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Distributed flood adaptation actions across scales: a participatory decision-making framework

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Abstract
As flooding becomes more frequent and intense, traditional flood risk management often overlooks the cumulative potential of smaller, decentralized actions and limits integration between public and private efforts. Contributing to a systemic approach to flood adaptation, this paper presents a participatory decision-making framework, supporting distributed flood actions. Developed through literature review, interviews, and focus groups in Milan and Melbourne, the framework combines different participatory steps to assess flood actions across five multidisciplinary dimensions based on management and governance principles. Complementing the current flood risk management practices, the framework builds socio-technical and institutional conditions for collective action.

Keywords: Flood Risk Management; Built Environment; Decision-Making; Multi-criteria; Adaptation.

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Introduction

The increasing intensity and frequency of flooding, particularly within complex urban dynamics, have prompted the adoption of catchment-wide Flood Risk Management (FRM) strategies. Today, FRM remains largely siloed, often overlooking the complex interdependencies and synergies among interventions across scales. This limits the ability to recognize the cumulative impact of multiple actions, particularly the integration of public and private ones (Kreibich *et al.*, 2015; Rehan, 2018; Raikes *et al.*, 2019). Despite integrating multiple strategies – defence, prevention, mitigation, recovery and preparedness- FRM commonly relies heavily on government-led, large-scale engineering interventions; they are also prone to failure thresholds, require significant resources, and can provoke localised conflicts over the distribution of costs and benefits (Bignami, Rosso and Sanfilippo, 2019). Veerbeek *et al.*, (2012) and Barendrecht *et al.*, (2020), among others, support systemic and decentralised approaches to adaptation for improved urban flood resilience. In this context, Flood Risk Governance complements FRM by reflecting broader shifts in societal governance and incorporating increasing trends of decentralisation.
Traditionally, FRM measures are evaluated from an engineering perspective, using damage reduction to assess their effectiveness and efficiency (Klijn *et al.*, 2021). At the same time, alternative or complementary tools, such as weighted analysis or spatial mapping, can contribute to the identification of the best and most equitable solution. Emerging approaches thus call for broader sets of indicators, encompassing environmental, social, and economic dimensions. This research departs from three critical gaps: i) the lack of a systemic approach to flood adaptation that accounts for the contribution of actions across strategies, scales, actors and risks; ii) methodological limitations in multi-scalar evaluation; iii) the unclear understanding of the interface between geographical scale, spatial distribution, and public and private stakeholders' contribution in flood adaptation.
This contribution proposes the FLOODS.ACT Framework (Flood Decisions towards Systemic Adaptative aCTions[1]), which aims to support decisions around flood adaptation strategies and design actions across management and governance principles, and steer design towards distributed and diversified flood actions. The Framework provides a structural evaluation process for analysing proposed and existing FRM actions on a (sub-)basin scale. Moreover, it encourages scenarios where public and private adaptation coexist, promoting active collaboration towards flood adaptation. Its evaluation structure is articulated in Dimensions, Criteria, Sub-Criteria and Indicators. The beneficiaries are decision-makers and policymakers, but it provides support for community-based advocacy groups seeking more community involvement. This paper briefly reviews existing FRM assessment methods, then details the development of the proposed Framework. It presents the Framework and its components, concluding with recommendations.

Existing methods

Several methods support the decisions for FRM actions, as reported in literature (Alves *et al.*, 2018). Economic evaluation of flood risk management alternatives is most commonly conducted through Cost-Benefit Analysis (CBA), which relies on damage estimates and probabilistic scenarios to assess net present value, benefit-cost ratio, or rate of return (Mechler, 2016). However, CBA has several limitations: it often excludes indirect benefits, externalities, and opportunity costs, and does not account for the distribution of costs and benefits or the full range of vulnerabilities and exposures (Molinari *et al.*, 2021). Multi-Criteria Analysis (MCA) is a common alternative or complementary approach for risk assessment and project appraisal, particularly when multiple objectives and stakeholder values must be considered (Meyer, Haase and Scheuer, 2007). However, MCA poses challenges in quantitative validation and can depend heavily on expert-driven judgments (Gallina *et al.*, 2020).
Building on multi-criteria analysis methods, tools such as LEED, BREEAM, the ITACA Protocol and the Australian Investment Framework For Environmental Resources (INFFER, 2024) have been developed to evaluate design options in the built environment, primarily by applying performance-

