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A Hybrid Process to Address Uncertainty and Changing Climate Risk in Coastal Areas Using Dynamic Adaptive Pathways Planning, Multi-Criteria Decision Analysis & Real Options Analysis: A New Zealand Application

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Abstract: Decision makers face challenges in coastal areas about how to address the effects of ongoing and uncertain sea-level rise. Dynamic adaptive pathways planning (DAPP) and Real Options Analysis (ROA) can support decision makers to address irreducible uncertainties in coastal areas. This paper sets out what we learned by complementing multi-criteria decision analysis with DAPP and ROA when developing a 100-year coastal adaptation strategy in Hawke's Bay, New Zealand. Lessons include the value of collaborative community and decision maker processes for increasing understanding about the changing risk over time, and the need to take early actions that enable a shift in pathway before those actions become ineffective. Modifications to the methods highlighted the importance of using several plausible scenarios for stress-testing options; considering costs and consent-ability early, to avoid the perception that hard protection will last; which criteria are appropriate for communities to assess; and making many pathways visible for future decision makers. We learned about the difficulties shifting thinking from short-term protection actions to longer-term anticipatory strategies. We found that a pathways system will require ongoing political leadership and governance with monitoring systems that can manage the adaptive process over long timeframes, by governments and their constituent communities.

Keywords: decision pathways; decision making under (deep) uncertainty; climate change adaptation; stakeholder engagement

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1. Introduction

Uncertainty is an intrinsic part of human interaction with dynamic coastal systems which is heightened when making decisions about how to adapt today to emerging and future risks from rising seas. Policy making is about the future, by definition, which is rife with uncertainties including partial knowledge and uncertainties that are deep—those that cannot be known or agreed upon and are contested [1,2]. Deep uncertainty includes surprises, and irreducible uncertainties associated with how global emissions will evolve and the resulting climate-ocean feedbacks [3], particularly the spectre of polar ice-sheet instabilities.

Consideration of such uncertainties is required because adaptation too early or too late can be costly, but adaptive tools are required that do not rely upon assigning probabilities (likelihoods) to drivers or impacts and can represent changing community preferences over generations [4]. In the coastal context, uncertainties affect the hazard exposure and drivers of change, such as ongoing sea-level rise (SLR) and consequential increasing frequency of coastal flooding and exposure of populations and assets [5]. These impacts are already in-train from past emissions, or will be affected commensurately by future emissions with a long lag in sea level response, e.g., several decades to centuries [6].

Uncertainties also affect our ability to assess the risks and costs of climate change impacts and how we can plan and respond to those impacts. Coastal settings are places of value to private and public interests. Accordingly, attempts to reduce risk and plan for the future are often contested between different interests, short- and long-term values and adaptation preferences.

The conventional coastal-protection paradigm and even accommodation measures (e.g., raising floor levels to reduce flooding losses or discouraging new development or intensification within coastal hazard zones), will become increasingly ineffective as seas continue rising and coastal flooding increases rapidly, especially for tide-dominated coasts [7]. Consequently, stranded communities and assets, and squeezed coastal environments, will continue to increase in many parts of the world [6]. While we are certain about the likely impacts in the next few decades, beyond that, the rate and magnitude of change have widening uncertainties. Such uncertainties relate to whether global emissions can be substantially reduced to limit warming sufficiently to avoid exceeding the tipping point for polar ice sheet stability and other feedback mechanisms [3,8].

Addressing the impacts of the changing coastal environments will require adaptation strategies that 'fit' the changing coastal system dynamics and increasing risk. With that comes the need for governance arrangements, decision tools and processes that incorporate both the changing risk profiles and future widening uncertainties, to enable timely, sustainable and cost-effective adaptation. Current practice uses governance, tools and processes (e.g., predict-and-act using best, most-likely or worst-case estimates) that are not agile and adaptive to future changes and surprises. Critically, in coastal settings where increasing risk is driven by ongoing sea-level rise and pressures for new land-use development, decision-making tools are required that can address the issues associated with uncertainty and risk [9,10].

Decision making under deep uncertainty (DMDU) tools [11] are designed for addressing complex and contested problems that exhibit the type of uncertainties that emerge as risk profiles change over time [12,13]. Adaptive tools have been developed to address such uncertainties [14] and applied in water management, including in the Netherlands [15–18], the United Kingdom [18,19], New Zealand [20], and in coastal [21,22] and forestry domains [23]. Increasingly, such tools are being applied globally to develop adaptation strategies to reduce the impacts of the coastal change. At a national and state level some countries have embedded uncertainty considerations and DMDU tools into coastal hazards and climate change guidance to assess options into the future that can be used with community engagement processes [5,24,25]. However, there are only a few examples of real-life decision making by public authorities in coastal settings where such approaches have been applied using tailored tools and adaptive processes, under 'fit-for-purpose' governance and collaborative engagement processes [26,27]).

This paper discusses another such application in which a Multi-Criteria Decision Analysis (MCDA) is set within a Dynamic Adaptive Pathways Planning (DAPP) framework using Real Options Analysis (ROA) to address future uncertainties around coastal hazard risk in a changing climate at a regional level in New Zealand. First, we discuss why the conventional assessment tools used for decision-making cannot by themselves address uncertainty and changing risk conditions. Second, we discuss the decision context of the application and then how the hybrid framing and assessment approach was applied. The lessons learned and their relevance for pathways applications in other domains and jurisdictions are discussed. Finally, we draw some conclusions for further research and for fine-tuning the application of pathways tools.

