and policy response pathway influence on the performance measures was modelled simply using linear trends or step changes, as appropriate. Hence, the temporal changes in Figure 9 are predominantly positive or negative linear trends. With further development, and more complex models to better capture feedbacks between the forcing conditions, policy actions and the measures themselves a more nuanced picture should emerge.

The results for this case study are sensitive to the social, economic, or environmental weighting of decision makers. The *RI* values for the economic and social perspectives are quite similar at the start of the simulation period but diverge over time for both pathways. In contrast, the environmental perspective weightings suggest a much lower resilience. The level of exposure and the potential to enhance community awareness and responsiveness results in an improved resilience compared to Pathway 1, which shows a progressive decline as the effect of climate change reduces the standard of defence. This in turn increases the residual risk due to the high population and asset base within the flood hazard zone.

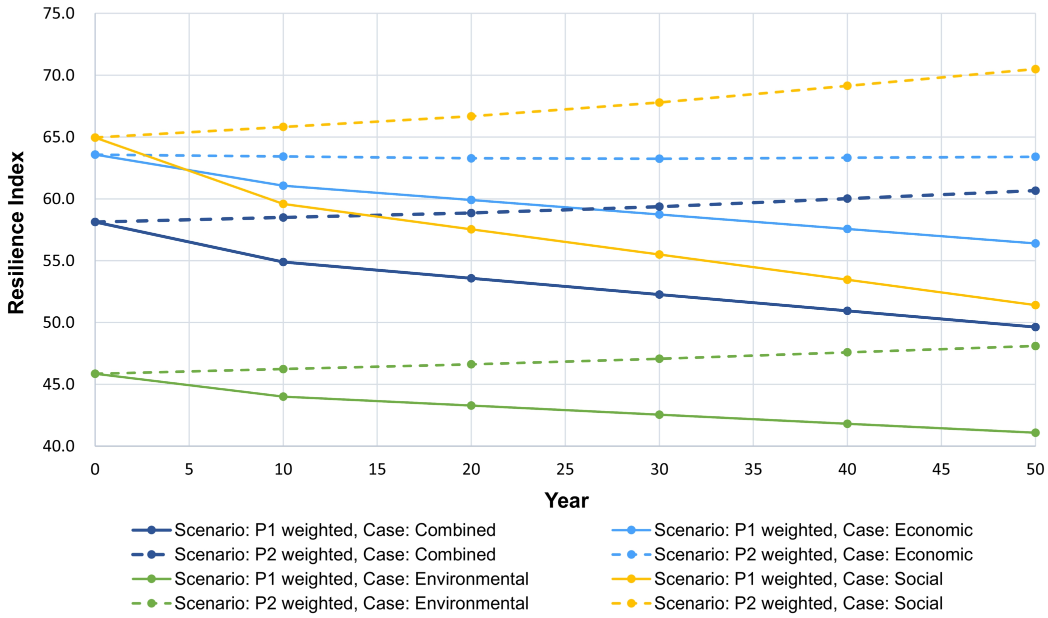

Figure 8: Time evolution of the coastal Resilience Index for Portsmouth under two Pathways (P1 and P2).

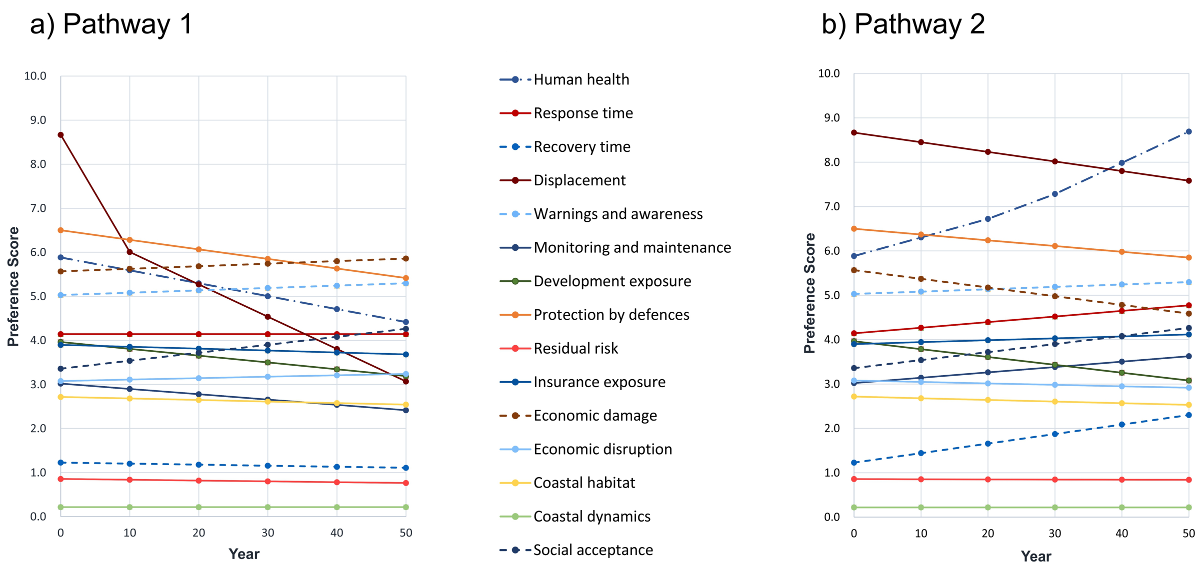

Figure 9: Time evolution of the preference scores in Portsmouth under a) Pathway 1; b) Pathway 2.

