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How normative interpretations of climate risk assessment affect local decision making: an exploratory study at the city scale in Cork, Ireland

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Abstract

Urban areas already suffer substantial losses in both economic and human terms from climate related disasters. These losses are anticipated to grow substantially, in part as a result of the impacts of climate change. In this paper we investigate the process of translating climate risk data into action for the city level. We apply a commonly used decision-framework as our backdrop and explore where in this process climate risk assessment and normative political judgments intersect. We use the case of flood risk management in Cork city in Ireland to investigate what is needed for translating risk assessment into action at the local city level. Evidence presented is based on focus group discussions at two stakeholder workshops, and a series of individual meetings and phone-discussions with stakeholders involved in local decision making related to flood risk management and adaptation to climate change, in Ireland. Respondents were chosen on the basis of their expertise and/or involvement in the decision making processes locally and nationally. Representatives of groups affected by flood risk and flood risk management/adaptation efforts were also included. The Cork example highlights that, despite ever more accurate data and an increasing range of theoretical approaches available to local decision makers, it is the normative interpretation of this information that determines what action is taken. The use of risk assessments for decision making is a process that requires normative decisions, such as setting 'acceptable risk levels' and identifying 'adequate' protection levels, which will not succeed without broader buy-in and stakeholder participation. Identifying and embracing those up-front could strengthen the urban adaptation process - this may in fact turn out to be the biggest advantage of climate risk assessment: it offers an opportunity to create a shared understanding of the problem and enables an informed evaluation and discussion of remedial action.

Key index words/phrases:
Climate risk assessment; urban adaptation; local decision making

1. Introduction

Urban areas already suffer substantial losses in both economic and human terms from climate related disasters such as flooding. These losses are anticipated to grow substantially in the coming decades, in part as a result of the impacts of climate change. It has been estimated that 40 million people and $3 trillion in assets are already vulnerable to coastal flooding in cities around the world. [1] Under even modest sea-level rise (0.5m), by 2070 those numbers could rise to 150 million people and $35 trillion. Urban decision-makers face the challenge of deciding how to respond to this risk amongst all the other pressures that urban areas face: Cities are subject to a complex interplay of economic growth, population trends, land-use and social processes, which all influence and are influenced by climate risk. Addressing this requires collaborative management across spatial, political and organisational boundaries involving a broad range of stakeholders, who take decisions that determine current and future risks – for example where to locate new housing developments, how to design new flood barriers, what materials to use for new roads, and how to ensure functioning water and power supply. [2]

Planning decisions have a potentially large effect on exposure to future flood risk. For example, projections of future flood losses in Europe indicate a possible six-fold increase in losses (from €4bn per year to €24bn per year by 2050); roughly two-thirds of that projected increase is accounted for by changes in exposure, with one third accounted for by the expected increase in flood hazard due to climate change. [3] Planning decisions taken today also have the potential to lock-in exposure for decades to come, thus making these decisions particularly sensitive to the uncertainty surrounding future risks associated with climate change. For example, observing rapid recovery following large-scale urban flooding, Kocornik-Mina et al. [4] note that "flooding poses an important challenge for urban planning because adaptation away from flood-prone locations cannot be taken for granted even in the aftermath of large and devastating floods" (p.4). For cities vulnerable to flood risk, these issues represent pressing and critical dilemmas in terms of how to balance the desire for urban expansion – particularly the development of dense urban cores – against the requirement to manage and limit flood risk. Avoiding rising flood losses needs to be balanced with the development requirements of urban areas, both in terms of population and infrastructure, prompting calls for investment in low carbon, climate-resilient infrastructure. [5]

Climate risk assessments, which capture the character and scale of different risks, can feed important information into these decision-making processes, offering a systematic approach to 'estimate the magnitude and frequency of natural hazards, the exposed assets and people, and how vulnerable those assets and people are given certain hazard conditions'([6],[7]). Indeed a number of recent reports and guidelines identify data and risk analytics as key components of climate adaptation planning and implementation for cities, (for example, see the 100 Resilient Cities programme and the work performed by Mehrotra et al. [8], Dickson et al. [9], Molin Valdés [10] and UN-HABITAT [11]).

Importantly, decision-makers tasked with using risk assessment to inform design and implementation of adaptation strategies have to do this 'in increasingly complex and uncertain environments' (p111) [12]: risk levels are dynamic, influenced by physical as well as social processes that change over time. Recognizing this within a comprehensive risk assessment approach is not a new challenge, but methods and models that capture this in a holistic and multi-disciplinary way are still in their infancy [6]. Weaver et al. [13] note how risk assessments are often 'not optimally designed and constructed to deliver the kind of actionable information decision-makers need' (p.1). Similarly, stakeholders interviewed by Carter et al. [14] noted that climate data may inadequately address the consequences of climate change, or may not be relevant to the local scale, making it difficult to justify new policies. It is this point of 'salience' - the relevance of the information produced to decision makers, as per Cash et al. [15] - that often appears to be missing, particularly at a local or city level. This has been explored by Howarth and Painter [16] in the context of using the IPCC reports for local adaptation decisions: They note that "while much emphasis is placed on credibility in the IPCC process and a growing emphasis on legitimacy, salience, particularly in the context of local decision-making, is lacking" (p.2).

While quality and relevance of the climate risk assessment is clearly important, it is the interpretation and the application in the decision making process that determines if and what action is taken. Ignoring or wrongly interpreting risk data when making urban decisions can lead to maladaptation, such as creating unnecessary costs today through the adoption of inefficient defensive measures and poorly thought out development restrictions. In turn, this can result in higher future costs.

This underlines the important role that those tasked with compiling a risk assessment need to play with regards to the interpretation of their risk assessments, as described by Krebs: "the role of scientists is to help policy-makers understand how far scientific understanding has evolved in this landscape, and, if there are competing hillocks, to explain why in the clearest possible terms." (p.4850)[17] While achieving an improved 'understanding' of the data is clearly an important aspect, it is the question of 'translating' risk assessments into policy that appears to be the biggest challenge for evidence-based decision making, requiring political judgement by "weaving together scientific evidence, economics and public acceptability of risk." (p.4845) [17]

Throughout any decision-process, there are points where objective risk data meets subjective prioritization and normative judgments, and potentially controversy. Typical examples are the appetite for risk and an understanding of what risk levels may be deemed acceptable, the choice of type and location of flood defenses, and how to balance current development pressure with increasing risk exposure. Existing appraisal tools such as cost-benefit analysis and impact assessments can give decision-makers options of how to respond to risks, but this is not without its challenges. As noted by Smith et. al. [12] "there is a tendency, using current evaluation approaches, for decision-makers to be absent from the evaluation process. (…) No matter how good the analyst, they are invariably working with limited understanding of the decision-drivers and complex interactions that the decision-maker is managing." (pp.117-118).

Indeed, decision-making frameworks designed to support those tasked with local adaptation planning offer little insights on the interplay of climate risk assessment, evaluations and normative decision making, treating them almost as parallel universes, that only intersect at delivery of data or appraisal tools.

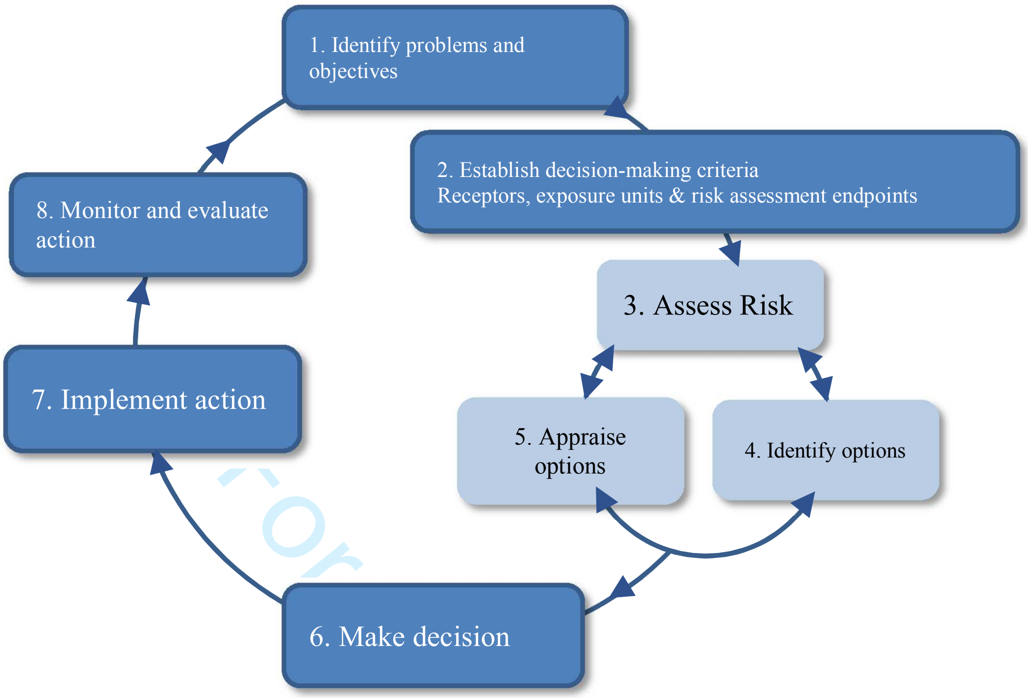
In this paper we investigate the process of translating climate risk data into action for the city level. We apply a commonly used decision-framework from [18] (as applied in [2], and illustrated in Figure 2 below) as our backdrop and explore where in this process climate risk assessment and normative political judgments intersect. We use the case of Cork in Ireland to investigate the challenges arising from normative decision points: In Cork, flooding is already a big issue, and now following detailed local risk assessment, informed and guided by new climate risk data, there are plans to implement a major flood relief scheme (at an estimated cost of €140m euro, and 10-year construction period), but this is proving controversial locally. [19]

Cork is a particularly interesting case as it is very advanced in its climate and flood risk assessment and management approach – with sophisticated risk analytics and high risk awareness as well as extensive participatory structures and approved budgets for flood protection. However, despite more accurate data and an increasing range of theoretical approaches that city planners can call upon to assist with using that data, there are some fundamental challenges that appear to hamper the translation of risk assessment into action. Identifying and embracing those up-front could strengthen the urban adaptation process - this may in fact turn out to be the biggest advantage of climate risk assessment: it offers an opportunity to create a shared understanding of the problem and enables an informed evaluation and discussion of remedial action. If used wisely this 'pulling power' of data can bring together those who make decisions, as proposed in Surminski [20].