2. Decision-Making Tools 'Fit for Purpose'?

MCDA is a commonly used analytical tool for assessing the impact of different actions where there are multiple conflicting objectives or alternatives. It enables the decision objectives to be decomposed into weighted criteria [28] which are then scored according to relative performance in achieving the objectives. MCDA is used by technical professionals across different domains of interest (e.g., water management, transport, utilities, flood risk management) and is increasingly used as part of participatory decision processes [29]. It can be used to assess priorities amongst different alternative actions using both normative judgment and technical elicitation [30]. Some countries have codified such processes in national guidance for example, the UK Government MCDA manual [31].

However, MCDA generally applies static assessments in time and static robust policymaking [31] and thus does not address uncertainties, time dependency and inter-generational community preferences. Accordingly, it is not robust by itself for comparing short-term actions with long-term options for complex problems that exhibit widening uncertainties and changing risk dynamics, over long planning and design timeframes, such as for climate change adaptation. This becomes important for addressing investments today that will persist over long timeframes [32], for example, intensifying or building new coastal settlements and their supporting infrastructure.

Consequently, there are calls for more appropriate MCDA assessment processes that incorporate uncertain future risk more specifically [30]; including minimisation of various risk measures, as criteria, or using MCDA with scenario planning [28] and shifting from optimisation-based management to an adaptive management paradigm [33]. Risk in this context is "the effect of uncertainty on objectives" (ISO 31000:2018 Risk Management Standard).

Robust decision-making tools (RDM) that are designed to address uncertainty and time dependency are available and in use [13]. By assessing suites of possible actions and stress-testing them against a range of climate and socio-economic scenarios, pathways of alternative actions can be developed that enable a future shift between pathways, depending on how the future turns out. The lifetime of investments and the conditions under which they cannot meet objectives, can therefore be made transparent. Intrinsic to this approach is the ability to monitor signals and triggers of the physical world [7,34] and societal and environmental change over long timeframes so that actions can be taken before thresholds are reached and unbearable consequences occur. One such approach is DAPP planning [15].

Conventional economic assessment tools also have limitations when operating in an uncertain and changing decision context where decisions taken today could create path dependency by locking in land uses, assets and people to exposure over long timeframes [35]. Robust economic analysis tools better 'fit' such circumstances, for example, ROA [36]. ROA is a costing method that enables the value of delay in implementing different options to be assessed, to reduce the chance of over- or under- investment in actions. This enables flexible implementation, depending on how the physical and socio-economic conditions evolve, and is therefore sensitive to community objectives over time. Accordingly, it has been applied for evaluating dynamic adaptive policy pathways [37] where the results demonstrated that a flexible investment strategy, enabling a change of course in the future, was more likely to deliver a lower cost outcome than pursuing a single option.

How DAPP and ROA can be used as a complement to MCDA to enable uncertainties and changing risk to be addressed, was the purpose of our real-life coastal decision-making application in Hawke's Bay, New Zealand. This paper focuses on how such a hybrid assessment methodology set within the DAPP framework was applied and the lessons learned from doing so.

3. The Real-Life Decision Application

The Hawke's Bay region is situated on the eastern coast of the North Island of New Zealand. The coastal section from Clifton in the south to Tangoio in the north on either side of the Port of Napier (Figure 1), has a history of coastal erosion and occasional wave overtopping spanning decades, exacerbated in some areas south of Napier City (e.g., areas J and K; Figure 1) and by coastal subsidence following a M7.8 earthquake in 1931 [38] (Komar, 2010). Coastal flooding during long-period swell events occurs more often, along with continued erosion in these areas. Managing these coastal hazards has been the subject of many reports [38,39], statutory land use planning restrictions have been applied through a regional coastal environment plan and associated district plans, and the withdrawal of insurance cover in the most exposed coastal areas. Like many coastal areas in New Zealand, peri-urban and holiday settlements have built up over the last century and expectations of on-going shoreline protection persist. This has intensified as coastal erosion and flooding/over-topping events gain prominence on top of rising seas. Community concern has increased about perceived inaction to ongoing damage at the coast to properties (several houses have been lost in coastal unit K; Figure 1) and hazard exacerbation by climate change.