Figure 10 maps the *RI* for each stakeholder perspective and the combined index for the Portsmouth and Humber case studies, respectively. This indicates the scale of analysis. There is a large variation in resilience across Portsmouth, with consistently high values at some sites such as Farlington, and lower values in some areas such as parts of Southsea. This reflects high economic exposure to hazard and the resulting residual risk despite a high level of protection from defences. This reduces *RI* from the economic perspective. Low resilience indices under the environmental perspective for areas in the centre of Portsmouth reflects a lack of habitat areas. The North Humber has a similar overall *RI* to Portsmouth, but the components differ. The extensive habitats to seaward of the defences contribute to higher *RI* values from an environmental perspective. However, economic and social resilience are lower than Portsmouth. ‘Response Time’ measured with emergency service data is lower than Portsmouth. This highlights how rural areas may be less well served by emergency services and so have a lower social resilience. The presence of various strategic infrastructure points, local wind turbines, and some ‘properties’ reduce its economic resilience. Aspects of the method also influence the results. For example, property density is enhanced because farms typically comprise multiple buildings. Such detailed analysis across all the diverse components of resilience shown in Figure 3 for both these study regions provide interesting new insights about the regions and raise detailed questions on further development of the methodology towards policy application.

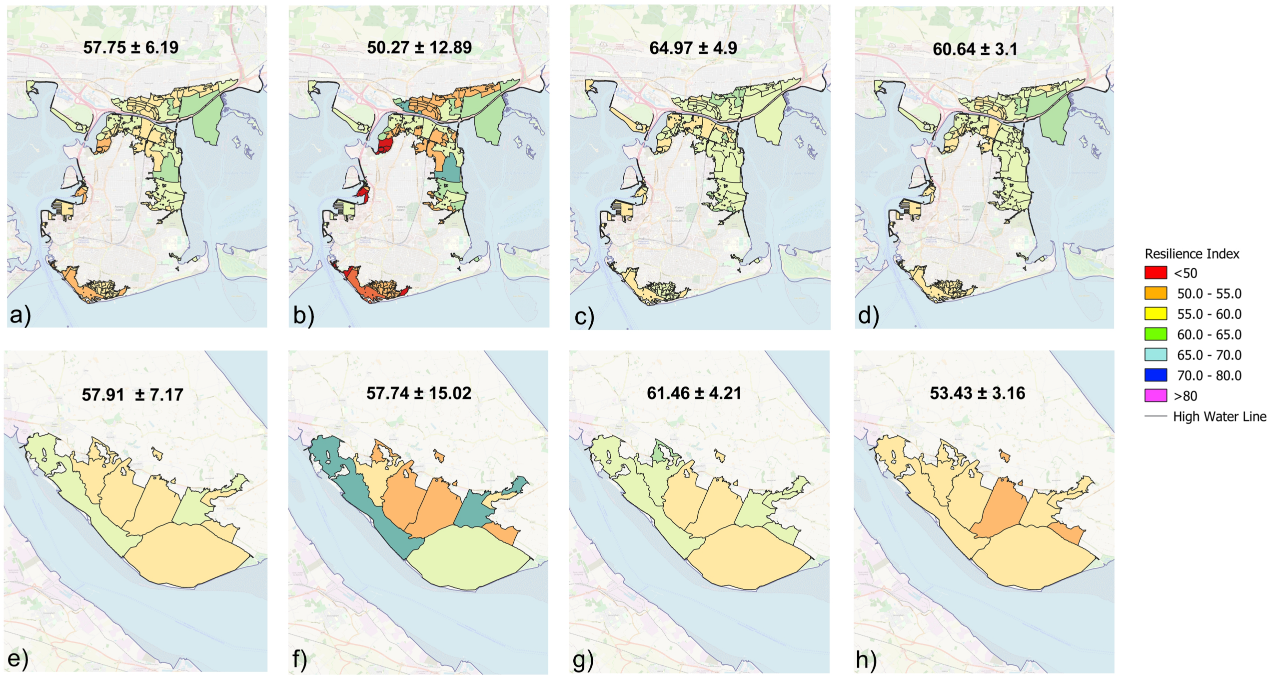

Figure 10: Portsmouth and Humber Case Studies showing the Resilience Index for each output area, while the number shown is the average RI *score: (a and e) Combined, (b and f) Environmental, (c and g) Economic, and (d and h) Social perspectives on resilience.*

6. National analysis: application to England

The MCA-based approach adopted in the Coastal Resilience Model (CRM) presented above can, in principle, be applied at any scale for which data are available, and a core goal was the development of an analytical approach that can be applied across multiple scales. Given the challenges of adapting to climate change at the coast (CCC, 2018; Oppenheimer et al., 2019) it is of particular interest to understand how geographic variations in resilience to coastal flooding and erosion might have a bearing on decision-making at a national scale. Accordingly, the same analytical workflow used in the Portsmouth and Outer Humber Estuary (North Bank) case studies was used to explore variation in the Resilience Index around the entire coast of England. Again, it is emphasised that this is a purely illustrative proof of concept exercise at this stage. Accordingly, the current state of resilience was modelled using the same set of weightings defined from the simulated elicitations of economic, social and environmental perspectives that were used to conduct the local case studies. Further consideration of this national analysis and its implications for measuring coastal resilience is reported elsewhere (Nicholls et al., in prep).

A considerable amount of geospatial data processing is involved in an analysis at this scale and the first task was to segment the coast into appropriate spatial units. Consideration was given to the use of existing SMP Shoreline Management Units. However, these are primarily defined by classifying the coast according to the hazard experienced, the urban or rural characteristics of the hinterland, and the status of the existing defences. This neglects broader social, economic and environmental aspects (Gerard, 2017) as well as the compound nature of the hazard in many locations. It was therefore necessary to construct an integrated hazard zone defined by a shoreline and erosion and flood extent datasets with an analysis layer constructed around spatial data Output Areas (OAs). These OAs typically contain less than 150 individual households and are the smallest unit of census reporting in the UK (Stokes, 2020). The national data sources for the erosion and flood hazard zones are summarised in Carpenter and Hill (2020).