based criteria. As some protocols have opened to neighbourhood- and city-level assessment, they maintain the same structure, with a modest representation of social aspects. Among those, the ITACA Protocol at urban scale is based on a multidisciplinary definition of sustainability, open-access data and easy-to-calculate indicators, which are flexible in their application across scales. The latter is a relevant example for the proposed Framework as it includes aspects of governance, including quality of planning process, citizens' participation, urban and architectural quality (ITACA, 2016). Criteria weighting is calculated empirically in relation to the scale, the impact duration and magnitude. As Attaianese and Acierno (2017) suggest, these protocols should be seen not just as certifications, but as tools to guide socially conscious design by integrating participatory methods and diverse criteria. Yet, they face limits—such as inconsistent scoring and gaps in local identity or institutional feasibility. The Framework introduced below addresses these by using stakeholder-defined weights and drawing on criteria from engineering, social sciences, architecture, and planning.

Methodology
The FLOODS.ACT Framework was built in multiple steps. Firstly, a literature review was conducted to define relevant Dimensions and Criteria. Secondly, these results were then reviewed through experts' interviews and the feedback received was integrated. The interviewees suggested adding, removing or grouping some criteria. This initial process of identifying relevant Dimensions and Criteria is published in Vanelli, Lavagna and Minifie (2024). Afterwards, to formalize the Framework and structure it with a workable weighting and scoring system, its final structure has been revised and adjusted to meet methodological requirements. For example, the category of Governance Capacity has been divided into Governance Legitimacy and Feasibility, to achieve a balanced distribution of criteria under each Dimension. The Framework is then detailed with indicators, against which alternative design scenarios can be scored. Thirdly, the preliminary Framework is then verified in the selected case studies. This step involved the setup of Focus Groups, with experts, community members, local authorities and architects. The preliminary Framework and the details of the Focus Group conducted in Australia are described in Vanelli, Lavagna and Minifie (forthcoming). The Focus Group aimed to discuss and validate the Framework in the specific context; discuss the application in the current decision-making process; and weight the Criteria. Followingly, the Framework is re-elaborated, integrating feedback. Changes included improving the clarity of Criteria names, checking for double counting and repetitions especially between Dimension A (Flood Risk Reduction) and E (Co-Benefit Provision), and Dimension C (Governance Feasibility) and D (Governance Legitimacy); and lastly, articulating Steps, Phases and Loops, presented below.
The Framework was tested through two case studies—the Seveso River Basin in Italy and the Maribyrnong River Basin in Australia—using scenarios developed from workshops and stakeholder interviews. The Seveso case addresses recurrent flooding in a heavily urbanised, polluted area with large-scale public interventions. The Maribyrnong case stems from the October 2022 flood that affected over 500 properties in Melbourne's low-density suburbs. The case profiles are available in the publications cited above.

The Framework
The Framework uses a multi-criteria analysis system to evaluate systemic flood adaptation responses across basin or sub-basin scales, assigning performance scores to sets of actions. It includes both existing and planned measures, structural, non-structural, grey, green, and those on public or private land, including financial or legal instruments. The Framework supports comparison between design alternatives while accounting for contributions to flood risk reduction. Its structure is organised into Phases, Steps, and Loops (Figure 1), informed by literature, interviews, and Focus Group insights. Each Step is described in Table 1. Moreover, we propose the creation of a Community Partnership Panel (CPP), following the model being promoted in Melbourne, to train and engage stakeholders during the process of Scenarios definition and ranking.

Phases, Steps, Loops
The Framework is structured into four distinct Phases, beginning with Phase 1-Analysis, which includes Hazard Assessment, Socio-Spatial Screening and Field Validation. The first two Steps can be conducted in-house by the competent authority or outsourced to technical consultants. Step 3 was introduced in response to feedback from the Maribyrnong Focus Group. The implementation of this Phase may vary in progress across different contexts; however, we assume a maximum duration of one year, consistent with the timeframe adopted for updating risk modelling in the Maribyrnong case study.