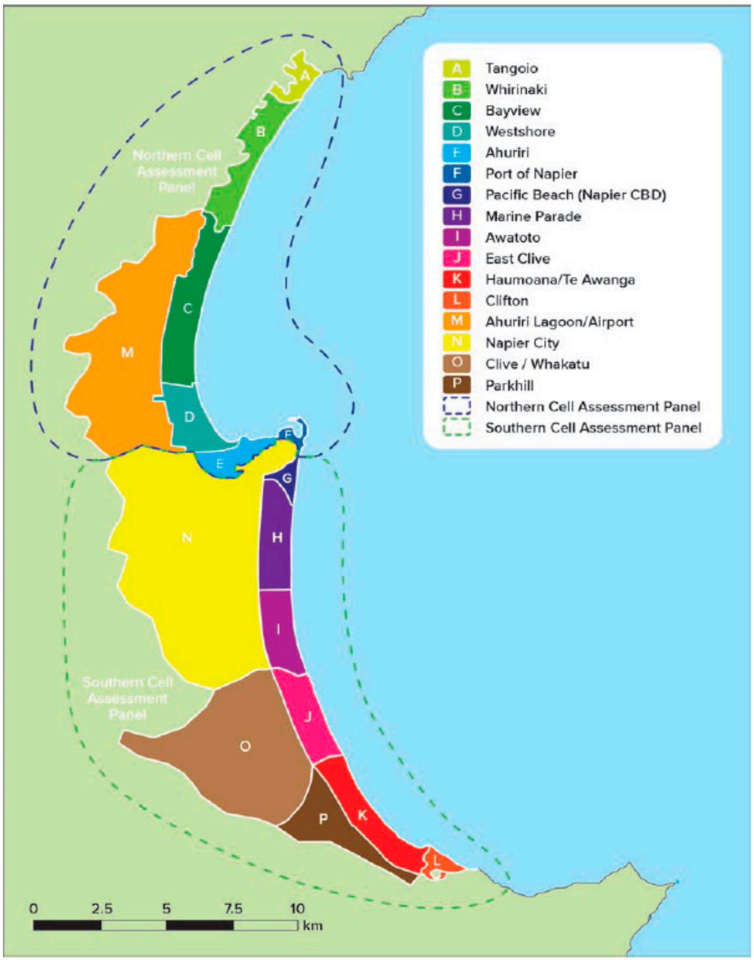

Figure 1. The two Assessment Panel Areas (dashed line) and coastal units in Hawke's Bay. (Source: [40]).

Accordingly, three councils with statutory planning responsibilities along the coastal margin in Hawke's Bay (Hawkes Bay Regional Council, Napier City Council and Hastings District Council), came together in a Joint Committee working through a non-statutory process to develop a 100-year Coastal Hazards Strategy out to 2120 collaboratively amongst local government technical advisors, councillors, members of the community, indigenous iwi/hapū, and stakeholders in assessment panels. The minimum 100 year planning timeframe for coastal environments (including assets, infrastructure and human settlements) is mandated in the 2010 New Zealand Coastal Policy Statement (NZCPS) that must be given effect to in all planning and consent decisions under New Zealand's Resource Management Act, 1991.The councils chose to jointly respond and work in collaboration with the community, on the basis that a combined response would have greater traction with the community and be more likely to be successful than differing attempts by individual councils.

As researchers we worked alongside the Strategy development process as “critical friends” through the Resilience National Science Challenge, ‘Living at the Edge’ project [41]. This enabled us to ‘test’ the dynamic adaptive planning and assessment tools in the joint council/community process based on the recently revised New Zealand national coastal hazards and climate change guidance for local government [42].

The Strategy comprised four stages: (1) Definition of the problem; (2) Framework for decisions; (3) Develop actions and options; (4) Implementation. The researchers became involved as Stage 1 and 2 were being completed. MCDA was the principal assessment methodology proposed, but it was recognised that the uncertainties, time dependency and the changing nature of risks from sea-level rise, storm intensity and elevated groundwater, needed to be considered and that MCDA is not well-suited as a stand-alone tool for this purpose. The DAPP framework was attractive to the Strategy developers, because not only was DAPP being embedded in national guidance, it enabled the problem to be framed in an understandable way for the community, by considering short-term actions and the long-term dependencies of decisions taken today.

4. The Hybrid Approach

4.1. The Governance Arrangement

The objective of the Strategy was to develop a sustainable adaptive plan that reduces hazard risk over at least 100 years. To identify the areas for assessment, the Hawke’s Bay coast was divided into diverse coastal units (Figure 1), and the hazard exposure and risks for each unit identified based on a combination of jurisdictional, topographic and land area boundaries affected by coastal inundation and erosion. These were then prioritised by a Technical Advisory Group (TAG) comprising technical managers and experts from the three councils.

Two assessment panels (north and south of the Port), with distinct physical coastal characteristics and issues, were set up to conduct the assessment of actions and options for the combined coastal areas north and south of the Port respectively (dashed lines; Figure 1). Both areas cover land or coastline administered by all three councils (one regional and two local). The Panels comprised representatives of the coastal communities affected, chosen following a public meeting at which nominations were sought, and augmented by wider Hawke’s Bay community representation and stakeholders e.g., engineering lifelines, business association, recreational interests and the three indigenous iwi/hapū groups (He Toa Takatini, Mana Ahuriri Incorporated and Maungaharuru Tangitu Trust Incorporated). Council decision makers were non-voting observers and the Panels were supported by an independent chair, Kaitiaki Roopu (process advisor), facilitators, the TAG members and consultants, and the ‘Living at the Edge’ (Edge) researchers in an independent trusted advisor role as “critical friends”. The mandate of the Assessment Panels lies in the “collaborate” part of the spectrum for public participation in decision making [43]. The governance arrangements and mandates for each of the parties were set out in a memorandum of understanding signed off by participants.

4.2. The Assessment Process

The assessment process broadly followed the Steps in the DAPP process (Figure 2), noting that modifications were made (see Section 5). Steps 1–2 were conducted by the Strategy consultants and Step 3 and 4 by the TAG and the Assessment Panels. The MCDA process was used at Step 4 with some modifications to the pathway’s development.

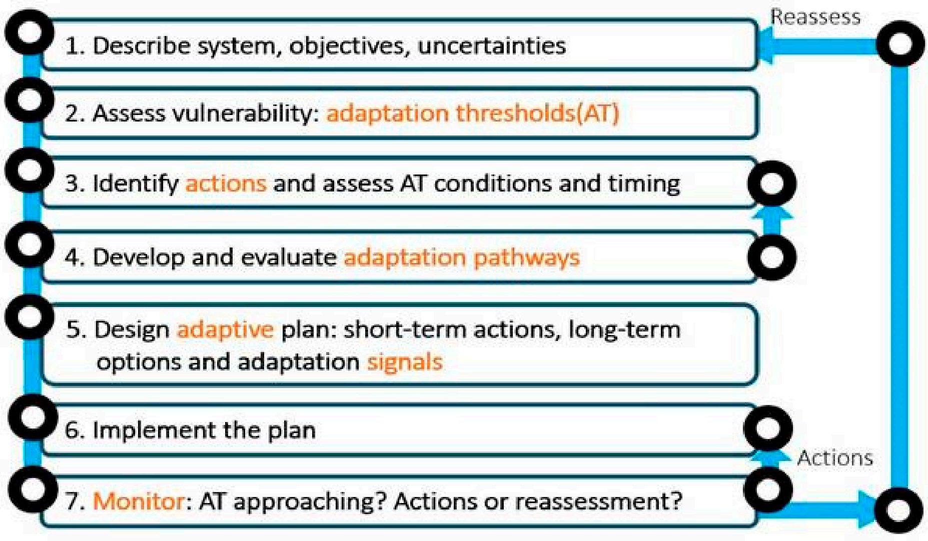

Figure 2. Dynamic Adaptive Policy Pathways step by step process. (Source: Adapted from [44]).