Application of the CRM algorithms to the geospatial datasets was undertaken for a total of 8,382 OAs within the combined coastal flood and erosion hazard zone. The raw output at this level includes small and narrow zones along the coastline, which are difficult to visualise at a national scale. Accordingly, aggregation to larger regularly-shaped areal units was used to achieve more effective visual representation. Hexagons were used to reduce sampling bias (Sahr et al., 2003) and to represent the irregular coastline without producing gaps within the data. After some experimentation, a hexagon area of 90km^2 was selected. An arithmetic mean *RI* value was determined from every OA within a given hexagon.

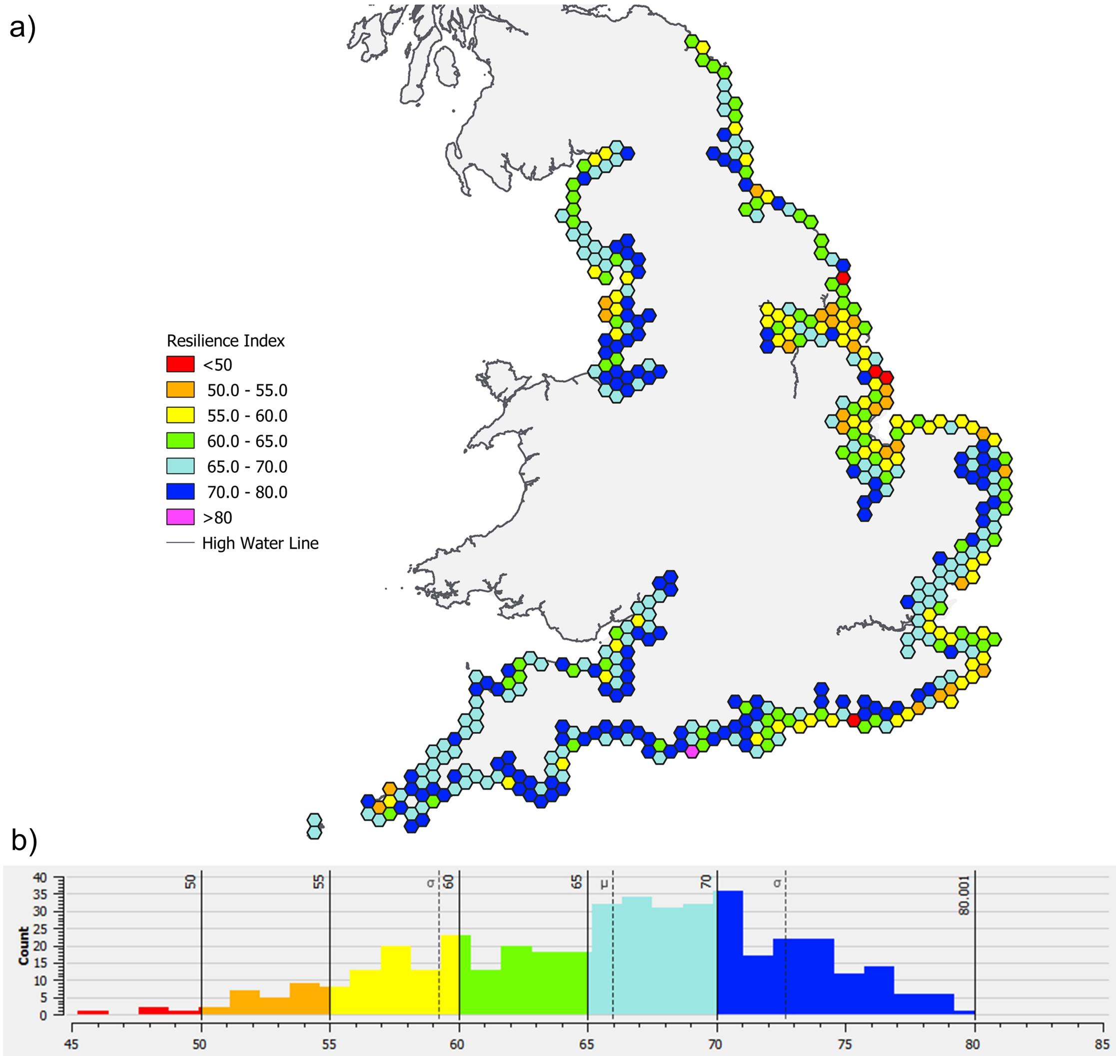

Figure 11: a) Geographical variation in coastal Resilience Index (composite of economic, social and environmental perspectives) around the English coast. Hexagons are 90 km² output areas. b) The distribution of RI *values.*

The *RI* takes similar values at a national scale to those observed in local case studies, although differences can be expected due to the aggregation from the 'native' OAs to the larger output hexagons used at the national scale. Nationally, the index has a mean of 66 with a minimum and maximum of 33.1 and 88.2 (across a possible range of 0 to 100). The distribution is unimodal with a slight negative skew (Figure 11(b)). A preliminary map of the combined coastal resilience index (i.e. averaging across the distinct economic, social and environmental perspectives) for England is shown in Figure 11 (a). It is notable that the southwest England appears comparatively resilient, whereas the east and southeast are more varied, with lower resilience scores that are well below the mean. These highlight coastal towns as well as stretches of coast with more rapid erosion or greater vulnerability to flooding. Coastal towns with higher levels of deprivation also stand out in the northwest.