2. Using climate risk assessment for urban decision making

The decision making process for adaptation at the urban governance level requires substantial normative decision making both prior to and in response to a climate risk assessment. A standard depiction from the decision theory literature (e.g. [18]) frames the pathway to taking action as a 'decision cycle' (sometimes called the 'policy cycle') (Figure 1).

Figure 1: Different Stages of the 'Decision Cycle'



The risk assessment stage is typically held out as a focal point across the entire decision making cycle. It is taken as the objective point of departure for normative decision making, and introduces key information, often in the form of a menu of scenarios and adaptation measures [2]. Yet the assessment itself is framed by subjective decisions and a host of underlying assumptions, albeit often introduced by outside experts who may be perceived as objective by the decision makers [12]. Such outside experts are themselves guided from the problem statements and the declaration of objectives set out in phase 1, as well as decision criteria in phase 2, with the task of reporting back to those making decisions in phase 6. Importantly, the scale and scope of the risk assessment tends to determine its suitability for specific project implementation. For example it is not uncommon for risk assessments to carry disclaimers about applicability, as was underlined by the Local Authority Adaptation Wizard in Ireland – which provides guidance to local decision makers and suggests for 'risk assessment':

"It is important to note that this step in the tool is designed for a high level risk assessment/risk screening. If you are making important investment decisions or designing a major project, a formal risk assessment will be required as the high level approach presented here will not be detailed enough."
(https://www.climateireland.ie/#/tools/localTool)

The objectives set in phase 1 in the cycle inform the risk assessment's applicability and value for the decision making process. This is however not always clearly established, and in reality, decision makers tend to pursue multi-facetted goals, which may stand in conflict, for example the objective to reduce flood risk and the objective to secure urban regeneration of the waterfront area.

At the urban level, availability and quality of the underpinning data is often a concern: there is often very limited spatial and hazard data at the city level. ([21], [22]) To the extent data does exist, it can be fragmented between different government departments. [23] How to integrate large volumes of complex data into cohesive studies is difficult, particularly as different data sets may not be compatible, often requiring lengthy manual data processing. These data issues can undermine the salience of risk assessment and the overall effectiveness of the decision cycle. Applying global data models to the city level (i.e. 'downscaling') can result in 'coarse assessments' of risk; for example, global models become less reliable at finer spatial scales and may not take into account the unique climatic features of local areas. ([8], [24]) Indeed, climate change projections in general lose certainty at finer spatial scales. As such, this data tends not to be tailored for local usage. However, Dickson et al. [25] have suggested that downscaling can provide a general indication of climate risks at the city level. And Viguié et al. [26] have used data modelling to downscale socio-economic growth at the city level; the intention being to inform policy makers in climate change decision-making. Downscaling also continues at the city and institutional level despite concerns with uncertainty. For example, downscaling has been used by the Asian Cities Climate Change Resilience Network in preparing resilience strategies for Indian cities. [24]

However, projections of future weather patterns from different climate models disagree, and these disagreements tend to be greatest for the kind of information that is most relevant for local climate risk assessment (e.g. short- or medium-term highly localized projections). ([27], [28]) Socio-economic trends, which will influence the impact of climate change on urban areas, also suffer from inherent uncertainty. [29] In fact the climate dimension just adds to the uncertainty derived from the wide range of socio-economic and environmental factors considered, often referred to as the 'cascade of uncertainty' or the 'uncertainty explosion'. ([30], [31], [32]) Jongman et al. [33] showed that vulnerability is an important driver of disaster damage and annual hazard variability alone only explains a minor part of the observed variation in the recorded damage. However, there is often scarcity of reliable data for predicting future vulnerability, as it tends to be highly endogenous to the behaviour of private and public agents before, during and immediately after a disaster. ([6], [34])

The inherent uncertainty that comes with climate risk assessments creates a dilemma for local decision makers who need to incorporate climate change into their plans. Natural responses to this dilemma might be (i) taking a central or 'most likely' scenario and plan accordingly, or (ii) postponing decisions until better information arrives. Unfortunately, ignoring uncertainty by taking the 'most likely' scenario risks maladaptation, such as poor investment decisions and unnecessary retrofit costs, and lock in a degree of irreversible urban development (for example, see Kocornik-Mina et al. [4]). However, waiting for new information may result in policy paralysis, and improvements in the quality of available information (our ability to forecast) is far from guaranteed. ([27], [28], [35], [36]) Regardless, using future predictions may provide a better sense of the consequences of climate change, but may not encourage buy-in for current adaptation planning. Importantly, the extent to which uncertainty affects decision-making depends on the type and context of the decision. In practice, it is not always necessary to accommodate for uncertainty or employ more complex decision-making tools. The first step should be to establish the relevance of uncertainty (of climate change projections) for the decision at hand. [37] Is the decision at hand likely to be sensitive to changes in climate variables, such as rainfall, sea levels and temperatures? Where sensitivity is established, standard decision-making tools (e.g. cost-benefit analysis) will need to be supplemented by additional screening devices. [37] Otherwise, they risk producing misleading evaluations. ([38], [39]]

A range of methods and approaches has been developed to help incorporate uncertain climate change information into local decision-making. Watkiss [40] provides an overview and discussion around these. The methods are categorized into three areas: traditional decision support tools for appraisal, uncertainty framing, and economic decision-making under uncertainty. They mainly offer instruments for phase 4 and 5 in the process – or offer an altogether different perspective on decision making, for example the iterative risk management or mainstreaming approaches. These tools and strategies are summarized in Table 1 below.

Table 1: Strategic approaches to support climate decision making

Approach	Brief Description	Urban Examples
Real option analysis	Treating a range of adaptation options as "real options" in the face of uncertainty and evaluating the merits of both action and inaction in this context.	Dhaka, Bangladesh. [41] Dar-es-Salaam, Tanzania. [41]
Robust decision-making approaches	Generally involves quantitative modelling methods which are informed by stakeholder driven processes. [42] Looks at large numbers of scenarios. [40]	Ho Chi Minh City. [43]
Portfolio analysis	Selecting a portfolio of adaptation options rather than single options and exploring which is most effective in terms of return and uncertainty. [40]. For example, Hunt [44] utilizes portfolio analysis in considering local flood management in the UK.	Shrewsbury and the River Severn, UK. [44]
Iterative risk management	Managing risk over time through monitoring, learning and adjustment rather than making irreversible decisions now. Involves considering the phasing and timing of adaptation.	Copenhagen Cloudburst Strategy
Rule based methods	Reliance on probabilistic data. [40]	Copenhagen Cloudburst Strategy New York City. [45]
Stainforth's "Climate Envelope"	Supports only considering uncertainty if the extremes of climate change projections from available climate models would alter the decision being made. [35]	
Scenario-based impact	Taking a 'science first' approach to climate risk and only then considering	

assessment	adaptation options (e.g. the Stern Review and IPCC Risk Assessment reports).	
'Context first'	Beginning with adaptation as the problem rather than climate risk projections.	Thames 2100 Estuary Project
Mainstreaming (integration)	Integrating adaptation into existing policies and decision-making (rather than as stand-alone measures). Applied in countries like Colombia and Ethiopia. [5]	Bandar Lampung and Semarang, Indonesia. [46]
Cost-benefit analysis	Comparing the costs and benefits of different adaptation options.	Copenhagen Cloudburst Strategy Klaipėda, Lithuania Glasgow, Scotland Aurich, Germany
Cost-effectiveness analysis	Involves analysing benefits in non-monetary terms, but rarely used. [40]	Copenhagen Cloudburst Strategy
Multi-criteria analysis	Analysing costs and benefits in non-monetary terms.	Klaipėda, Lithuania Cork, Ireland
Other quantitative methods	Such as 'known probabilities', 'expected utility', 'expected value', 'unknown probabilities' and 'minimax regret' amongst others. [40]	
Decision Scaling	Links bottom-up vulnerability assessment with multiple sources of climate information [47]	

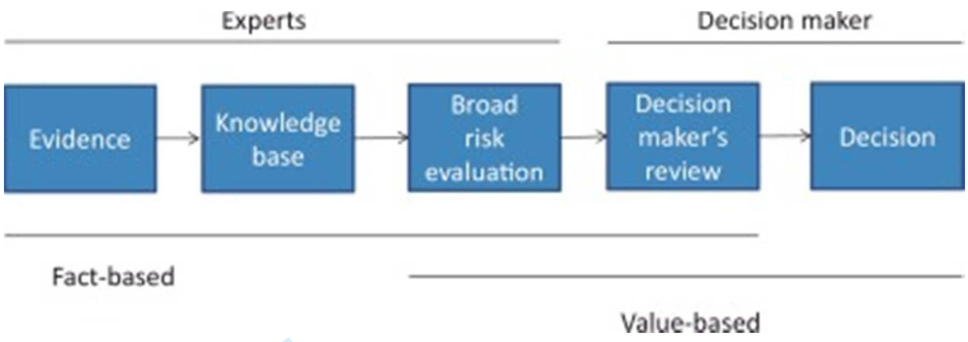
Source: Authors

While the application of these tools remains somewhat limited [40], Table 1 highlights some examples where they have helped urban decision-makers in their quest to understand risks and identify responses. For example, the Copenhagen Cloudburst Strategy, which is designed to mitigate Copenhagen's risk of flooding, is designed so that new projects can be approved annually. These decisions are based on prioritization selection. As such, it involves building flexibility into the decision-making process itself. [48]

In terms of guiding the selection of adaptation options these tools and instruments tend to evolve around some form of economic evaluation, usually based on CBA, which guides appraisal and evaluation. However, this is not without challenges. The highly inter-temporal nature of climate risk makes such evaluations very sensitive to the discounting methodology adopted, and many remain critical of its applicability. This often motivates a departure from standard net-present-value methods, which adopt discount rates from financial markets (e.g. [49], [50] [51]). The inter-generational nature of some risks also creates moral dilemmas that decision makers are often ill-equipped or ill-incentivized to resolve [50]. A succinct discussion of the above issues is given by Smith et. al [12].