4.2.1. The DAPP Process

Accordingly, the Assessment Panels were tasked with: (a) identifying short-term actions and long-term adaptation options; (b) combining them into pathway sequences to form an adaptation strategy over 100 years; (c) evaluating the actions and pathways; and (d) signing-off on a final combined report from both panels. This consensus report recommended pathways for each priority coastal unit [40] (Refer https://www.hbcoast.co.nz/resources/ for further details) for the governing Joint Councils' Committee to consider and for the respective councils to endorse before preparation of the implementation plan at Stage 4 of the Strategy process. The assessments were conducted at 12 monthly workshops for each of the northern and the southern panel assessment areas, with technical input from the TAG, consultants and the Edge researchers between workshops as required.

The Assessment Panels [40], with assistance from the TAG and consultants, developed assumptions/context and objectives for the assessment, brainstormed the potential adaptation actions for the priority coastal units (some units were not considered due to lower present risks). Eighteen possible actions were identified comprising the following types of adaptation measures:

- Status quo—e.g., do nothing/monitor/private owner's responsibility
- Hold the line—defend/manage natural processes with protection works (potentially through the use of both hard structures, such as rock revetments and groynes, and soft engineering responses such as beach re-nourishment, wetland buffers or created wetlands)
- Realignment—allow shoreline to re-align with a feature, road or levee, with limited retreat of dwellings
- Managed retreat—a staged retreat in the face of an increasing or changing coastal hazard risk, by withdrawal, relocation, or abandonment.

The efficacy of each of the actions was considered for each of the coastal units with several being discarded as being impractical. A shorter list of actions was chosen and reasons recorded for each coastal unit that best matched their specific characteristics such as differences in beach material (sand or mixed gravel/sand), geography of the site (room for some of the options), historic preferences, or would exacerbate existing risk or have negligible effect. The short list was further refined into a manageable number of actions that could be used for pathways development by the TAG, with advice from the consultants and the Edge researchers.

This short list of actions was then used to develop up to six pathway sequences for each coastal unit on the basis of technical feasibility, practicality to implement, and ability to adapt over at least a 100-year period without locking in dependencies. The pathways developed were guided by the objectives for pathways that: (1) Manage the communities' exposure to coastal hazards risks; and (2) Provide flexibility to respond to increasing hazard risks as they change over time.

For simplicity, the pathways were developed as a sequence of nominal short-term (20 years), medium-term (20–50 years) and long-term (50–100 years) options to cover the required 100-year planning timeframe. However, it was stressed that short- medium- and long-term may be shorter (if no longer effective) or longer than the nominal timeframe and that pre-defined triggers (decision points) would be established in Stage 4 of the Strategy, to determine the conditions for switching to the next option in the sequence of the preferred pathway, or a shift to an entirely new pathway. Triggers (via indicators) will be designed for a monitoring and review process that can track changing conditions that indicate that the overall objective of reducing risk and minimising harm is no longer being met. The nominal monitoring period chosen was 10 years, or sooner should information or conditions change.

An example of six 100-year pathway sequences for one of the coastal units is shown in Table 1.

Table 1. Example of six 100-year pathway sequences developed for a coastal unit (Source: Adapted from [40]).

Priority Unit	Pathway #	Short Term		Medium Term		Long Term
Unit B (Whirinaki)	Pathway 1	Status quo	→	Managed Retreat	→	Managed Retreat
	Pathway 2	Status quo/Renourishment	→	Renourishment + Control Structures	→	Managed Retreat
	Pathway 3	Status quo/Renourishment	→	Renourishment + Control Structures	→	Renourishment + Control Structures
	Pathway 4	Status quo/Renourishment	→	Renourishment + Control Structures	→	Sea wall
	Pathway 5	Status quo/Renourishment	→	Sea wall	→	Managed Retreat
	Pathway 6	Status quo	→	Sea wall	→	Sea wall

4.2.2. The MCDA Assessment

Up to six 100-year pathway sequences for each coastal unit were then assessed using the MCDA methodology in Tables 2 and 3.

Table 2. MCDA process used by the Assessment Panels (Source: Adapted from [40]).

Process	Description
Decision Criteria	Develop a set of social, environmental and economic criteria to score potential adaptation options
Scoring	Assess the expected performance of each option against the criteria. Then assess the values associated with the consequences of each option for each criterion.
Weighting	Assign weights for each of the criteria to reflect their relative importance to the decision.
Weighted Scoring	Combine the weights and scores for each option to derive an overall value
Sensitivity Analysis	Conduct as sensitivity analysis: Do other preferences or weights affect the overall ordering of the options?

Table 3. MCDA criteria and scoring guide (Source: Adapted from [40]).