The Phase 2-Design Scenario Planning introduces a more participatory approach, in contrast to traditional top-down practices, and involves the Conditional Scenario development. The Framework is supported by the Atlas for Flood Adaptation Desing action, a portfolio of actions to support the participatory Steps. The Atlas was tested in the Maribyrnong River Basin for the scenarios' co-design. Followingly, the Weighting Step supports the definition of context-specific weighting for the evaluation of scenarios. Rather than relying on expert-defined weights, the Framework adopts the Playing Cards method, enabling the identification of weights that reflect local values and priorities. This Step may be completed early in the process, before the workshops begin, or run in parallel, without influencing the definition of scenarios. In Phase 2, we also include the Technical and Feasibility Planning, which translates scenarios into a strategic or masterplan-level design. Integrating the workshops' results, technical feasibility is downstream of the co-design, to not limit speculation and innovation. The Phase, which concludes with Consultation with local stakeholders for review and further input, is anticipated to take up to one year, accommodating multiple rounds of workshops, as aligned with the timeframes envisioned by the relevant authorities in the Maribyrnong case.
Lastly, Phase 3-Scenario Assessment focuses on evaluating the design scenarios through a participatory and transparent scoring process, which includes the Scoring of the Scenarios against the Value Protocol. This results in the Ranking of scenarios based on total performance, with the top-ranking scenario representing the most balanced and preferred option across all dimensions. Followingly, the Reporting, where the results of the assessment are formally compiled and communicated, mirrors the public consultation practices typically undertaken by authorities to present upcoming projects. The final scenario(s) are submitted for formal approval, outside the current scope of the Framework, towards implementation, securing funding streams, initiating project delivery, and establishing monitoring mechanisms.
This type of decision is not usually straightforward but could instead go back and forth between steps and require constant adjustments and monitoring. Therefore, we introduce Loops to the Framework. For example, Step 3 could involve a revisit to the risk modelling and hazard profile, as well as a clarification of vulnerable groups or spatial target areas. Considering the structured yet time-intensive setup of Phase 2, where participation is embedded throughout the process, Phase 3 is expected to benefit from a higher level of consensus. Therefore, we do not anticipate iterative loops at this stage. Nonetheless, the Framework remains adaptive: any substantial change in the area's risk profile could trigger a review of earlier phases, to ensure continued relevance and responsiveness of the proposed actions.

The Value Protocol
The Value Protocol is the tool developed to assess and evaluate the performance of the alternative Scenarios. The Protocol collects five Dimensions, articulated in Criteria and sub-criteria (Table 2). Dimension A, Flood Risk Reduction, reflects the traditional cost-benefit evaluation and the technical feasibility of actions while preferring actions across different FRM strategies (Dieperink *et al.*, 2016). Dimension B formalizes Spatial and Design Quality as a key objective of flood adaptation, building

on the Dutch experience of the Room for the River project (Busscher, van den Brink and Verweij, 2019), while also examining to what extent the combinations of design actions are multi-scalar. Dimension C, Governance Feasibility, refers to institutional feasibility, the possibility to be implemented through existing mechanisms and governance arrangements (Alexander, Priest and Mees, 2016; Juhola *et al.*, 2022); it also checks the coexistence of public and private adaptation actions (Tompkins and Eakin, 2012). Under Dimension D, Governance Legitimacy, the Protocol verifies whether the scenarios are socially acceptable, properly fitting the community risk profile, while providing forms of appeal and participation (Barquet and Cumiskey, 2018). Lastly, Dimension E, Co-benefit Provision, checks whether the scenario contributes to the reduction of multiple risks and the degree to which it provides environmental, economic and social benefits (Alves *et al.*, 2019). The Framework's dimensions are structured into Criteria, Sub-Criteria, and Indicators, scored on a -1, 0, 3, 5 scale adapted from the ITACA Protocol and later converted to a 1–100 scale. Each Dimension can receive a maximum of 20 points. A negative score signals maladaptation or failure to meet minimum standards; 0 indicates non-applicable or neutral performance (still counted in the calculation); and positive scores reflect improvement or above-average outcomes. For existing actions, some indicators (e.g., Costs, Co-benefits) may score zero if already absorbed. When two indicators relate to one sub-criterion, they are equally weighted. Thresholds are drawn from existing standards, developed during the research, or benchmarked against context-specific data—for example, cost indicators reward scenarios where costs stay within or below available budgets. As in Table 3, each Indicator is defined by the demand, a description, the application level, whether is action-based, or scenario-based; the scale, and lastly, instructions on how to assign the scores. Regarding co-benefits, it is important to note that their calculation is extensively covered in the literature (e.g. European Commission and Directorate-General for Research and Innovation, (2021)). To keep the Framework viable, we included only those co-benefits identified as most relevant through interviews and literature, and triggering private initiatives. However, users can adapt these, as well as adjust indicator thresholds, to fit their specific context and scoring needs.