7. Discussion

In this paper, we present a decision-making framework and the Coastal Resilience Model that measures resilience as a composite property of a set of coupled natural, social and economic sub-systems. We opted to use the MCA methodology as it is well-established, but are aware that the method has its critics, particularly regarding the subjective nature of scoring and weighting. As already noted, there are a range of methods for eliciting the preferences of stakeholders and decision makers, such as Deliberative Mapping (Burgess et al., 2007) and the Analytic Hierarchy Process (Saaty, 1980) that formalise the development of scoring functions and weightings. We see the development of these methods in partnership with stakeholders as a way of making the, hitherto hidden, divergence of views explicit and debatable. This turns a perceived weakness of the MCA method into a strength and the resulting understanding of stakeholder views and preferences is essential for the successful operationalisation of resilience in the way we have advocated in this paper.

To illustrate the method, we made a conscious decision to explore how the existing policies, regulatory framework and management practices could be adapted to meet the overarching objective of enhancing coastal resilience. Our use of MCA, whilst fundamentally data-driven, also uses the explicit representation of stakeholder perspectives to develop a more nuanced understanding of the options and their likely impact (see also Bostick, et al., 2017). Comparing the results for different stakeholder perspectives over multiple scales – from local management unit to national analysis - adds an important dimension that can support the decision-making process. Recognising that societal priorities and policies change over time, the ability to include projections based on prevailing paradigms and then update these to reflect changing stakeholder preferences ensures that the CRM can remain robust over time. The generic method used in the CRM is flexible, can be applied using different combinations of resilience metrics and/or data sources, and could be adapted to address the specific needs of different countries, as well as diverse policy goals and contexts.

There are two limitations of the CRM as outlined that are worth highlighting. These relate to data and projections into the future. Data are essential to quantify the current state of the performance measures and how the state changes over time. Our experience was that marrying data sets that are currently available with specific performance measures was challenging. Even after several iterations, our choice of metrics remains sub-optimal and would benefit from further development. This includes enhancement of national coastal datasets. In addition, future projections require an understanding of what is changing, both within the system and externally, that can alter the state of the system. However, modelling the implications of known environmental and social change (e.g., changing demographics) is difficult. Superimposing the additional changes that arise from planned interventions adds to this complexity. Here we took a simple approach, considering only linear and stepped changes of the performance measures in response to changing conditions, and using subjective assessment to define the interaction between measures and the implications of potential feedback loops. Developing this prognosis dimension to the CRM requires a more sophisticated modelling approach to the system dynamics. The need to address the interactions across the physical-biological-social-economic sub-systems makes both identifying suitable metrics and representing them in any scenario-pathway model particularly challenging and, hence, is an aspect that merits further research.

Mapping the current state of resilience provides a snapshot and relies on historic records. This, of itself, is useful to identify the more vulnerable locations. but is unlikely to differ dramatically from previous risk-based analyses, although the different economic, environmental and social perspectives can be illuminating. Important benefits of the CRM are in its potential use for forward planning. By providing a formal framework to engage with stakeholders and capture their views in an explicit resilience statement – the “resilience signature” - the CRM can be used to establish a dialogue. Policy pathways are predicated on local knowledge which will need to be developed by local groups of stakeholders. If these were developed alongside integrated models that can define representative future scenarios, the state of resilience can be examined over time, as illustrated by the results presented. A national appraisal could then consider different allocation models (e.g. economic benefit, social wellbeing, environmental gain, etc) to explore how different policy choices impact the overall state of resilience at a national scale and the implications of these choices at a local scale. This would provide a robust basis for policy guidance to inform local decision making and the refinement of policy pathways.

8. Conclusions

The adoption of resilience as an overarching framework for strategic coastal hazard management has hitherto been limited, possibly due to the success of the prevailing risk-based management paradigm. As the extent of climate change impacts become apparent, it is clear that higher levels of risk from flooding and erosion will have to be tolerated. Resilience is a broader concept that incorporates risk but goes beyond it to consider the ability to anticipate and recover from adverse events that will inevitably occur. The main challenge is to devise a robust framework for quantifying resilience, such that comparative geographical assessments and forward modelling of temporal changes and the effects of specific adaptation pathways become possible.

In this paper, we adopt an existing definition of resilience and devise a model to quantify resilience that can support a decision-making framework with the overarching objective of enhancing the current state of coastal resilience. This is necessarily pragmatic but includes an explicit consideration of stakeholder preferences and a wider policy-making context that determines the purpose and potential beneficiaries (i.e. 'resilience against what?' and 'for whom?'). A set of existing indicators that quantify the economic, environmental and social dimensions of coastal resilience utilizing national open-access geospatial datasets are evaluated using Multiple-Criteria Analysis. The analysis integrates what are presently a disparate set of policy objectives, moving on from the traditional engineered options associated with shoreline management planning to a broader perspective that takes greater account of coastal community characteristics and priorities. A prototype model generates a system-wide Resilience Index that can be mapped spatially across a range of scales, as shown by illustrative case studies for Portsmouth and part of the Humber estuary at one level, and a broader-scale analysis of the entirety of the English coastal flood and erosion hazard zone. We also show how, given appropriate hazard and socio-economic scenarios, time trajectories of coastal resilience can be modelled to reveal the impact of alternative adaptive pathways. Formalising resilience depends on the context and goals and this will differ around the world. In some countries the legacy of coastal defences will dominate the debate (e.g. UK and the Netherlands), whereas elsewhere disaster risk management and recovery is the major consideration (e.g. USA and Bangladesh). Applying resilience in other coastal contexts is likely to lead to further diversity.