	Criteria	Description	Scoring Guide
Technical Assessment Criteria	Manages the risks of storm surge inundation	Reduced exposure to risks from storm-surge inundation. Meets objectives over long timeframes. Proportionate to the scale and nature of risk.	5—High/Good 4— 3—Mid 2— 1—Low/Bad
	Manages the risks of coastal erosion	Reduced exposure to risks from coastal erosion. Meets objectives over long timeframes. Proportionate to the scale and nature of risk.	5—High/Good 4— 3—Mid 2— 1—Low/Bad
	Ability to adapt to increasing risks	Readily responds to uncertain climate outcomes. Includes measures to support future adjustments.	5—High/Good 4— 3—Mid 2— 1—Low/Bad
	Risk transfer	Exacerbation of hazard risk in other areas. The transfer of risk to others, including future generations.	5—Low/Good 4— 3—Mid 2— 1—High/Bad
Impact Assessment Criteria	Socio-economic impacts	Social effects, e.g., • effects on community safety, • loss of amenity value, • decline in recreational values and community facilities. Indirect economic/industry impacts (e.g., tourism, fishing)	5—Low/Good 4— 3—Mid 2— 1—High/Bad
	Relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wāhi tapu, and other taonga	Impacts on any cultural sites of significance. Maintains access to, and enables the carrying out of, customary activities.	5—Low/Good 4— 3—Mid 2— 1—High/Bad
	Natural environments impacts	Impacts on natural coastal ecosystems. Impacts on the natural character of the coastal environment.	5—Low/Good 4— 3—Mid 2— 1—High/Bad

The criteria and weightings were first discussed by the TAG (panel members and elected councillors could observe) and a draft of both was then debated and agreed to by the Assessment Panels. During the MCDA scoring process, the TAG, consultants and the Edge researchers met separately from the Panels (panel members and councillors observed) to score various technical criteria (Table 3). The technical assessment criteria scores were confirmed with the Panels, and some non-material changes were negotiated, which required some consequential readjustment of scores for pathways in coastal units not challenged, for consistency (e.g., The criterion "Readily responds to uncertain climate outcomes" (Table 3) was initially scored low (1) by the technical assessors for seawalls, but was increased by 1 after discussions with the Panel which required cross-calibration increases in scores for the more flexible re-nourishment options in some coastal units to maintain consistency. The impact assessment criteria (Table 3) were assessed by the Panels, except the cultural criteria scoring which was undertaken by a Māori subgroup with the Strategy facilitator and confirmed with the Panels after some discussion, exchange of differing world views and resulted in minor changes in MCDA scores for those criteria.

Assessment of values, objectives, vulnerability and risk, a social impact assessment (current), Māori (indigenous) cultural values assessment and population demographics, were available to the Assessment Panels to score the impact assessment criteria (Table 3).

4.2.3. The Real Options Analysis

Real options analysis (ROA) was used to assess the relative costs of the pathway sequences for each of the coastal units [45]. The ROA process added two additional measures—a Cost + Loss figure and a Value for Money measure for each pathway.

The Cost + (Residual) Loss figure is equal to the total cost estimate (operational + capital costs) for building and maintaining the full 100-year pathway sequences (discounted over time), plus a calculated loss figure from damage caused by events that exceed a 1 in 100-year chance of occurrence. The loss figure reflects that defended assets within a hazard area (e.g., houses behind a sea wall, or groyne field) cannot expect 100% protection, given both the uncertainties associated with climate change effects and the inevitable limitations of engineering design standards and in-situ resilience. This reflects the residual risk. The adaptable pathways approach can incur transition costs—the cost of moving from one option to another along a pathway or to another option in another pathway. For example, it may not be possible to raise a seawall without first strengthening its foundations. If a higher wall is built to begin with, the total cost of the wall might be lower than under a staged approach. However, this additional cost is fully taken into account in ROA when it balances the residual loss associated with an option against the cost of implementing it.

The Value for Money (VFM) measure is a calculated figure to aid in comparison of effectiveness for the money spent between each pathway sequence. It compares the total cost estimate (operational + capital costs) for building and maintaining each 100-year pathway sequence (discounted over time), against how many MCDA "points" (weighted scores) the pathway received. The result is a measure of the cost of each MCDA point and thus measures the value for money of the pathway. This costing information for each pathway was augmented by a measure of the rating (property taxes as contributions from the direct and indirect community beneficiaries for implementing the actions) impact of each pathway based on public/private cost allocation as a proxy for affordability. Table 4 shows an example of the MCDA and ROA assessments for the Te Awanga coastal unit.

As well as comparing the six 100-year pathway sequences in each unit, the permutations of options to produce alternative pathways were re-tested using economic criteria to determine whether there were other pathways worth considering on economic grounds (an economic 'stress-test'). In the case of Te Awanga, 28 additional pathways were analysed with ROA, of which four were identified as potentially worth considering and which had not been through the MCDA assessment. In each case, these were interrogated by the Panels and were either not appropriate for the unit or were not sufficiently different to warrant MCDA assessment. This analysis was a validation process to test the robustness of the MCDA assessment process for identifying the recommended pathway sequence for each coastal unit.

Table 4. MCDA and ROA assessments for one coastal unit K2—Te Awanga (Figure 1). Costs in $NZ, VFM = Value for Money (Source adapted from [40]).