Upon delivery of a strategic evaluation of climate risk assessment, decision makers must form subjective judgements and take appropriate action. A growing body of work in the risk management literature has emphasized the difficulties in transitioning from expert (or objective) evaluation to normative (or value based) decision making. For a review see [52] and [53]. Figure 2 (adapted from [53]) illustrates this transition.

Figure 2: Epistemic to Normative Decision making



A key insight of this literature strand is the importance of bridging the "no man's land" between science, expert opinion and policy. To surmount this, the normative nature of the decision should not be eschewed but embraced [52]. The challenge of translating information into action necessitates that decision makers reflect on important criteria for using risk assessments. All of those methods listed in Table 1 will require non-objective judgments, for example about acceptable levels of risk, level of adherence to some 'cautionary principle', as well as current and future societal needs. These choices can be supported by decision making tools and be informed by data, but they will nevertheless require normative decisions.

The question of 'acceptable risk' is perhaps the most clear-cut example of how decision makers must exercise normative judgment before final policy outcomes can be decided. It is by no means intractable per se, but it is (as the Cork case shows in Section 4) distinctly different in that it is explicitly subjective/normative. Some frameworks offer guidance for policy makers on this issue. For example, the ALARP ('as low as reasonably practicable') principle combines risk informed and (pre)cautionary thinking. It typically relies on some principle of gross disproportionality (i.e. adopt risk-reducing measures unless the costs are grossly disproportionate to the benefits). [54] Yet it is unclear if the ALARP framework can guide, or is simply guided by, normative judgments of 'acceptable risk' [e.g. [55], [54], [56], [57]]. If indeed it can guide normative decision making, it is also likely to be frustrated by the deep uncertainties and ambiguities present when facing climate risk. That being said, ALARP may become more useful in guiding normative decision making as the climate risk space becomes more codified (e.g. through safety specification litigation). This was indeed true in the context of Nuclear Safety, which today is highly objective in terms of risk decision making. [17] Another possible framework that has been held as informative for normative decision making in multi-attribute utility methods (MAUT) which "can address the perceptions of all stakeholder groups, facilitating constructive discussion and elucidating the key points of disagreement. It is also argued that by being explicitly subjective it provides an open, auditable and clear analysis in contrast to the illusory objectivity of CBA." (p.207) [54]. It offers a methodology for aggregating a variety of normative beliefs, and as such introduces a form of weighted majoritarian objectivity. However, as with ALARP, it does not directly address the problem of 'translating' risk assessment information into normative decision making.

3. Methodology and case study outline Cork city, Ireland

3.1

This paper builds on the understanding that the nexus between risk analysis and the decision cycle is highly non-linear. While literature underlines the importance of 'salience' of risk assessments for urban level adaption decision making, the question of translating epistemic information (risk assessments, economic evaluation, strategic frameworks) into successful normative decision making requires considerable attention. What follows might be thought of as a guiding discussion of the 'translation' issue, supported by evidence from a recent project addressing flood risk in Cork, Ireland. Whilst we do not provide a holistic framework, we offer preliminary insight for policy makers and researchers alike who seek to tackle this problem. The evidence has been gathered as part of the two-year research project 'Adaptive Responses to Climate impacts (ARC)', which aims to bridge the gap from vulnerability and impact assessments to the formulation of evidence-based local adaptation plans – i.e. moving from phase one to phase two of the adaptation approach adopted under the National Climate Change Adaptation Framework 2012 [58], and the EU's Strategy on Adaptation. Applying a mixed-methods approach the project focuses heavily on stakeholder engagement locally, as well as nationally, to investigate the interplay of risk assessment and economic evaluations with local decision needs.

Table 2: overview of the evidence base and methods

Type of evidence	**Overview of method and approach**
Literature review and development of analytical concept of translating risk assessment into urban decisions.	Analysis of wider academic literature on risk governance and adaptation decision making at an urban level.
○ Adaptation policy documents and guidance: • EU Directive 2007/60/EC • The National Climate Change Strategy, 2007. • Ireland's National Climate Change Adaptation Framework, 2012 [58], and draft 2017 [75] • *EPA's 2012 State of the Environment* report (EPA 2012) ○ Catchment Flood Risk Assessment and Management programme guidance (OPW [71]; Halcrow [60]; Options Report [59]) ○ Local planning guidelines: • Cork City Development Plan 2015-2021 • Regional Planning Guidelines for the South West 2010 – 2022 • The planning system and flood risk management: Guidelines for planning authorities [72]	Document review, key word search to identify role of risk assessment in decision making process
National-level workshop in Dublin (June 2016) reveals key challenges for translating risk assessment into decisions	Focus group discussion
Workshop in Cork (May 2017) and focus group discussion: 1. What has been your experience to date in relation to the use of risk information and climate projections to inform local decision making? 2. What are the key barriers or challenges to incorporating climate change into local decision-making? 3. What is needed to facilitate the use of climate information for local decision making?	Focus group discussion

Face to face interviews and discussions with workshop participants and other key stakeholders throughout the project 2016-2017 including Cork City Council officials (planners/engineers), representatives of insurance, representatives of OPW, Dept. of Communications Climate Action and the Environment (DCCAE), and EPA.	Semi-structured interviews following up on the three topics of the Cork workshop

Initial engagement with stakeholders nationally and locally in Cork provided insights into issues related to flood risk management generally in Ireland, and the development of the Catchment Flood Risk Assessment and Management (CFRAM) process in particular, and highlighted existing barriers to its local applications. We then conducted two sets of focus group discussions at stakeholder workshops - one on national level issues related to data generation, risk assessment and collaboration with the local level held in Dublin in June 2016. The second focused on the local city level, held in Cork in May 2017, with stakeholders discussing their experience with using risk assessment for local decision making. In addition, we held several bilateral meetings nationally and in Cork to follow-up on particular points raised during the workshops, as well as some discussions over the phone.

Participants were invited on the basis of their expertise and/or involvement in the decision making processes locally and nationally, including officials from a number of national Government departments and agencies, and local authorities.

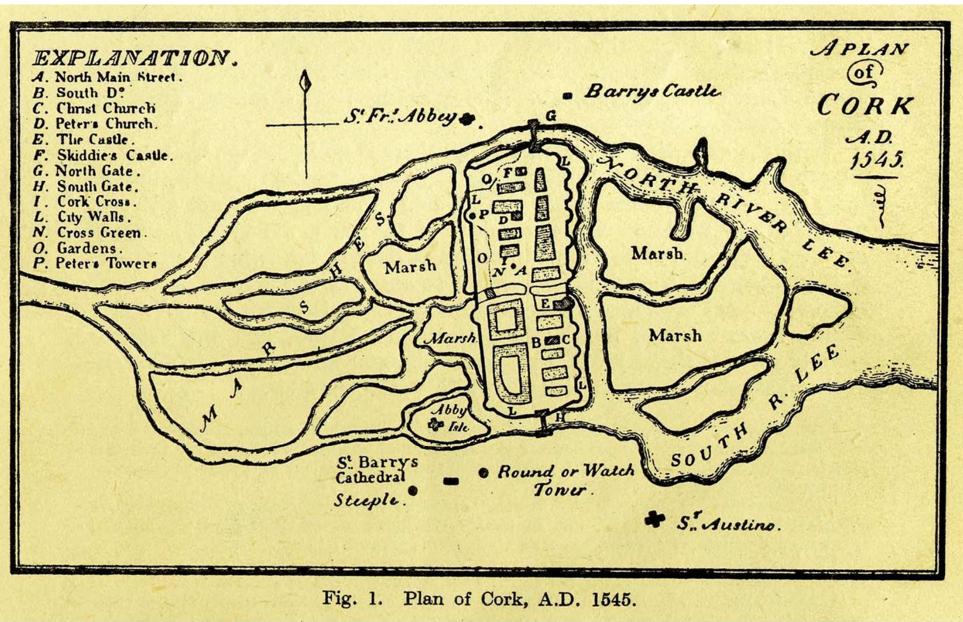
Representatives of groups affected by flood risk and flood risk management/adaptation efforts were also included such as local business groups, experts from the insurance industry, engineering firms, other academics and researchers. In the Cork workshop we explicitly asked the stakeholders to engage with the challenges of translating data/risk assessment into local action. This was supplemented by individual interviews with national and local stakeholders. See Appendix 1 for a full list of organisations represented in our stakeholder engagement throughout the ARC research project.

3.2 The Cork city case study

Cork is Ireland's second largest city, with a population of 125,000. Located in the south-west of the country, Cork city is highly vulnerable to flooding, largely as a result of its geography. The city is located at the mouth of the river Lee, which flows west to east through the city, dividing in two to the west of the city centre, merging again to the east of the city as it flows out to sea. Much of the city centre is low-lying and exposed to both fluvial and tidal flooding events. In fact, the Irish (Gaelic) name for Cork is Corcaigh, meaning bog or marsh.[1] Early maps of the city from the 16th century show large parts of what is now the city centre marked as 'Marsh' or 'Marshes' (see [Figure 3]).

1 Corcaigh comes from the word 'corcach' (or corcass, see http://www.tearma.ie/Search.aspx?term=corcach), which means a marsh or mud flat along the bank of a tidal river (https://www.merriam-webster.com/dictionary/corcass).