A shift from a predominantly risk-based to a broader resilience-based approach for the management of coastal hazards requires a firm commitment from government to develop a consensus methodology, including agreement on the weightings of the component indicators. We advocate using these subjective weightings constructively to highlight the convergence/divergence that arises from differing stakeholder perspectives. Further, there is a need to establish the incentives for coastal managers to engage with and apply this new approach, particularly where the process or outcomes could be complex or have long lasting implications. Such a policy transition to a less sectoral approach would challenge existing governance arrangements in many countries and require more integration and inter-agency cooperation. However, it would provide a robust evidence-based framework that could deliver more sustainable, equitable and societally acceptable adaptive responses to climate change at the coast.

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Figure summary

Figure 1: a) Generalised resilience management framework that includes risk analysis as a central component (reproduced from Linkov et al., 2014). The dashed line shows that a resilient system can adapt such that its functionality may improve with respect to its initial state, enhancing system resilience to future adverse events; b) Objectives that serve to enhance coastal resilience by maximizing the capacity to cope and minimizing the potential for loss.

Figure 2: Workflow for development of the prototype Coastal Resilience Model (CRM) based on Multiple Criteria Analysis (MCA) with explicit representation of (i) stakeholder perceptions and priorities and (ii) timelines of change and pathways of adaptation.

Figure 3: A set of objectives that need to be maximised or minimised, in order to enhance coastal resilience, and which can be quantified using indicators and associated data-driven metrics.

Figure 4: Schematic of the derivation of the Resilience Index (RI). Metrics for the performance measures are converted to a common scale (e.g. 0-100) to give a score. Performance measures are weighted to reflect stakeholder preferences. These weighted scores combine to give the RI at a given point in time. This can be mapped spatially to reveal geographical variation in resilience. Applying predicted changes (social, economic and environmental) and adaptation pathway actions, generates a timeline for each performance measure. Summing the time dependent preference scores gives a timeline of the RI for each projected pathway.

Figure 5: Location of Portsmouth and Humber case studies. The erosion and flood prone areas analysed are indicated.

Figure 6: Current preference scores for Portsmouth using weights allocated according to social, economic and environmental perspectives, and the combined perspective

Figure 7: 50-year projection for the preference scores of individual performance measures in Portsmouth for a) Pathway 1; b) Pathway 2.

Figure 8: Time evolution of the coastal Resilience Index for Portsmouth under two Pathways (P1 and P2).

Table summary

Supplemental Material

Section S1: Analysis of national policy documents relating to coastal resilience in England and Wales

(see file: Section-S1_Supplementary-marterial.docx)

This supplementary material contains supporting documentation for: Townend et al (20XX) 'Operationalising Coastal Resilience to Flood and Erosion Hazard: A Demonstration for England.' Science of Total Environment Paper

Supplementary Material: S1

Analysis of national policy documents relating to coastal resilience in England and Wales

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1 Background and method

Here we explain the process used to assess the prevalence (frequency) and utilisation of the concept of resilience in key coastal management policy documents for England and Wales. We then assess the extent to which the objectives of Shoreline Management Plans (SMPs) address the resilience agenda. A simple content analysis (word search and count) is used to determine: the frequency of the term 'resilience'; and the presence of definitions of resilience.

2 Content analysis of national policy documents

2.1 Method

Nine national policy documents (see Table S1) were selected for content analysis based on three criteria: i) evidence of high level strategic policy; (ii) relevant to coastal management, and (iii) considers resilience. The content analysis comprised two activities. First, within each document, a simple search for 'resilien*' [1] was undertaken, and the total count of references to 'resilien*' recorded. Second, each document was searched specifically for a definition of resilience. A summary of findings from the content analysis of national policy documents can be found in Table S1. A brief analysis of each policy document follows.

[1] The truncated term 'resilien*' was used to pick up references to: resilience, resilient, and resiliency.

Table S1. Overview of textual content analysis of policy documents for England in chronological order

Document	Author (year)	Frequency of use of 'resilien*' (# mentions)	Definition of resilience provided (Y/N)
Guidance on 'Flood and Coastal Resilience Partnership Funding	DEFRA (2011a)	3	N
Understanding the risks, empowering communities, building resilience: the national flood and coastal erosion risk management strategy for England	DEFRA, (2011b)	24	Y
Flood Resilience Community Pathfinder Evaluation Final Evaluation Report	DEFRA (2015)	746	Y
National Flood Resilience Review 2016	HMG (2016)	108	N
Rising to the Climate Crisis. A Guide for Local Authorities on Planning for Climate Change (Royal Town Planning Institute)	RTPI (2016)	57	N
Managing the coast in a changing climate	CCC (2018)	21	Generally – N PLR – Y
Public Summary of Sector Security and Resilience Plans	Cabinet Office (2018)	113	Y
The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting	DEFRA (2018)	270	Y (annex 2)
Draft National Flood and Coastal Erosion Risk Management Strategy for England	EA (2019)	210	Y

Key to acronyms used above: CCC = Climate Change Committee; DEFRA = Department for Environment, Food and Rural Affairs; HMG = Her Majesty's Government of the United Kingdom; PLR = property-level resilience; RTPI = Royal Town Planning Institute.

2.2 Document analysis

The findings of the content analysis are presented for each report (listed in chronological order).