Conclusions

The proposed Framework creates the socio-technical and institutional foundations that support actions by different local agents, reveal alternative forms of design and challenge current flood governance practice. The construction of the Framework was carried out through an initial phase of literature and report review, followed by a series of interviews and stakeholder-based validations. This process helped transform it into a multidisciplinary and applicable approach for decision-making, integrating technical expertise, community knowledge, and participatory processes. The idea of a (sub-)basin-level Community Partnership Panel could support the creation of a shared vision and sense of responsibility. The FLOODS.ACT framework, while more complex and time-consuming than traditional processes, offers flexible tools that can be used independently or integrated into existing practices. Decision-makers may adopt the full Framework or apply selected steps to enhance participation. The Protocol supports scenario evaluation across five dimensions, and they can serve as a checklist to assess and strengthen aspects like feasibility, support, and participation. Further work should explore its sustainability and integration in specific FRM contexts.

Notes

[1] Technical literature mostly uses the word measure, which is solution oriented. Against the perspective that flood can be solved, we prefer action.

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Images

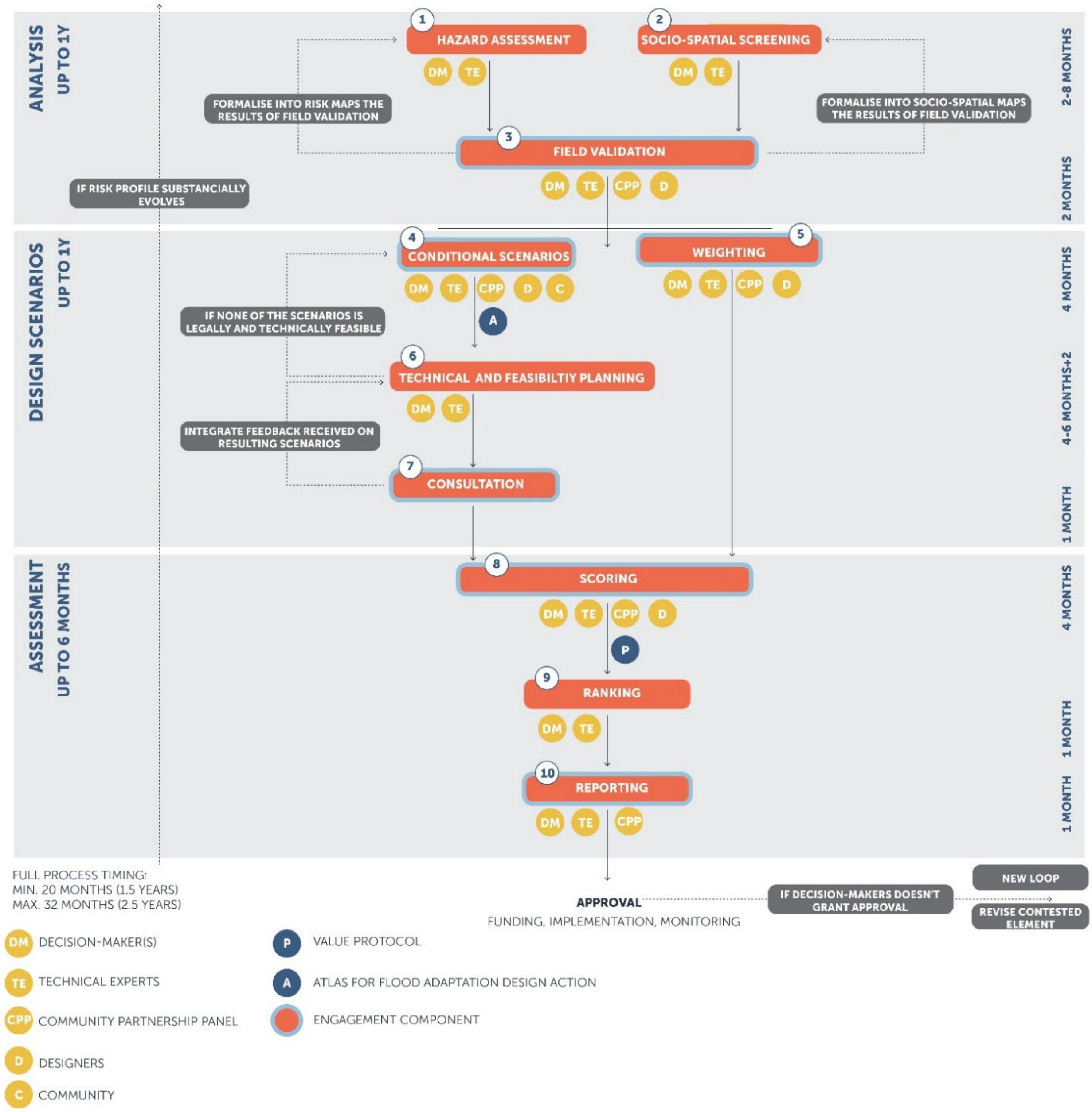

Fig. 01 – The Framework

Phase	Step	Name	Activity	Method	Agents
1	1	Hazard Assessment	Evaluating hazard in the basin	Hazard assessment via in/outsourcing	Decision-maker(s), technical experts
	2	Socio-Spatial Screening	Evaluating exposure and	Socio-Spatial assessment via in/outsourcing	

			vulnerability in the basin		
	3	Field Validation	Integrating community knowledge, historical data, and on-site observations to verify the risk modelling	Updated data via consultation with communities and fieldwork	Decision-maker(s), technical experts, CPP and designers
2	4	Conditional Scenarios	Codesigning alternative scenarios, including conditions for implementation and priorities.	Design scenarios and prioritization of actions via participatory workshops.	Decision-maker(s), technical experts, CPP, and designers; open to community consultation
	5	Weighting	Negotiating the context-specific weights for the Criteria.	Weights of criteria via Playing Cards	Decision-maker(s), technical experts, CPP and designers
	6	Technical and Feasibility Planning	Operationalising each scenario in terms of technical, legal, and economic feasibility.	Feasibility study via in/outsourcing	Decision-maker(s), technical experts