Figure 3: Historical map of Cork city (1545).



Source: Cork City Council [61]

Cork has experienced frequent flooding throughout its history; some 292 floods were reported over the period 1841-1988. [62] In more recent times, floods causing damage to property in the city occurred in 1996, 2000, 2009, and 2014. [63] The floods of 2009 in particular were one of the most severe ever to hit the city. ([64], [65]) Insurance claims for this one event are estimated at €244m.[2] While the 2009 event was a result of fluvial flooding on the river Lee, Cork is also exposed to sea-level rise and the city already suffers regular tidal flooding. Recent scientific estimates suggest that global mean sea level could rise by over 2m by 2100 (see e.g. [66]; [67]). For a given amount of global mean sea level rise, the local (or relative) rise experienced will vary considerably in different parts of the world, due to a range of factors including land subsidence, tectonics, changes in ocean circulation, groundwater pumping and dredging ([70]; [69]). In the case of Cork, much of the city core is low-lying, while the city is located in a geological zone that is gradually sinking (see Shennan et al. [70]), which will exacerbate the local effects of global sea-level rise (see Kopp et al. [69]).

2 Estimate provided by the insurance industry representative body Insurance Ireland.

Exposure to flooding in Cork has recently been assessed as part of the Irish government's Catchment Flood Risk Assessment and Management (CFRAM) project, overseen by the Office of Public Works. [71] In addition, local planning policies are the responsibility of the Local Authorities (City and County Councils), in accordance with guidance from national government, in particular the 2009 Guidelines for Planning Authorities [72], as well as national planning and spatial development guidelines.[3] More generally, guidelines for adapting to climate change are outlined in the National Climate Change Adaptation Framework, which is currently being updated. ([73], [75]) Local and sectoral adaptation plans are also being developed as part of this (statutory) update.

The Lee Catchment (the river catchment surrounding Cork city) was chosen as the primary pilot project of the national CFRAM programme, beginning in August 2006, with a final report produced in 2014. [60]

The decision-making framework applied in the Lee CFRAM study (see Figure 1-2 in [60], p.4) involves six main stages, as follows:

(i) Set flood risk management (FRM) objectives
(ii) Establish decision-making criteria (indicators, targets, assessment units)
(iii) Assess risk
(iv) Identify measures/options for managing risk
(v) Assessment of measures/options (combining benefit-cost and multi-criteria analysis)
(vi) Make decision and prepare plan

These steps are very similar to those depicted in the decision-cycle framework in Figure 1 above. Appendix 2 provides a detailed overview of how those six steps have been pursued in Cork city.

Given the city's exposure to flooding, and the costly impacts of recent flood events, the area has been prioritized as part of the Irish government's flood risk management efforts. A major flood relief scheme for the city is now planned, which will take ten years to complete, at an estimated cost of €140m. The flood relief scheme plans have been formulated and evaluated as part of the Catchment Flood Risk Assessment and Management (CFRAM) project.

This decision making process as carried out for the case of Cork appears to be a textbook example, which follows closely a standard decision framework, as set out in Section 2. However, in spite of the detailed risk assessment that has been carried out, and a process of public consultation[4] on the selection of options for managing flood risk in the city, the proposed scheme has proved controversial with a concerted local campaign now opposing the proposals. ([19], [76])

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3 The latest national spatial strategy "Ireland 2040 – Our Plan" is currently under development/consultation. As part of this process a Strategic Flood Risk Assessment Report has been produced, which details how the planning guidelines on flood risk management are to be incorporated into the new national spatial strategy. [74]
4 For details see Section 2.2.3 and 2.2.4 of Halcrow [60] and also Section 3 of the 'Options Report' [59].

In parallel to the development of flood risk management options, the other policy field where the risk assessment could have an impact is planning policy. In Ireland, national level guidance on managing flood risk feeds in to regional level planning guidelines (e.g. Regional Planning Guidelines for the South West 2010 – 2022), which in turn feed in to the development of local development plans (e.g. Cork City Development Plan 2015-2021). The local context for planning decisions in Cork is set out in the Cork City Development Plan (2015-2021- Vol 1), one of the goals of which is "to mitigate and adapt to the challenges of climate change such as the increased risk of flooding through the design, layout and location of appropriate land-uses" (Goal 6). The city development plan also makes reference to the national planning guidance in relation to flood risk management, which advocates the 'sequential approach' when considering development proposals, i.e.:

- Avoid: Preferably choose lower risk flood zones for new development.
- Substitute: Ensure the type of development proposed is not especially vulnerable to the adverse impacts of flooding.
- Justify: Ensure that the development is being considered for strategic reasons.
- Mitigate: Ensure flood risk is reduced to acceptable levels.
- Proceed: Only where Justification Test passed. Ensure emergency planning measures are in place. [72]

The guidelines also note that "with climate change, the frequency, pattern and severity of flooding are expected to change, becoming more uncertain and more damaging". [72] Given the degree of uncertainty in relation to the potential effects of climate change, a precautionary approach to planning is advised, including:

- "Recognising that significant changes in flood extent may result from an increase in rainfall or tide events and accordingly adopting a cautious approach to zoning land in these potential transitional areas;
- "Ensuring that the levels of structures designed to protect against flooding, such as flood defences, land-raising or raised floor levels are sufficient to cope with the effects of climate change over the lifetime of the development they are designed to protect;
- "Ensuring that structures to protect against flooding and the development protected are capable of adaptation to the effects of climate change when there is more certainty about the effects and still time for such adaptation to be effective". [72]

4. Analysis -- challenges and barriers in translating risk assessment into local action at the city level

In this section we investigate the issues and challenges that arise in the translation of risk assessment into local action at the city level, drawing on experience from the case study of flood risk management in Cork city. During our stakeholder work there was widespread acknowledgement that more and more data is being created and made available, and that the available data and risk analyses are becoming increasingly detailed and complex, and include a growing emphasis on local precision in risk assessment. The CFRAM process, for example, has been praised for the level of detailed local assessment that has been conducted, and the outputs of the project – in particular the flood risk maps -- clearly represent valuable contributions to the understanding of flood risk at a highly localized level. These assessments are now being used by the OPW as the basis for formulating flood risk management plans for the study area(s). However, in spite of these extensive efforts, the selection of preferred options for managing flood risk in Cork has not been without controversy, while it is also not clear to what extent the new risk information is being incorporated into decision making by stakeholders outside of the agency responsible for flood risk management (who created the risk assessments).

Whereas in Section 2 we outline the theoretical problems of data 'salience' and 'translating' information from risk analysis into normative policy action, in this section we use the case of Cork to analyse factors revealed to be crucial to success at this local level. First, we briefly comment on the 'salience' of the data utilized in the Cork case study. Next, we highlight where in the decision-making cycle key normative choices arose in the case of Cork. We then discuss barriers to translation – specifically the political, communication and engagement barriers - that were highlighted during the Cork case.

4.1 Normative choices

The decision-making process described in Section 3 represents a scientific exercise, with risk assessment and option evaluation informed by detailed observational data, risk modelling, and the rigorous application of project evaluation techniques. This has not made the process immune from criticism, however. A number of these criticisms relate to normative choices – for example in relation to risk, the treatment of extremes, setting of objectives and targets, and how these are evaluated ([19], [77]). In this section we highlight normative choices that arise as part of the decision-making process, illustrating for the case of Cork where in the process these choices occur.

i) Social appetite for risk

The definition of an appropriate or acceptable level of risk is a particularly tricky issue, from a number of perspectives. Various stakeholders in Cork raised the concern that there appears to be a very low risk appetite amongst the general public, but also from private sector e.g. business groups and the insurance industry. It was suggested that there is an expectation that flood defences would provide complete protection such as to rule out the possibility of flooding occurring. This was seen as unrealistic and likely to impose unreasonable costs, which in turn might constrain development of the city.

In relation to planning decisions, in attempting to translate national guidance into practice at a local level, questions naturally arise about what precisely is meant by a "cautious approach", and how "acceptable" risk levels are defined (and by whom). The national level guidance also conveys a sense of strong risk aversion, e.g. in the advice to "[ensure] that the levels of structures designed to protect against flooding … are sufficient to cope with the effects of climate change over the lifetime of the development". [72] A normative judgment is required when determining what "sufficient" means in this context. Furthermore, ensuring that protective structures are "sufficient to cope with the effects of climate change" requires that the effects of climate change are known. A local planner might justifiably ask what effects should be planned for, and where she should find such information.

Normative choices in relation to the treatment of risk arise in the decision making process for example when deciding on the scenarios to analyse, and the treatment of extremes. The flood risk assessment for Cork included analysis of current flood risk as well as two future scenarios (mid-range and high-end scenarios, as detailed in Appendix 2). However, the proposed flood relief scheme has not been immune from the charge that it will prove inadequate in the face of more extreme future scenarios. A group opposed to the proposed scheme – 'Save Cork City' -- has raised fears that the scheme could potentially put the city at greater risk in times of flood, with any failure of the system likely to have catastrophic results. ([77], [78])

The treatment of extremes in flood risk management decision making processes is made all the more critical by two additional features of this public policy challenge: (i) the uncertainty surrounding the future effects of climate change on flood risk, and (ii) the effect of flood risk management strategies on future exposure to risk – for example where flood defences stimulate further development of defended areas (moral hazard risk) – see e.g. McDermott [37], and Hallegatte and Rentschler [79], on the need to consider 'worst case scenarios' in developing risk management strategies. Smith et al. [12] also note that standard evaluation techniques (such as cost-benefit analysis) tend to report the 'expected value' of project costs and benefits – i.e. the weighted average over all contingencies (where weights represent the probability of a given outcome), without consideration of the option value or insurance benefit of particular options.

ii) Defining objectives, targets and evaluating performance

Normative questions also arise in relation to the objectives of flood risk management. For example, the multi-criteria analysis approach used to evaluate options for dealing with flood risk in Cork enables the combination of targets measured in different ways (including social, environmental as well as economic objectives), but there is controversy over competing priorities and differing perspectives on what should be given precedence. Ultimately many of the decisions are down to choices and prioritizations.