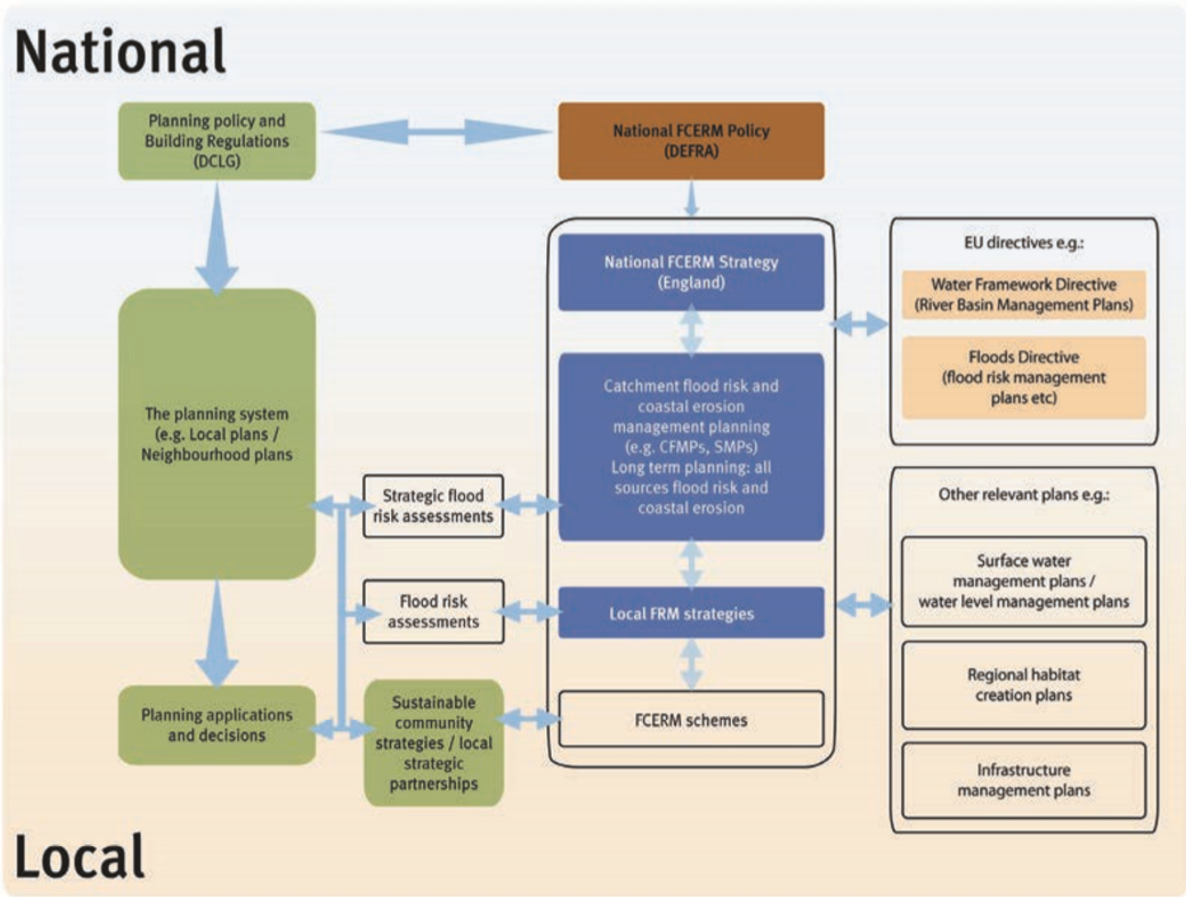
i) DEFRA (2011a) Flood and Coastal Resilience Partnership Funding

Only three references to 'resilien*' appear in this document. Resilience is not defined or used widely in the text, but appears to be taken as synonymous with risk reduction.

ii) DEFRA (2011b) Understanding the Risks, Empowering Communities, Building Resilience: the National Flood and Coastal Erosion Risk Management Strategy for England.

Despite an extensive search. it was not possible to find a non-draft version of the flood and coastal erosion risk management (FCERM) strategy for England and Wales on the government website. This document (DEFRA, 2011b) appears to be the current draft DEFRA FCERM strategy document: https://www.gov.uk/government/publications/national-flood-and-coastal-erosion-risk-management-strategy-for-england (accessed 10/02/2020). The document contains a useful figure (p.20; reproduced below as Figure S1) that shows how flood and coastal erosion management strategies and plans relate to other planning initiatives. Given that this is the key FCERM strategy document influencing coastal management policy it is interesting that there is no link to Local Resilience Forums in this diagram, and there is no mention of 'resilience' in any of the components within the figure.

Figure S1: FCERM strategies and plans and their relationship with other planning initiatives



(source: DEFRA (2011b) p.20)

DEFRA (2011b) includes 24 references to 'resilien*', and the following definition of resilience is provided in an Annex: "*The ability of the community, services, area or infrastructure to avoid being flooded or lost to erosion, or to withstand the consequences of flooding or erosion taking place.*" (DEFRA, 2011b p.52). This definition of resilience aligns with the later Cabinet Office (2018) report, focussing on managing risk to reduce losses, and 'living with' risk - as opposed to the more managerial use of resilience (i.e. bouncing back, adapting or transforming into something better), or the EA (2019) articulation of managing trade-offs between objectives, and acceptable losses.

iii) DEFRA (2015) Flood Resilience Community Pathfinder Evaluation Final Evaluation Report