	7	Consultation	Presenting the results back to local stakeholders.	Presenting viable scenarios via open meeting.	Decision-maker(s), technical experts, CPP, and designers; open to community consultation
3	8	Scoring	Scoring the scenarios across the dimensions of the Framework.	Scores of Dimensions for each Scenario in Working Groups	Dimension A and C: Decision-maker(s), technical experts; Dimension B and E: Decision-maker(s), technical experts, CPP and designers Dimension D: Decision-maker(s), CPP
	9	Ranking	Aggregating and weighting the scores for each scenario, obtaining a rank.	Final rank by Working Group	Decision-maker(s), technical experts
	10	Reporting	Compiling and communicating results.	Result report	Decision-maker(s), technical experts, CPP

Tab. 01 – The Steps

A. Flood Risk Reduction	B. Spatial and Design Quality	C. Governance Feasibility	D. Governance Legitimacy	E. Co-Benefit Provision
A.1 Multi-Strategy	B.1 Multi-Scale	C.1 Multi-Actor	D.1 Acceptability	E.1 Multi-Risk
1. FRM Strategies Coexistence	1. Spatial Scales Coexistence	1. Public-Private Adaptation Coexistence	1.Stakeholder Acceptance	1. Multi-Hazard Risk Reduction
A.2 Costs	B.2 Spatial Value	C.2 Governance Mechanisms	D.2 Social Justice	E.2 Environmental Co-Benefits
1. Implementation Cost	1. User Value for Public Space	1. Existing Actor-Based Mechanisms (Actor Feasibility)	1. Recognitional Justice	1. Conservation Of Water Resources
2. Maintenance & Operation Cost	2. Experience Value for Public Space	2. Existing Rule-Based Mechanisms (Legal Feasibility)	2. Distributional Justice	2. Climate Change Mitigation
3. Transaction Cost	3. Future Value for Public Space	3. Existing Resource-Based Mechanisms (Economic Feasibility)	3. Restorative Justice	3. Soil Erosion Reduction
A.3 Risk Reduction Benefit	B.3 Design Quality	C.3 Institutional Feasibility	D.3 Risk-Aligned Preparedness	4. Water Quality Improvement
1. Expected Avoided Damage	1. Design Vision	1. Long-Term Vision	1. Alignment With Level of Worry	5. Groundwater Recharge
2. Expected Avoided Casualties	2. Housing Expectation	2. Institutional Complexity	D.4 Participation	6. Biodiversity Improvement
3. Retention Capacity	3. Landscape And Context Integration	3. Political Will	1. Participation Across Phases	E.3 Economic Co-Benefits
A.4 Technical Feasibility	4. Multifunctionality	4. Supra-Municipal Scale	3. Participation Quality	1. Real Estate Variation
1. Technical Feasibility		C.4 Planning Adaptability		2. Reduced Insurance Premium
		1. No-Regretability		3. Increased Building Insurability
		2. Innovation		4. Reduced Interruption for Economic Activities
				E.4 Social Co-Benefits