In any risk management decision process, normative choices clearly arise in relation to the definition of objectives and targets, as well as at the point of drawing up lists of options for managing risk and evaluating these against defined targets. While it may be possible to draw up lists of options, objectives and targets that encompass a wide range of viewpoints, deciding on how these are evaluated – particularly in relation to the scoring and weighting of individual objectives – clearly represents a subjective judgement, and individuals or groups might reasonably disagree on the prioritization and/or evaluation.

For example, the Save Cork City campaign has strongly criticized the flood relief scheme proposals for not taking sufficient account of the potential impact on cultural heritage and visual amenity in the environs of the river. ([77], [78]) While cultural heritage was included as one of the 'environmental' objectives in the assessment of options for managing flood risk in Cork, it was given a relatively low weighting in evaluation. This raises the issue of differing views on how to evaluate outcomes, and how to incorporate local preferences into the decision making process.

There is of course no objective way to decide whether cultural heritage should be given precedence over economic or other considerations; this requires input from affected communities.

iii) Equity – distributional issues and discounting the future

An important normative choice in any project evaluation is how to value future costs or benefits. Discounting is commonly applied to allow comparison of future values with today's investment. However, as noted by Smith et al. [12] applying standard discount rates often means that costs or benefits occurring more than 25-35 years into the future are given minimal value in evaluating options. This has important consequences for disaster risk management strategies, given that more extreme (low probability, high consequence) events may not be 'expected' to occur within this limited timeframe and so are implicitly given little consideration in the evaluation.

In response to these concerns, it has increasingly been argued that discount rates for long-term investment projects (e.g. those evaluated over more than 50 years), or those with inter-generational effects, should be allowed to decline over time – as is now the case in the UK ([80]; as cited in [12]).

These choices have non-trivial impacts on the evaluation of flood risk and options for managing that risk, as highlighted in the case of Cork. A reduction in the discount rate applied in the benefit-cost analysis from 4% to 3% was found to increase uncapped damages in one location by 19% (capped damages by 6%). In relation to varying the future scenarios considered, an increase in sea levels of 0.55cm was found to increase damages for the areas affected by tidal flooding by an order of magnitude (from approximately €70m to over €880m). In combination, these choices over discount rates and the specification of future scenarios to consider in the analysis, might lead to very different outcomes of the evaluation process.

Distributional issues can also present barriers to action. In the case of flood defences their benefits are highly concentrated (in the flood prone areas), while their costs (both financial and amenity or environmental) are likely to be more diffuse across the local community, or even nationally. Such distributional effects can lead to distinct 'camps' in favour or opposed to a particular set of risk management proposals – as appears to be the case in relation to the proposed flood relief scheme for Cork.

The distribution of costs related to the inclusion of flood risk in the planning process was also noted in stakeholder discussions in Cork. Where development is proposed in a flood-prone area, a flood risk assessment must be carried out and measures for coping with flood risk detailed in the planning application, before permission is granted. In practice this might mean raising floor levels or implementing other flood protection measures on-site. As noted above, national level guidance advocates that such measures should be "sufficient to cope with the effects of climate change over the lifetime of the development they are designed to protect". [72] But concerns were expressed by stakeholders (including local authority officials and representatives of local businesses) about the potential costs involved in implementing these policies – particularly where large allowances have to be made for the uncertain impacts of climate change, resulting in more costly measures being required -- and how those costs should be distributed across different actors (from both public and private sectors).

"[The national planning guidelines] make frequent reference to the need to take a precautionary approach, particularly with respect to the potential impact of climate change. Now that's relatively easy to put down in a document, but how do you actually apply that, particularly where the decision could have very significant impacts in terms of land values and so on."
- (government official, statement made as part of focus group discussion at Cork workshop, 9 May 2017)

4.2 Political realities

The literature on disaster risk management and climate change adaptation has increasingly advocated a shift towards a 'resilience' perspective (see e.g. Smith et al. ([12]; Mechler [81]; Fankhauser and McDermott [82] ; Surminski and Tanner [83]). As noted by Smith et al. ([12], p.114), this approach requires "a governance system that promotes monitoring of decision outcomes, re-evaluation, and a willingness to experiment and innovate". However, these authors also point to the political challenges implied by such strategies; because of the difficulty of communicating to the general public the need for revision and re-evaluation, the danger that this may be interpreted as failure, and the extended timeframes involved in such an approach.

Flooding is already a politically sensitive issue in Cork. Aside from the emerging controversies over the selection of the preferred option for a flood relief scheme in the city, there is also the related issue of flood insurance availability, with local anger reflected in increasing political attention on the issue (see [20]). While the process of risk assessment and evaluation of options for flood risk management in Cork, described previously in Section 3, has been non-political, ultimately the decision on whether or not to implement the preferred option rests with central (national) government. It is clear that political capital and reputations are at stake:

***"**Cork cannot wait any longer for flood relief - but the right solution has to be found."*
- (statement attributed to Kevin Moran, Junior Government Minister at the Office of Public Works (OPW) the state agency responsible for flood risk management, as reported in local media, 26 July 2017) [5]

At the local city level, decisions are being made daily with far reaching consequences for flood risk, in particular in relation to planning and land-use decisions, which may

[5] Evening Echo, 26/07/2017. Available at: http://www.eveningecho.ie/corknews/Cork-flood-defences-cannot-be-delayed-further-6fd0a9d6-f71c-47dc-beae-39d966a1e181-ds [accessed on 6/10/2017].

lock-in exposure to risk for the long term. Planning guidance at the national level rightly advocates a precautionary approach, particularly given uncertainty over the precise effects of climate change on local flood risk. But with numerous competing pressures -- not least the need to provide accommodation for a growing population, while also meeting other goals of good urban planning -- decisions cannot always be postponed until uncertainties are reduced.

"[The city is] looking for expansion into areas to provide employment. So the urgency is to do it yesterday. The balance of that is that we need to have better planning. We need to have better building design. We need to have better building resilience."
- (local business representative, statement made as part of focus group discussion at Cork workshop, 9 May 2017)

It was also noted by stakeholders that "local authority plans are ultimately decided on by the elected members" – in other words, by politicians.

In practice, the general principle of avoiding development in flood prone areas is applied. However, in the case of Cork this is particularly challenging given the city's geography, with much of the city, including large parts of the urban core, vulnerable to flooding. In addition, established areas are generally given a derogation from this restriction, with precedent being set by existing use. This practice further underlines the long-term implications of planning decisions – once development of an area is allowed, the precedent is set. This potential for locking-in of risk for the long-term increases the sensitivity of decisions to uncertainty in risk assessment.

There is a mis-match between the long-term implications of planning decisions and the reality of political time horizons, noted as a potential barrier to actions aimed at managing risks in the long-term:

"Lots of decisions were made because of political cycles which tend to be short-term."
- (government official, statement made as part of focus group discussion at Cork workshop, 9 May 2017)

Stakeholders were mindful of the difficult position facing local decision-makers:

"We have to, I think, be understanding of the challenges [faced by] local authorities, in terms of their competing demands"
- (local business representative, statement made as part of focus group discussion at Cork workshop, 9 May 2017)

While political realities clearly create challenges for long-term risk management and climate adaptation, the current situation in Cork also presents opportunities for advancing local decision-making processes. The controversy over flood defence proposals demonstrates that there is significant local public engagement on the issue, which has ensured that political attention is also focused. There is a strong enabling environment being created by national level policy, while public engagement in

Ireland on issues related to climate change has recently been demonstrated by the Citizens Assembly.[6]

In interviews and focus group discussions most stakeholders in Cork acknowledged that successful flood risk management strategies would require engagement and buy-in of the local community. One simple proposal that we heard (suggested by technical experts working in the insurance industry), aimed at raising awareness around flood risk, was to erect public markers around the city showing the heights of flood water from historical flooding events, as has been the practice in other cities.

More broadly, a point that emerged from the discussion in Cork is the need for narratives around climate risk and adaptation in order to achieve action. This point was made for example, by a government official, during focus group discussions at the Cork workshop on 9 May 2017. As seen elsewhere, the need to address risks is mostly considered in a negative sense, as a possible constraint on growth, and a barrier to development. However, a negative narrative is unlikely to capture the imagination of those tasked with future strategies for the city. As such the business organization 'Cork Chamber' does not make any references to flooding nor climate change in its submission on Ireland's draft National Planning Framework 'Cork 2040: Our vision' (March, 2017). Instead, there may be value in a more positive narrative around flood risk management, presenting this as a sign of city strength and community cohesiveness. This positive notion of climate resilience is gaining more traction, as highlighted by the 'triple dividend of resilience concept' [83], which shows climate and disaster risk reduction as investments that can bring a range of co-benefits to locations such as Cork.

4.3 Communicating the science:

i) Transparency, usability and interpretation of risk information

"Data in itself is no bloody good unless you're analysing it properly"
- (local business representative, statement made as part of focus group discussions at Cork workshop, 9 May 2017)

There is a large and increasing volume of data available related to flood risk, climate change and projections[7], including extensive efforts to assess flood risk at a local scale (e.g. via the CFRAM programme). But is all of this enough to ensure better informed decisions are being made locally? There is a danger of data overload. Concern was repeatedly expressed during the focus group discussions (for example by other academics not involved directly in our research, and by local authority officials)

[6] The Citizens Assembly is an 'exercise in deliberative democracy', made up of 100 ordinary Irish citizens, deliberating on a set of pre-defined topics and making recommendations to government. It spent two weekends recently (30 Sept – 1 Oct and 4-5 Nov, 2017) considering the issue of "How the State can make Ireland a leader in tackling climate change". See https://www.citizensassembly.ie/en/How-the-State-can-make-Ireland-a-leader-in-tackling-climate-change/ (last accessed on 2 March 2018).
7 As an example, Met Eireann – the Irish national weather service – has recently moved to an open data policy. However, even in terms of practicalities this presents challenges given the sheer volume of data involved. One recent reanalysis project alone reportedly generated some 150 terabytes of data.

that decision makers end up drowning in data, while other stakeholders – including the general public – are turned off by the seeming complexity (and uncertainty) of the data and risk assessments, and as a result are more likely to disengage from local decision-making processes.