DEFRA (2015) contains 746 references to resilien*, although over one third (250) of these references to resilience were in titles/subheads/FRCP scheme name and/or in references to other reports. Within the text 'resilience' is used to refer to both specific measures (resilience measures), and desired outcomes (more resilient/something better). Despite a higher level of engagement with the concept of resilience than earlier reports, flood risk resilience is not explained or defined. For example, the objectives of the Pathfinder scheme contain reference to improvements in 'resilience': *"(i) Enhance flood risk management and awareness in ways which quantifiably improve the community's overall resilience to flooding.; (ii) Demonstrably improve the community's financial resilience in relation to flooding; (iii) Deliver sustained improvements which have the potential to be applied in other areas." p. 14.* However, 'overall resilience', and 'financial resilience' are not defined within the document. In an improvement on earlier documents, DEFRA (2015) contains detailed descriptions of other forms of resilience, notably: property level resilience, economic resilience, institutional resilience, infrastructural resilience, social resilience (pp 11-12). The definition provided for community resilience is notably very clear:

> *Communities working with local resources (information, social capital, economic development, and community competence) alongside local expertise (e.g. local emergency planners, voluntary sector, local responders) to help themselves and others to prepare and respond to, and to recover from emergencies, in ways that sustain an acceptable level of community functioning*. (adapted from Twigger-Ross et al., 2011: 11), p.9

The report also cites another notably clear definition of 'disaster resilience' taken from DFID (2011):

> *Disaster resilience is the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses – such as earthquakes, droughts or violent conflict – without compromising their long-term prospects. DFID, 2011: P. 29.*

Overall, there is not a consistent use of resilience within this DEFRA (2015) document.

iv) HMG (2016)

HMG (2016) contains 108 references to 'resilien*'. Resilience is not defined, and not used consistently throughout the document. Resilience is used to articulate 'something better than now' or ensuring security under a range of disruptive risks.

v) RTPI (2016)

RTPI (2016) contains 57 generic and specific uses of 'resilien*'. Generic uses tend to be used to refer to 'something better', although it is never specified what this means. Specific uses relate to local planning and provide a good level of detail relating to: Sustainable Urban Draining Systems, green roofs and reducing overheating in buildings. For example, in the Camden Local Plan within the document: "*Any development involving 5 or more residential units or 500 sq m or more of any additional floor space is required to demonstrate the above in a Sustainability Statement*" (p.35). Overall, RTPI (2016) provides a mix of clearly articulated local resilience approaches, as well as referring to vague higher level unspecific improvements in 'resilience'.

vi) DEFRA (2018) The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting

DEFRA (2018) contains 270 references to resilien*. Resilience is very clearly defined in Annex 2 of the document, where there are also specific objectives relating to resilience. These objectives are well specified, and relate to best practice environmental management. However, this clarity relating to resilience is not evident throughout the document. Within the body of the text, resilience is sometimes used as a characteristic meaning 'something better' or simply 'living with stress' or accommodating change.

vii) Cabinet Office (2018): Sector Security and Resilience Plans

This document contains 113 references to resilien*. Resilience is clearly defined, using an engineered resilience definition: *"its … approach to security and resilience focuses on Resistance, Reliability, Redundancy, and Response & Recovery"P.7.* Each of the five 'R' elements is further defined within the document. While there is a very clear articulation of what is meant by resilience, Cabinet Office (2018) does not include language relating to typical elements of resilience, i.e. focus on systems and potential for loss of some components within the system, and managing significant change. Further, the language maps onto ideas of risk management used in the UNDRR disaster risk reduction cycle (mitigate, prepare, respond, recover). In this regard, the meaning of 'resilience' within Cabinet Office (2018) is vastly different to most other HMG policy documents.

viii) Climate Change Committee (2018): Managing the Coast in a Changing Climate

CCC (2018) contains just 21 references to resilien*. Of these, four mentions are specific and relate to a well-defined 'Property Level Resilience'; the other 17 uses are generic whereby resilience is simply an improvement on the current situation.

ix) EA (2019) Draft National Flood and Coastal Erosion Risk Management Strategy for England

EA (2019) includes 210 references to 'resilien*'. There is a definition provided on p.6, where resilience is defined around concepts of adapting and living with change, and accepting trade-offs between objectives:

> *"Resilience includes accepting that in some places we can't eliminate all flooding and coastal change, and so we need to be better at adapting to living with the consequences. For example, by designing homes that can be restored quickly after they've been inundated with water, or potentially moving communities out of harm's way. It also includes plans to ensure we respond effectively during a flood, and that people and livelihoods can recover as quickly as possible"* (EA, 2019, p.6)

A suite of nine resilience tools is introduced. These essentially combine best practice environmental and risk management e.g. '*responding quickly and effectively to flood and coastal erosion events*', combined with changing social discourse around acceptable loss '*accepting that some areas will flood and erode*' (pp. 19-20). Overall, EA (2019) provides a relatively clear overview of what resilience means, but less clarity on how the methods proposed would deliver that.

2.3 Overview of use of resilience within national policy documents

It is concluded, based on the content analysis of key national coastal resilience policy documents for England and Wales, that there is a wide variety of understanding, usage and application of the term 'resilience' within policy documents. The more recent policy statements, those published in 2018 and 2019 tend to contain a formal definition of resilience, whereas earlier policy statements tend not to define resilience. Even in the most recent policy documents, however, there is no consistent use of the term resilience; it can variously mean: accepting loss, living with change, or standard risk management. In many cases, resilience is used vaguely, without a 'who' or 'to what'. This suggests a lack of high level understanding of the meaning and implications of pursuit of a resilience policy. Further it suggests the need for a clearly defined and measurable resilience indicator (or indicators) to avoid multiple inconsistent uses.