Unit K2: Te Awanga												
Pathway	**Short Term**	**→**	**Medium Term**	**→**	**Long Term**	**MCDA Score**	**MCDA Ranking**	**Cost + Loss [1] (NZ $m)**	**Cost + Loss [1] Ranking**	**VFM ($'000/point)**	**VFM [2] Ranking**	**Short Term Build Costs [3] (NZ $m)**
PW 1	Renourishment	→	Retreat the Line	→	Managed retreat	50	4	24.15	6	403	6	8.84 (0.55/yr)
PW 2	Renourishment + Control Structures	→	Renourishment + Control Structures	→	Retreat the Line	58	2	17.08	2	194	2	8.98 (0.60/yr)
PW 3	Renourishment + Control Structures	→	Renourishment + Control Structures	→	Renourishment + Control Structures	62	1	16.77	1	171	1	8.98 (0.60/yr)
PW 4	Renourishment + Control Structures	→	Renourishment + Control Structures	→	Seawall	53	3	18.48	3	232	3	8.98 (0.60/yr)
PW 5	Renourishment	→	Seawall	→	Retreat the Line	43	5=	20.00	5	329	5	8.84 (0.55/yr)
PW 6	Seawall	→	Seawall	→	Seawall	43	5=	18.67	4	291	4	9.08 (0.66/yr)
PW 30	Retreat the Line					—	—	14.94	—	—	—	

[1] Cost + Loss = total cost estimate (operational + capital costs) for the full 100-year pathway + residual losses due to events that exceed a 1 in 100-year occurrence. [2] Value for Money measure–how much it costs to "purchase" each MCDA point based on the MCDA score and total cost estimate (operational + capital) of each 100-year pathway. [3] Mid-point cost scenario (including operational costs) for the first stage of each pathway (i.e., the short-term option). Numbers in brackets are the annual rating cost in NZ $m of the short-term option over 20 years.

4.2.4. The Wider Community Assessment

Wider community feedback was sought at two points during the process: (1) on coastal units to be prioritized, long- and short-lists of options and draft MCDA assessment criteria; and (2) on development of 100-year pathway sequences, scoring of pathways through MCDA, the outcome of the economic analysis and preliminary recommendations from each panel. This wider feedback was used by the Panels to finalise their recommendations. Recommendations were agreed in February 2018 [40] and presented to the Joint Councils' Committee for endorsement, then approved individually by each of the three councils to proceed to the implementation phase that is expected to take 1–2 years.

5. Lessons from Combining DAPP & ROA with MCDA

The principle behind the DAPP process is to enable uncertain futures to be considered by retaining flexibility, rather than prescribing a single solution. This is achieved by identifying short-term actions that do not foreclose a shift to longer term options, if the objectives can no longer be achieved by the short-term actions (i.e., an adaptation threshold is reached).

While it was acknowledged by the TAG that DAPP had value for addressing the time and change components of coastal dynamics and DAPP was included in the decision framework, the DAPP and ROA processes were modified to simplify their use by the Panels. The main reasons were that the Panels were unfamiliar with such assessment processes (with the national guidance only publicly released towards the end of the panel process) and had limited time at each of the monthly panel sessions. The consequences of the modifications are now discussed.

1. The DAPP approach was presented in a workshop by the researchers after the councils' and community-based panel decision framework was largely determined and the optioneering and assessment stage was about to start. The DAPP was reflected in the amended decision framework (acknowledging the need to be adaptable), while the erosion, coastal flooding and SLR assessments had been completed by the technical consultants to the councils and accepted (Step 1). The modified DAPP and the ROA processes used a single SLR scenario for coastal flood hazard and risk assessments based on RCP 8.5 and applied at 2065 (0.5 m) and 2120 (1.0 m) to limit the modelling effort. A wider range of SLR scenarios was used for coastal erosion assessments [46]. The consequence of using only one scenario constrained exploration of present and future adaptation thresholds (Step 2) and the stress testing of options for their 'shelf-life' to reduce flooding risk. This reduced consideration of long-term flooding exposure. The ROA did however, do sensitivity tests for some of the pathways by bringing forward or pushing backwards long-term protective measures as a proxy for higher/lower SLR scenarios, and increasing the assumed residual loss as a proxy for accelerated SLR. The use of four scenarios of sea-level rise for risk and vulnerability assessments is now advocated by the national coastal hazards and climate change guidance [25,42]. In hindsight, using the four scenarios would have enabled the effectiveness of the candidate options to be consistently evaluated in reducing risk and communicating residual risk, and how the shelf-life of different actions/options fitted with the nominal planning timeframes.
2. The economic (cost) criterion was excluded from the MCDA assessment criteria (Step 3) for later consideration for some good reasons, but led to the perception that coastal protection options could be sufficiently engineered to protect the coast over any of the nominal timeframes considered. This constrained a broader consideration of candidate option feasibility, with a preference for "protection" (hard or soft shoreline management) options (Table 3). This aligns with the "hold-the-line" paradigm upon which most coastal communities rely [47]. Such options enhance perceptions of safety for undefined periods of time, while residual risk increases from rising seas and may be difficult to quantify, especially if further development is not restricted. Supporting land use planning measures were also not included as candidate options because they were viewed as applying to all options. Considering supporting planning

measures as options could have extended the focus of the Panels towards exploring the limits of "protection", and towards how staged retreat from the coast could be managed sequentially across longer-timeframes as coastal-flooding supersedes erosion as the dominant risk by the middle of this century, as shown by the hazard assessments [46].