Broadly speaking, a major challenge in relation to the use of ever more complex and detailed data is in relation to how that data is used and interpreted. The available scientific data also need careful interpretation. This requires expertise at local level and close interaction between the science and the decision maker to help interpret the data. This should include transparency on limitations and usability of the data. For example: what data can be used for which decisions? There may be a risk of over-interpretation.

> *"The danger … is they're only possible scenarios, but … people who don't understand the context of why they were produced may see them very black and white. So, for example, on the flood zoning I've seen instances where local authorities take the view, if you're in a flood zone … thou shall not develop. If you're in [a less risky area] build whatever you like. And actually that's only a line on the map and the reality of it is that essentially some areas are very sensitive to the climate change scenario, whereas others aren't. So a different approach is needed in those areas."*
> *- (government official, statement made as part of focus group discussions at Cork workshop, 9 May 2017)*

There is also a danger of creating a false sense of precision, particularly since a finer spatial scale of assessment (e.g. the urban context of Cork, Ireland) very often comes at the expense of greater 'deep' uncertainty in relation to the effects of climate change hazards.

Increasingly detailed and complex data and risk assessments can also be a source of controversy, creating a barrier to action, as opposed to acting as an enabler for local decision making. In the Cork case study, this has been apparent in controversies over, for example, the expected costs of alternative proposals for flood relief interventions, in relation to the visual impact of proposed defensive structures, and in relation to the potential effects of climate change.[8]

These issues appear particularly acute where there is no shared understanding of risk, and where the data and methods used to assess risk are not transparent and easily understood by the end user and other relevant stakeholders.

The academic literature emphasizes that in order for evidence to result in effective decision making, particularly at the local level, it must be salient – i.e. the information produced must be relevant to decision makers. [16] This might be particularly relevant for local decision making, which is also subject to a political process:

8 Junior Minister at the OPW, Kevin Moran, has been critical of 'misinformation and scaremongering' that has dominated the debate on the defences so far. "There is some wrong information out there in the public and we have to correct that. People are afraid that the city will be cut off, but I am only 5 ft 3 and many of the walls don't even come up to my waist". [84] See also Irish Examiner [85].

"We need to somehow make the information … easily understandable … Local authority plans are ultimately decided on by the elected members. Many of them won't have technical understanding of it (how climate change affects local risk levels)."
- (government official, statement made as part of focus group discussions at Cork workshop, 9 May 2017)

As well as the need to change the way that risk is perceived in relation to planning for the longer-term:

"A real difficulty for planners and local authorities [is] to make that change [of] mind-set from an assumptive approach where it's very comfortable to say, look we've planned for sea level rise X to well you need to consider your decision in the context of where we might be and when we might [get] there, because … the development has a lifetime of 50 years. Well are you making decisions then for 50 years or making it for 100 years? If we build this now what's likely to happen as a consequence following on?"
- (government official, statement made as part of focus group discussions at Cork workshop, 9 May 2017)

ii) Framing of uncertainty in relation to climate change

"The difficulty is people are comfortable when they have a scenario. People are probably less comfortable when there are a number of possible scenarios, particularly [local] decision makers."
- (government official, statement made as part of focus group discussions at Cork workshop, 9 May 2017)

An important barrier to translating risk assessment into decisions at the local city level appears to be in relation to the framing of uncertainty. One comment during a stakeholder workshop was that climate change was being used as a "grenade" in public debates over flood defence proposals; because the effects of climate change on flood risk are perceived as being so uncertain, climate change can be invoked to support almost any position, or in order to dismiss particular options (for example by claiming that a particular proposal would be totally inadequate to cope with the effects of climate change). As an example, we heard an anecdote in relation to debate over a proposal for a tidal barrier in Cork; one assessment of the proposal suggested the barrier would only become viable (in benefit-cost terms) for sea level rise of at least one meter. A proponent of the barrier argued that "you're saying it needs to be a metre but everyone knows it's going to be six metres [of sea level rise] so you need a barrage", to which a critic of the proposal pointed out "if it's six metres a barrage is going to be no good to you."

More generally, there was a perception that the very phrase 'climate change' had become such an emotive term as to become a barrier to constructive debate:

"It strikes me the very moment you use the word[s] climate change it's such a loaded term that emotion comes into the discussion and logic has gone out the window." … "Using the words climate change just poisons the discussion. [It is] such a polarised, emotional and loaded term".
- (academic researcher (not involved in the research project), statement made as part of focus group discussions at Cork workshop, 9 May 2017)

4.3 Engagement and participation (at the local city level)

"Almost everyone who has spoken today has paraphrased in a different way the importance around the actual decision making process having buy-in in order for us to make the right decisions"
- (local authority official, statement made as part of focus group discussions at Cork workshop, 9 May 2017)

Given the concerns outlined above in relation to uncertainty, and the questions raised about how acceptable levels of risk are defined, and by whom, a practical response may be to provide greater transparency (or more effort at communicating to the public) about how risk categories are chosen in risk assessments, how objectives are defined and criteria created for scoring these. This process is likely to benefit from greater participation of stakeholders – in order to secure buy-in and support for the objectives and criteria to be used in the risk assessment from the outset. One of the criticisms being raised by opponents of the flood relief scheme proposals in Cork is a lack of engagement on the part of the authorities; this in spite of a process that has involved a number of phases of public consultation (including public awareness and information days, briefings for elected representatives and business groups and public exhibition of the preferred option).

During our focus group discussion as part of the Cork workshop, technical experts working in the insurance industry and government officials also referred to the problem of short communal memories in relation to historical episodes of flooding and its impacts. In order to generate public buy-in for any response to flood risk, there needs to be an appreciation of the potential damage and disruption that flooding can cause, in order to motivate intervention.

One specific problem that emerged during discussion with stakeholders is the lack of in-house expertise at the level of local decision making to process and analyse complex climate risk data.[9] This issue has been recognized by government in Ireland, and in response part of the process of translating national level guidance on climate change adaptation to the local level has included training sessions and regional workshops for local authorities [86], as well as guidelines and an online tool to assist with preparation of local adaptation strategies. [87] [75]

But this still might not be enough to generate behavioural change. Taking pre-existing scientific information and attempting to apply it to a decision may not be effective;

9 It was also pointed out in relation to the local authorities, that there is "a lot of expertise there, maybe not in terms of accessing the climate data … but actually in terms of decision making on key infrastructure projects, decision making on planning issues and so forth that is very relevant."

"people also need cognitive representations (or 'mental models') of the processes creating and controlling the risks, and thus causing uncertainty about them". [[88] pp.37-8] This enables participation in public debate and evaluation of alternative policies and ultimately affords people "the warranted feelings of self-efficacy needed before acting". [88] (pp.37-8) This point was also acknowledged by stakeholders in Cork:

> *"It's hugely important that the local councils [work] with the likes of OPW ... in terms of how they develop their plans so that they have a degree of understanding and knowledge, rather than just being the filter to the information and then saying, this is what we suggest you do."*
> *- (local business representative, statement made as part of focus group discussions at Cork workshop, 9 May 2017)*

The issues highlighted here seem to point to the idea of the need to "co-create" data together with stakeholders, to generate a shared understanding of risk and encourage greater participation, and buy-in from the general public in order to facilitate constructive debate on the options for dealing with climate risk locally. In this context a risk assessment has some 'pulling power', bringing together different stakeholders with varying views on risk and how to manage it. This may in fact turn out to be the biggest advantage of climate risk assessment: it offers an opportunity to create a shared understanding of the problem and enables an informed evaluation and discussion of remedial action. Far from being an objective study, a risk assessment can house a variety of subjective perspectives and serve as a salient focal point for the entire normative decision-making process. Put differently, a risk assessment should leverage the 'pulling power' of data which brings together experts, stakeholders and normative decision makers to achieve optimal adaptation to flood risk levels in Cork [20].

5 Conclusions

The example of Cork illustrates the complexities of translating risk assessment into local action. The city appears to fulfil all the usual criteria for supporting urban action: there is significant awareness of the problem and a broad acknowledgement of climate change; regular flooding acts as reminder of the urgency and scale of the risks; technical experts at local and national level engage in seeking solutions; there is allocation of funding for flood risk management work; and a wide involvement of researchers and local stakeholder groups in this discourse. In addition, risk assessment data is available, in particular through the CFRAM programme, which has included a detailed local flood risk assessment for Cork city and the surrounding area. Furthermore, local city officials have guidance on how to use the data for policy decisions, for example in the context of planning, while there are a range of theoretical approaches that city planners can call upon to assist with the process. However, as highlighted by the Cork example, it is the interpretation and the application of those that determine if and what action is taken.

A risk assessment can provide the necessary evidence and assist those tasked with making these relevant decisions, but it also needs local buy-in. In the case of Cork we note a general willingness to engage with and consult risk because the flood risk challenge is so evident and flooding in the city a regular occurrence. However, even then there are conflicting priorities, as seen with urban planning decisions. Given this challenge, any notion of uncertainty or lack of evidence around the consequences of climate change and impacts on flooding can negatively impact the buy-in of urban planners (for example, see Carter et al. [14]), as well as the general public (as noted in our stakeholder discussions). Uncertainty in relation to the effects of climate change on future risk need not be a barrier to action; there are now more and more examples of how to make decisions under uncertainty, as outlined in Section 2, as well as a growing number of examples of climate risk assessments in cities where uncertainty has not been treated as a barrier to urban adaptation. For example, in the Cloudburst Management Plan in Copenhagen, Denmark, additional calculations were conducted based on Finance Ministry guidelines to illustrate the uncertainties. And a study into uncertainty around flooding in Odense, Denmark, concluded that climate change uncertainty may not necessarily have a significant impact on the net present value of different adaptation measures. [89] This underlines the idea that uncertainty related to climate change will be more relevant for some decision contexts than for others – a point that was also highlighted by stakeholders in Cork. However, the presence of uncertainty must be acknowledged openly and its relevance to the decision at hand assessed and communicated clearly both to end-users (decision-makers) and the broader public, in order that uncertainty does not become a "grenade" in local debates, used to undermine any proposed interventions.