3 Background on the policy shaping the SMPs

It is worth noting that most SMPs were produced prior to the significant shift in discourse around resilience. All current SMP documents are required to follow the guidance laid out in DEFRA's March 2006 policy document 'Shoreline management plan guidance Volume 1: Aims and requirements' (DEFRA, 2006), which contains clearly stated objectives for SMPs:

"The objectives of an SMP need to be in line with the Government's strategy (DEFRA 2005) for managing risks from floods and coastal erosion (also see our website: www.defra.gov.uk/environ/fcd/policy/strategy.htm) and should:

- *set out the **risks** from flooding and erosion to people and the developed, historic and natural environment within the SMP area;*
- *identify opportunities to maintain and improve the environment by **managing the risks** from floods and coastal erosion;*
- ***identify the preferred policies for managing risks** from floods and erosion over the next century;*
- ***identify the consequences** of putting the preferred policies into practice;*
- *set out **procedures for monitoring** how effective these policies are;*
- ***inform others** so that future land use, planning and development of the shoreline takes account of the risks and the preferred policies;*
- ***discourage inappropriate development** in areas where the flood and erosion risks are high; and*
- *meet **international and national nature conservation legislation** and aim to achieve the biodiversity objectives"* (DEFRA, 2006, p.11)

DEFRA (2006) guidance states that SMPs need to be in line with the government's flood and coastal erosion risk management (FCERM) strategy. The current FCERM strategy is still in draft form (DEFRA 2011b). This document contains a clear definition of resilience - relating to avoiding and minimising losses. It is worth noting that none of the SMP objectives directly relate to building resilience. Rather the SMP objectives tend to align with the DEFRA (2006) SMP guidance document which encourages a focus on minimising risk.

4 Assessment of SMPs objectives to identify the extent to which they deliver resilience

Three SMPs were checked for reference to the language of resilience. The three SMPs were randomly selected from the 22 current SMPs from the Government's Shoreline Management Plan website (https://www.gov.uk/government/publications/shoreline-management-plans-smps/shoreline-management-plans-smps). The three SMPs were selected using an online random number generator (from 1-22). The three SMPs selected are: Isle of Wight, North West and North Wales, and South Wales.

4.1 Isle of Wight Shoreline Management Plan, May 2011 (accessed 27/1/2020)

- Online source: http://www.coastalwight.gov.uk/smp/
- Author: Isle of Wight Steering Committee and Royal Haskoning (2010)
- **Frequency of references to 'resilien*' = 0**
- Aim of IOW SMP: *"to determine sustainable policies for management of the shoreline management and to set a framework for the future management of erosion and flood risks along the coastline"*

- Conclusion: language relates to managing risk, not building resilience

4.2 North West England and North Wales Shoreline Management Plan SMP, July 2010 (accessed 27/1/2020)

- Online source: link from the DEFRA website on SMPs did not work https://www.mycoastline.org.uk/shoreline-management-plans/ suggests there is a policy document for May 2016, but this could not be located. The following page contained the SMP for Blackpool from July 2010: http://www2.blackpool.gov.uk/democracy//members/admin/files/7b806c32-b3c8-411c-a4d5-247dafa05fa1/Annex%201%20SMP%20Main%20Document%20for%20Blackpool.doc
- Author: Halcrow (2010)
- **Frequency of references to 'resilien*' = 7**
- Resilience not defined in the document, it appears to be used as a synonym for adaptation and resilience measures (6 mentions), and resilience and resistance measures (1 mention)
- Aim of NW&NW SMP: *"To identify policies to manage risks"*
- Conclusion: Language relates to risk management and adaptation, and not building resilience

4.3 South Wales Shoreline Management Plan SMP2 (Lavernock Point to St Ann's Head), Jan 2012 (accessed 27/1/2020)

- Online source: http://www.southwalescoast.org/smp/files/SMP_2012/FINAL%20SMP2%20Report%20and%20Appendices%20PDF%20version/SMP2%20Main%20Document/Main%20SMP%20Document.pdf
- Author: Halcrow, 2012
- Frequency of references to 'resilien*' = 0
- Aim of South Wales SMP: *"Planning for Balanced Sustainability, i.e. optimising the achievement of objectives for people, nature, historic and economic realities".*
- This SMP contains clear language recognising the need for trade-offs – which is inherent to resilience:
  "One of the main objectives of the SMP2 is to achieve 'balanced sustainability' by considering the needs and objectives of people, nature, historic and economic realities. ***However, it is clearly impossible to achieve all of these often conflicting objectives.*** *For example, building large-scale defences to reduce the risk of coastal erosion and flooding to a coastal town would not comply with objectives to allow the coastline to develop naturally. Careful planning and management, through development of this SMP2, has allowed a balanced plan to be reached which considers these issues both now and into the future." (Halcrow, 2012: p.32)*
- Conclusion: Contains no language about resilience, but clearly acknowledges the need to make trade-offs between the stated objectives for FCERM in Wales.

5 Reflection on the use of the concept of 'resilience' in Shoreline Management Plans

There is no clear requirement for SMPs to consider resilience within DEFRA (2006) Guidance. There is a note in DEFRA (2006) that SMPs need to align with the current government strategy on flood and coastal risk management. Since the most recent FCERM strategy documents (DEFRA, 2011b) were published after the production of most of the Second Generation SMPs, there is little likelihood that many / any of these plans contain clear statements relating to the delivery of coastal resilience.

There is a lack of consistency in the language relating to sustainability, risk and resilience in the three randomly selected SMPs. This could be due to the changing authors of the three documents – each taking different approaches; it may also relate to the timing of the plans – 2010, 2011 and 2012. Each SMP may have been influenced by policy documents released in the year of publication. Only one of the three randomly selected SMPs contains language of resilience (SW Wales). The SW Wales SMP recognises the need to make trade-offs between the multiple objectives at the coast (and aligns with the EA, 2019 vision). The analysis of the randomly selected sample of three SMPs, suggests a lack of consistency in the language and focus of SMPs.

6 References

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