3. At Step 4 of the DAPP process, candidate options were sequenced into preferred nominal short-, medium-, and long-term, rather than into combinations of different short-term actions and long-term options, with varying shelf lives, to form pathways that cover the prescribed minimum 100-year planning period. 'Fixing' the pathway as one linear trajectory (i.e., a single sequence) created an issue for applying ROA, which is designed to compare the value of delay across different pathways over the 100-year planning timeframe. Having one preferred pathway also de-emphasised the value of pathways thinking in the DAPP which enables several pathways to be examined, particularly when the short-term actions no longer meet objectives. This dynamic adaptive approach, keeping alive alternative pathways, thus retains flexibility (as conditions change) after the first action or option is implemented and eventually becomes ineffective. Recommending a single sequence of actions over three nominal timeframes, runs the risk that the uncertainties of the outcomes, changing objectives or perceptions and the realistic "shelf-life" of options may not be understood by subsequent communities or decision makers, because the other possible pathways (or combinations) have not been formally carried forward from the MCDA process. Having this flexibility is important, if the short-term or medium-term actions fail earlier than anticipated or a large damaging event occurs, and the next option in the sequence is perceived as no longer suitable or inappropriate, with too many side-effects including cost. Having a suite of future pathways developed through the full DAPP process provides this flexibility for communities in the future before the next adaptation threshold is reached, provided the pathways are embedded in formal planning documentation. While six different pathway sequences and many individual options/actions were considered during the panel process, and are documented in the project report [40], the challenge will be how this assessment can inform such a switch if needed at the next juncture in the future.
4. Evaluation of the sequences was undertaken using MCDA (DAPP Step 4; Figure 2). Technical and impact assessment criteria (Table 2) were scored respectively by the TAG and the Panels (including the cultural criterion by the Māori panel members). The natural environment criterion included a breadth of considerations, including effects on ecosystems, amenity value and aesthetics, in addition to changes and shifts arising from climate change. The breadth of considerations proved challenging for the Panels to appraise, suggesting that the environment criterion could have been added to those criteria assessed by the TAG. Following this, the assessment then could have been augmented with community knowledge in a manner consistent with the statutory assessment of environmental effects under the relevant legislation and policy. Doing the assessment in this manner could have contributed to a preliminary identification of issues for consideration of consent-ability for the recommended actions in the implementation stage.
5. The exclusion of consent-ability of the actions and options in the pathway sequences as an assessment criterion meant that relevant statutory considerations could have influenced the selection of the preferred pathway sequence. In particular, Policies 25 and 27 of the New Zealand Coastal Policy Statement 2010 (Available at https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement-2010.pdf) can support the implementation of the pathways, directing councils to avoid increasing the risk and to develop strategies that promote and identify long-term sustainable risk reduction, while generally discouraging hard-engineering options. These aspects will be challenging as the councils enter the final implementation phase, including securing the necessary permits, consents and changes to regional and district plans.

6. Discussion

The main objective of the Coastal Strategy was to assess the ability of options and pathways to deliver risk reduction at the coast over the long-term (at least 100 years). The DAPP framework was used to enable uncertainties and the changing risk profiles over time to be considered in the options and pathways chosen. The robustness of the pathways developed relates to whether the actions and possible pathways will reduce risk, whatever the future holds. While the pathways developed were a sequence of actions for each coastal unit based on indeterminate timeframes at short-medium-long-term, the Panels understood that the timeframes for each period of time could be shorter or longer than these nominal times and that there is a possibility that the medium and long-term options could be started earlier or later depending on conditions, or that the medium-term option could be bypassed in favor of the more sustainable long-term option. However, the sequences do not constitute pathways as envisaged by DAPP. DAPP assesses many possible actions and presents them as options in possible pathways. A choice is made to start with short-term actions that do not close off future pathways, to which a switch may be made before the short-term actions reach the end of their "shelf-life". At this point, harm and damage is reached (threshold). To increase the robustness of the Panels' approach, all the sequences considered for each coastal unit could be recast as pathways for each coastal unit and be used as the basis of the long-term implementation process to follow when the next decision point (trigger) is reached. This would provide a transparent basis for the early warning signals and triggers (the decision switch point) to be developed for the monitoring of trajectories towards adaptation thresholds under DAPP. This would clearly show that there are several different pathways available that could meet objectives, thus enabling the future uncertainty to be visualized by future decision-makers and communities.

The DAPP framework and ROA assessment methodology enable time and change dimensions to complement the MCDA assessment methodology which conventionally compares and contrasts options at a juncture in time. As we move into an era of rapidly changing climate impacts, characterized by deep uncertainty and on timeframes that will affect decisions taken today, it is imperative that the effect of uncertainties on those decisions and monitoring/review processes are mainstreamed in decision practice.

The application discussed in this paper was an experiment, within a real-life decision context including community contestation, to better understand whether and how a hybrid methodology that introduces time and change into the decision process can affect the outcomes in a situation of planning for changing risk at the coast.

The results discussed in this paper were mixed, due to the later introduction of the adaptive approaches into the decision process, the simplifications made, and which of the parties did the assessment or scoring. Considering uncertainties and the changing risk profiles had a beneficial impact on thinking by the TAG and the Panels. We witnessed changed understanding of a greater range of options, rather than a traditional "either-or" approach (e.g., managed retreat was originally shunned by the communities at the start of the process, yet appeared in several of the medium- and long-term actions in the preferred pathways as mind sets changed).

While costings were arguably left out of the MCDA process (to avoid shifting the focus from an assessment of benefits to a qualitative cost benefit analysis and to avoid the natural tendency to focus on costs and make choices to fit accordingly), until the short-listed six preferred pathways were finalized and scored for each coastal unit, the criteria around plausibility (practicability or sustainability) of each option could have been more explicit. There is considerable uncertainty around whether coastal protection structures can be maintained for 100+ years in these coastal units. If rough order costs had been available for the options when the scoring was done, it may have avoided the impression that protection structures could be built to last for at least 100 years. This may have influenced the choice of short-term actions for some of the priority coastal units away from hard structures, or beach re-nourishment held in place by lateral groynes. Managing expectations of coastal protection measures, and how they may change the environment and amenity, were tensions throughout the process, particularly for the long-term evaluations. This is understandable given the Panels' stake in the process.