Equally important is transparency and clarity on data limitations as a means of defusing controversy and tension over identifying risks and selection of risk management options. Otherwise, risk assessments and risk data provision can turn into political discussions – for example in the US, where the introduction of new flood maps from the federal government was met with refusal from some local authorities, who claimed that the underlying risk assessment was flawed and the resulting maps inaccurate and would lead to loss of development land for the local communities. [90] Therefore, clarity on data limitations is important to avoid misinterpretation and misuse. This explains the sensitivity around releasing new risk data and risk assessment and the often-lengthy list of caveats and health warnings. However, this can also deter some from using available information. A shared understanding across stakeholders is important to reduce controversy, mistrust, or division. One point raised in Cork, and currently explored across Ireland (for example through Climate Ireland [89] or Met Eireann), is the need for a boundary organization to facilitate creation of a shared understanding of risk, and assist those tasked with risk assessment in engaging with end-users and other stakeholders. Co-creating risk data with users and jointly codifying and standardizing data could be important steps in diffusing controversy and achieving greater transparency. Making data available is not sufficient.

These last two points – on uncertainty, and on limitations of data – represent important future challenges for researchers (and practitioners) engaged in climate risk assessment; to find meaningful ways of communicating to non-specialists how risks are anticipated to evolve in future – both as a result of climate change, and due to other risk drivers including socio-economic factors – without shying away from a frank presentation of the uncertainties and limitations inherent in any such forecasts.

[17] An important component of responding to this challenge will likely require a greater degree of interaction between the data scientists and the end-users.

This underlines the importance of participation of end-users in the whole process from data generation, and risk assessment to decision making. Generally speaking, most climate change risk assessments conducted at the city level have placed significant emphasis on the participation of a broad range of stakeholders. Encouragingly, this point has gained prominence in Ireland and is increasingly embedded in policy documents and official guidelines (e.g. the latest version of the National Adaptation Framework, Local Authority guidelines, and the Climate Ireland platform [89]), which now promote a participative approach to adaptation planning. Some international examples, noteworthy for their inclusion of stakeholders, are the development of complex embankment and dyke systems in the Smeltalė River, Klaipėda city [91], or coastal planning in Aurich, Germany, which focused heavily on stakeholder interviews [92]. Stakeholders assisted with identifying the risks, identifying possible courses of action for dealing with major issues (e.g. clay-and-sand abstraction), and expert interviews into the results of the project. [92] And a project to reduce the risk of Nigmejen, Netherlands, to flooding by increasing room for the river involved the inclusion of stakeholders and the local community through newsletters, information meetings and interactive workshops. The inputs received at these workshops were used to adapt flood protection plans for Nijmegen and the Lent. [93] We also note related research in Ireland that has demonstrated the potential of scenario analysis [94] and integrated coastal management [95] as participative decision tools or mechanisms for delivering action on local adaptation.[10]

Participation is clearly important with regards to the normative decisions that occur during the translation of risk assessment data into action, for example when setting 'acceptable risk levels' and identifying 'adequate' protection levels, which can lead to controversy over competing priorities and differing perspectives on what should be given precedence. This can be a challenge but also an opportunity: controversy brings engagement, which in turn can also help to focus political attention. As such the normative decisions required for local action should not be seen as insurmountable road blocks, but as necessary intersections. Those tasked with preparing risk assessment and evaluation of options should recognize this early on. Importantly, the challenges that we have identified are not insurmountable; embracing these challenges up front, fostering greater participation of stakeholders and decision-makers earlier in the process, the co-creation of data, and generating buy-in from the local community, represent potentially powerful responses. These types of initiatives will not be without costs (in terms of both time and resources), but may help to avoid or reduce the kind of controversies we have observed in the Cork case study, which risks derailing the decision-making process and delaying adaptation actions at the implementation stage.

Finally, an important, but often overlooked aspect is the need for narratives to bridge the gap between risk assessment and normative decisions: risk management tends to come with a negative connotation. In Cork, for example, we noted that a local business association did not make a single reference to flooding nor to climate change

[10] We thank one of the anonymous referees for pointing us to these references.

in its recent submission on government planning policy, *Cork 2040: Our Vision*, giving the impression that flood risk management, and adaptation to climate change more generally, have no place in the articulation of a city's future aspirations. Challenging this mind-set is an important task in responding to the risks of climate change. During our stakeholder discussions, the value in presenting a more positive narrative around flood risk management was acknowledged; the ambition of achieving climate resilience might be seen as a sign of city strength and community cohesiveness. Creating that kind of shared vision of a climate resilient future at a local level could be an important first step to generating the buy-in and engagement that appears crucial to navigating the challenges we have identified in moving from risk assessment to action in an urban context.

In conclusion we find that the translation of risk assessments into local action should be seen as a process that requires buy-in and development from within the local decision-making body, as well as support from others, for example through data and expertise. Recent efforts in Ireland, for example through Climate Ireland [89], to support greater openness and provision of data, decision making tools and advice to support adaptation planning is promising, but all involved need to recognize that providing data and tools is not necessarily sufficient and more emphasis needs to be put on creating an ongoing process of engagement, involvement, and participation to navigate the difficult normative decisions that local decision makers face.

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Appendix 1: List of organisations represented during our stakeholder engagement as part of the two year ARC research project.

Government agencies and departments (national):
Environmental Protection Agency
Office of Public Works
Climate Change Advisory Council
Met Eireann (Irish weather service)
Irish Water
Dept of Communications Climate Action and Environment
Dept of Finance
Dept of Public Expenditure and Reform
Office of Emergency Planning

International:
OECD

Local and regional authorities:
Cork City Council
Cork County Council
Kildare County Council
Limerick City and County Council
Southern Regional Assembly

Local and national representative groups:
Cork Business Association
National Flood Forum
National Forum of Community Flood Committees
Save Cork City

Private sector:
Aviva Insurance
Arup Engineers
Ambisense
Fehily Timoney & Co.
ESB Networks
Insurance Ireland
IPB Insurance
Malachy Walsh & Partners
RMS

Other academics (not directly involved in the research project)

Appendix 2: Details of the CFRAM decision-making process in Cork city

The first two steps of the process involved establishing flood risk management objectives, as the basis for assessing options (see Section 4 in Halcrow [60], pp.27-37). The objectives were grouped under four core criteria: technical (three objectives), economic (three objectives), social (three objectives, including risks to human health and life) and environmental (six objectives, including landscape character and cultural heritage). For each objective (and sub-objectives), an indicator, minimum target and aspirational target were defined.[11] Options for managing flood risk are then scored based on how they perform on each indicator relative to these targets. The objectives were developed "in conjunction with the steering group and stakeholders" (p.27).[12]

This stage also involved the definition of assessment units (geographic areas) for use in the assessment of flood risk and options for managing that risk.

In step (iii), a detailed risk assessment was carried out to determine the current (baseline) level of flood risk for both fluvial and tidal flooding under three main categories of impacts: economic, social and environmental.[13] According to the OPW: "Flood maps are one of the main outputs of the study and are the way in which the model results are communicated to each of the end users. The studies will then assess a range of potential options to manage the flood risk, and determine, if there are viable options, which is preferred for each area and will be recommended for implementation within the Flood Risk Management Plans." [71]

The maps produced show the extent of flooding for various Annual Exceedance Probabilities (AEP) – a measure showing the likelihood of a flood event of a certain intensity occurring or being exceeding in any given year.[14] Potential impacts of anticipated flooding are then assessed across the three headings mentioned above (social, economic, environmental), with a focus on the 1% AEP for fluvial and 0.5% AEP for tidal events. Economic damages were estimated by combining the modelling of flood characteristics with information about buildings in the affected area and applying standard depth-damage curves (for details see Halcrow [60]).

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11 The full list of objectives, indicators, and minimum and aspirational targets are included in Table 4-1 of Halcrow [60] (see pp.28-33).

12 The Lee CFRAM project steering committee included representatives of the OPW, the two local authorities (Cork City and County Councils) and the Environmental Protection Agency. Stakeholders identified at the beginning of the project included environmental bodies, government departments and agencies, non-governmental organisations and local business and industry representatives. For more details see Section 2.2 and Appendix B of Halcrow [60].

13 The process involved the development of a suite of hydraulic computer models, using a range of data inputs (including meteorological, hydrological and tidal data, as well as detailed elevation and building data). Economic impacts include loss or damage to infrastructure, the disruption of activities that have economic value and flood risk to agricultural land. Social impacts include loss or damage to human health and life, community and social amenity. Environmental impacts consider the sensitivity to flooding of the river environment, habitats and species, plus the cultural and historical environment.