1. Minimise Population at Risk
2. Reuse Of Abandoned Spaces
3. Public Space Improvement

Tab. 02 – The Value Protocol

A	Flood Risk Reduction	
A.2	Costs	
A.2.1	Implementation Costs	
Demand	The scenario's Implementation Cost (IC) estimation is sustainable.	
Description	Capital investment to realise the scenario. If the budget is known, the DM can compare scenarios against the available budget; if it is unknown, we take the qualitative analysis of Alves et al. (2018) to compare scenarios in terms of reduction of costs. The Threshold can be modified by the DM upon adoption of the framework.	
Application	Action-based	
Scale		
Points	Description	Threshold
-1	Very High Cost	Implementation cost exceeds available budget.
1	High Cost	Implementation cost is <80% of available budget OR the scenario generally does not entail reduced costs compared to the other alternatives. (most expensive)
3	Medium Cost	Implementation cost is <50% of available budget OR the scenario to some extent entails reduced costs, compared to the other alternatives (average expensive)
5	Low Cost	Implementation cost is <20% of available budget OR The scenario fully entails reduced costs, compared to the other alternatives (least expensive).
0	Not Relevant	No current implementation costs OR No difference between alternatives.
How to Calculate	The cost is estimated sustainable against the available budget of the decision-maker. This may include different sources. > DMs-based calculation of available budget, adding on existing funding streams for the part of its competency. > If there is a private or external contribution involved which is guaranteed to be covered, there is a bonus of + 1 > Expert-based calculation of IC of each action.	
C	Governance Feasibility	
C.3	Institutional Feasibility	
C.3.4	Supra-Municipal Scale	
Demand	The scenario foresees the participation of multiple municipalities (or local government areas).	

Description	The scenario takes a Supra-Municipal perspective to tackle flood risk and involves spatial actions on different municipalities. Elaborated from: Deliberazione XI/5135, Lombardy Plan Regional Law 20/2020 - Regional Contributions for the Construction of De-Waterproofing Projects presented by Municipalities - Definition of Selection Criteria for Inspection by ERSAF	
Application	Scenario-based	
Scale		
Points	**Description**	**Threshold**
-1	Not Supra-Municipal	The scenario is entirely focused on a single municipality and does not consider broader regional or metropolitan aspects.
1	Partially Supra-Municipal	Some elements of the scenario extend beyond municipal boundaries, including 2 municipalities.
3	Moderately Supra-Municipal	The scenario considers regional or metropolitan factors, extending on 3 to 4 municipalities.
5	Highly Supra-Municipal	The scenario fully integrates supra-municipal considerations, extending on 5 or more municipalities, addressing broader urban and regional contexts.

Tab. 03 – Example of action-based and scenario-based Indicators

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Azioni distribuite di adattamento alluvionale: un modello decisionale partecipativo multi-scala

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Abstract
Con l'aumento della frequenza e dell'intensità delle alluvioni, la gestione tradizionale del rischio spesso trascura il potenziale cumulativo di azioni più piccole e decentralizzate, limitando l'integrazione tra interventi pubblici e privati. Contribuendo a un approccio sistemico all'adattamento, questo lavoro presenta un framework decisionale partecipativo che supporta azioni distribuite. Sviluppato tramite analisi bibliografica, interviste e focus group a Milano e a Melbourne, il framework integra diversi passaggi partecipativi per valutare le azioni raggruppate in cinque dimensioni multidisciplinari di management e governance. Complementare alle pratiche attuali, crea condizioni sociotecniche e istituzionali un agire collettivo.

Parole chiave: Flood Risk Management; Built Environment; Decision-Making; Multi-criteria; Adaptation.