Because consent-ability of each of the short-term actions was not considered explicitly in the hybrid process, it will be one of the main challenges (along with targeted funding mechanisms) in implementing the coastal strategy through the statutory consenting processes. Potential hurdles include possible opposition from the wider community (e.g., loss of beach amenity and access, rises in council property taxes) and the need to demonstrate hard shoreline management options are necessary with "no more than minor effects" on the environment, along with their longevity (structural integrity, rock/gravel resource and maintenance costs).

The exclusion of planning controls as supporting options (e.g., planning controls through rules and policies) constrained detailed discussion of management options that could reduce the long-term risk (including the residual risk behind coastal protection) by signaling the temporary efficacy of the short-term actions. Planning controls support implementation of all adaptation options and pathways and be applied with immediate effect (e.g., planning rules, policies) before the short-term options are in place, to avoid further development (other than minor modifications to properties) that increases exposure to hazard risk and makes future adjustments by switching pathways, more costly.

The nominal planning timeframes of short/medium/long-term constrained the assessment because each action or option has a different shelf-life (adaptation threshold) and there was no information on triggers for switching between options in a sequence or to other pathways assessed. The essential question in DAPP of "Under what conditions will the option fail?" (Rather than When will it fail?), was not wholly satisfied using the hybrid process due to its simplification into nominal timeframes. While the Panel members understood the nominal nature of the timeframes, future decision makers and property owners could misunderstand that there are no guaranteed timeframes for each stage of the sequences. In lieu of analyzing condition-based pathways, more sensitivity analysis that varies the timing of the different sequences of protection, would be useful. A proposed work package for the Coastal Strategy to develop indices as signals and triggers to monitor, will also assist with this issue.

There was a dominance amongst the short-term options, of 'known' preferred options. It was difficult for thinking to shift from designing a structure or action to last for a given design life, to asking what strategy leaves options open for the changing climate risk. This was partly influenced by the dominance of existing and persistent erosion hazards and current actual and imminent risk at most of the priority coastal units assessed, combined with a high expectation that coastal protection works will solve the erosion problem (Blackett et al., 2010; Rouse et al., 2016). This highlights the importance of using the full DAPP approach, which is now embedded in national coastal guidance for New Zealand [25], to appraise the next adaptation threshold and enable a more detached discussion at the assessment phase.

The consideration of parallel seawall consent applications that were in-train at two locations along the coast in response to recent storm erosion, was perceived by some in the wider community to undermine the long-term strategy and reinforce reactive decision making. However, legacy consents moving through the statutory consenting and implementation processes are a reality for which credible processes are needed to remove mixed messaging to decision makers and the communities affected.

MCDA assessments are usually undertaken as technical exercises by practitioners at councils. While the environmental criteria could have been added to the technical assessment, splitting the assessment of criteria between those that require greater technical knowledge, from those that reflect the community values, gave the process credibility and a platform for interaction—otherwise most of the criteria would have been assessed by practitioners. This is consistent with the findings of [29] about using MCDA interactively. The assessment undertaken by the cultural advisor that informed the assessment of the cultural criterion by Māori iwi panel members and which was discussed by the Panels, was a beneficial part of process and an opportunity to learn from the exchange of worldviews. It informed perspectives around hard versus soft protection options and transparently highlighted the differences in values placed on land ownership and long-term stewardship, which in turn informed the final recommendations of the Panels.

The level of resource required to undertake such a hybrid DAPP/MCDA/ROA process is a present issue for decision makers. However, the process is scalable and can be used to screen priority areas and then employ resources to those areas in more depth. Investment of time in such processes, however, has a real learning benefit by building trust, increasing understanding and awareness of the emerging problem and building capability to address climate change adaptation. Such processes, however small or large, can reduce community tensions as observed [48] and create greater efficiencies, compared with reacting to adverse events as they occur. In particular, flooding events will be much more frequent at the coast as the seas rise, and considerably more expensive to address reactively. In this case, using the hybrid approach enabled shared learning and co-production of local knowledge at various entry points in the process, amongst practitioners, technical experts, council staff and politicians.

7. Conclusions

This hybrid application of DAPP/MCDA/ROA has enabled the feasibility of using a pathways framework to be tested in a real-life decision-making context. The impact of simplifications to the pathways approach and areas for further development have been identified. The stress-testing and sensitivity analysis of short-term actions and long-term options alongside community engagement is critical to effective pathways applications. For implementation of pathways, the design of signals and triggers for monitoring are key to ongoing use of pathways in decision making.

The approach taken here and its critique provides a basis for the researchers and practitioners to take the lessons learned and to share them with other councils and communities, in New Zealand and elsewhere, that are grappling with how to make decisions under conditions of uncertainty in coastal and other hazard settings. The hybrid approach is particularly helpful in addressing situations where there is contestation between councils and communities seeking historic redress from quick solutions under conditions of imminent risk. Systematic use of the hybrid approach at the appropriate scale for the problem, has real value for engaging the affected and wider communities and reaching shared decisions. While the lessons have relevance for other localities and domains that exhibit similar situations, more applications are required across different domains of interest to further test the ability to implement pathways and thus shift decision making from reactive to anticipatory modes.

In this case, the hybrid approach used moved coastal communities towards a longer-term viewpoint, from a situation of imminent threat from erosion, to considering a wider range of adaptation actions and actions needed for transitioning to more transformational change as the seas rise and before coastal flooding becomes a more pervasive reality. While the mindset shift may seem small at the moment, the processes to implement the adaptive plan and to design signals and triggers for monitoring change and building the capacity of the community to deal with the change, will reinforce anticipatory long-term thinking.

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