14 As well as flood extent, maps were also produced for flood depth, velocity and hazard.

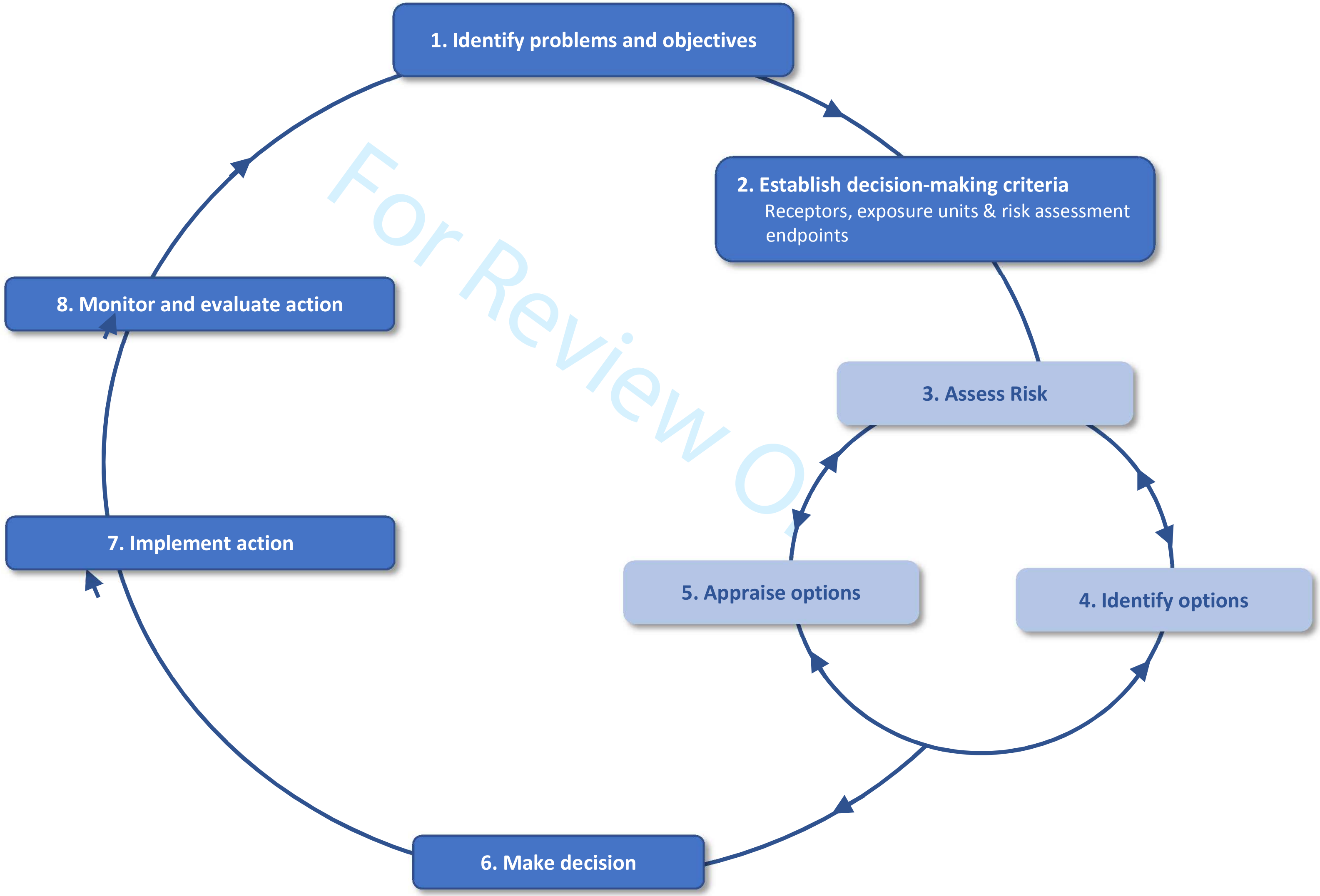
Economic damage estimates are expressed in terms of Average Annual Damages (AAD) and Present Value Damages (PVD), and include provision for intangible damages and capping of damage values not to exceed the value of the property affected. The PVD is calculated based on a 4% discount rate and a project lifespan of 50 years.[15] The PVD for Cork city, combining up to 1% AEP fluvial and 0.5% AEP tidal flood risk, was estimated at €180 million (2007 values).

Climate change is represented in the CFRAM process with the inclusion of two future scenarios: a Mid-Range Future Scenario (MFRS), which allows for a 20% increase in flow and 0.5m rise in mean sea level, and a High-End Future Scenario (HEFS), which includes a 30% increase in flow and 1.0m rise in mean sea level. According to the Lee Catchment CFRAM report, there are over 1,100 properties that would be damaged by flooding associated with either a 1% AEP fluvial or 0.5% AEP tidal event. [60] This estimate doubles to over 2,300 properties for the mid-range future scenario, which allows for a 20% increase in river flow and 0.5m rise in sea level. There is also some assessment of the potential effects of sea level rise: for areas exposed to tidal flooding (including the city), the PVD of damages associated with up to 0.5% AEP for tidal flooding increases from €79 million for current risk, to over €880 million for 0.55cm of sea level rise.

Steps (iv) and (v) involve the identification and assessment of options for managing flood risk. An initial long list of 16 (structural and non-structural) measures were screened to filter out measures not applicable for a particular assessment unit (location). The remaining measures were evaluated using a Multi-Criteria Assessment (MCA), involving the combination of scores across the predetermined objectives and targets described previously.

The scores on each objective are aggregated using a combination of global and local weightings. The global weightings are fixed nationally, and place a heavier emphasis on risks to human health and life and on the economic return (benefit-cost calculation) relative to other objectives. The local weightings vary by assessment unit and are used to reflect the relevance of a particular objective to that unit (location).[16] Those options with the highest combined (weighted) score from this process were taken forward for potential inclusion in the draft Flood Risk Management Plan.[17]

15 A sensitivity analysis for one location (Midleton APSR) showed that reducing the discount rate to 3% increased PVD for uncapped damages by 19% or for capped damages by 6% – see Table 6-6 on page 55 of Halcrow [60].
16 Full details on the scoring and weighting system used in the MCA are included in Sections 7.4.5 and 7.4.6 of Halcrow [60].
17 Further screening and assessment of options was carried out as part of the Lower Lee (Cork City) Options Report [59], on the basis of which a preferred flood relief option was selected.


1. Identify problems and objectives
2. Establish decision-making criteria
Receptors, exposure units & risk assessment endpoints
3. Assess Risk
4. Identify options
5. Appraise options
6. Make decision
7. Implement action
8. Monitor and evaluate action

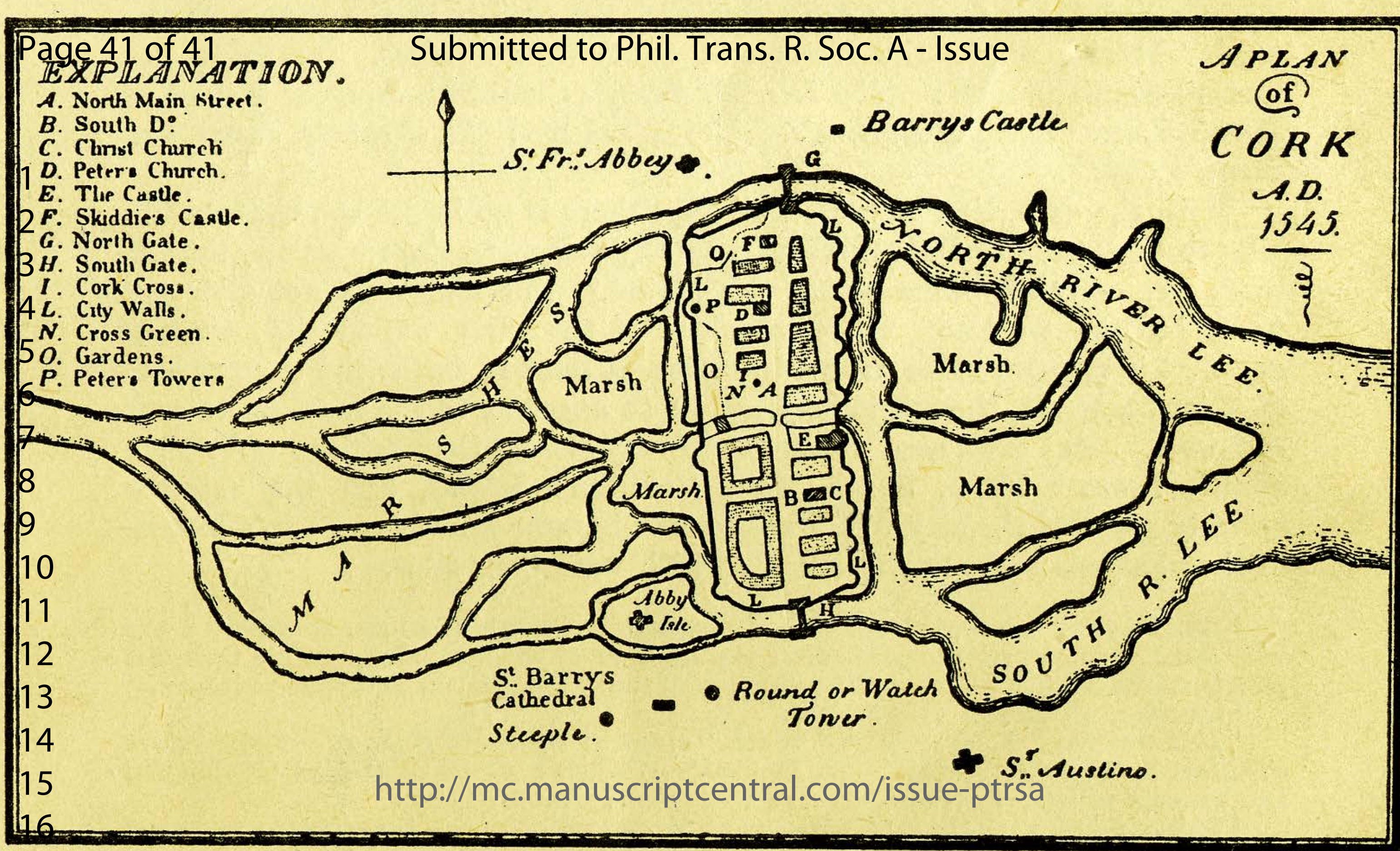


Fig. 1. Plan of Cork, A.D. 1545.