Introduzione

L'aumento dell'intensità e della frequenza degli eventi alluvionali, soprattutto in contesti urbani complessi, ha incentivato l'adozione di strategie di gestione del rischio di alluvioni (*Flood Risk Management* – FRM) su scala di bacino idrografico. Tuttavia, le pratiche attuali di FRM restano prevalentemente settoriali, trascurando le interdipendenze e le sinergie tra interventi a differenti scale. Questo limita la capacità di riconoscere l'impatto cumulativo delle misure adottate, in particolare per quanto riguarda l'integrazione di azioni pubbliche e private (Kreibich *et al.*, 2015; Rehan, 2018; Raikes *et al.*, 2019). Nonostante l'adozione congiunta di strategie di difesa, prevenzione, mitigazione, recupero e preparazione, interventi ingegneristici pubblici di ampia scala sono spesso favoriti, anche se possono essere soggetti a fallimento, richiedere risorse significative e generare conflitti nella distribuzione di costi e benefici (Bignami, Rosso and Sanfilippo, 2019). Veerbeek *et al.* (2012), Barendrecht *et al.*, (2020) tra gli altri, supportano approcci sistemici e decentralizzati per l'adattamento ai fenomeni alluvionali. In tale contesto, Flood Risk Governance si configura come un approccio complementare al FRM, riflettendo mutamenti più ampi nella governance sociale e recependo le tendenze emergenti verso la decentralizzazione. Tradizionalmente, le misure di FRM sono valutate da un punto di vista ingegneristico, sulla base della riduzione dei danni come indicatore dell'efficacia e dell'efficienza (Klijn *et al.*, 2021). Al contempo, strumenti alternativi o complementari, quali l'analisi ponderata, possono contribuire

all'individuazione di soluzioni più eque ed efficaci. Approcci innovativi richiedono quindi insiemi di indicatori più ampi, che riflettano le dimensioni ambientali, sociali ed economiche.
La presente ricerca diparte da tre lacune principali: i) l'assenza di un approccio sistemico all'adattamento ai rischi alluvionali, capace di valorizzare il contributo delle azioni a livello di strategie, scale, attori e rischi differenti; ii) i limiti metodologici nell'analisi multi-scalare; iii) la scarsa comprensione dell'interfaccia tra scala geografica, distribuzione spaziale e contributo pubblico-privato nei processi di adattamento.
Questo contributo introduce il Framework FLOODS.ACT (*Flood Decisions towards Systemic Adaptative aCTions*[1]), uno strumento concepito per supportare le decisioni strategiche e progettuali di FRM, all'intersezione tra principi di gestione e governance. Il Framework mira a orientare il progetto verso un insieme distribuito e diversificato di azioni di adattamento. La struttura valutativa proposta consente di analizzare azioni di FRM esistenti o proposte a scala di (sub-)bacino, promuovendo scenari in cui l'adattamento pubblico e privato coesistano. La sua struttura valutativa è articolata in Dimensioni, Criteri, Sotto-Criteri e Indicatori. I principali destinatari sono decisori pubblici e policy-makers, ma il Framework fornisce anche supporto a gruppi di advocacy comunitaria per una maggiore partecipazione. Il contributo si articola in revisione dei metodi valutativi esistenti in ambito FRM, descrizione dello sviluppo e della validazione del framework proposto, presentazione e raccomandazioni conclusive.

Metodi esistenti
Diversi metodi a supporto delle decisioni in materia di FRM sono stati documentati in letteratura (Alves *et al.*, 2018). La valutazione economica delle alternative di FRM si basa prevalentemente sulla *Cost-Benefit Analysis* (CBA), che utilizza stime di danno e scenari probabilistici per calcolare valori attualizzati netti, rapporti costi-benefici o tassi di rendimento (Mechler, 2016). Tuttavia, la CBA presenta diversi limiti: tende a escludere benefici indiretti, esternalità e costi opportunità, e non considera né la distribuzione spaziale di costi e benefici né la varietà di vulnerabilità ed esposizioni (Molinari *et al.*, 2021). La *Multi-Criteria Analysis* (MCA) rappresenta il principale approccio alternativo o complementare per la valutazione del rischio e l'analisi di progetti, soprattutto quando vi siano obiettivi multipli e valori differenziati tra portatori di interesse (Meyer, Haase and Scheuer, 2007). Al contempo, la MCA comporta difficoltà nella validazione quantitativa e dipende spesso da giudizi di esperti (Gallina *et al.*, 2020).
Sulla base dei metodi multicriterio, sono stati sviluppati strumenti quali LEED, BREEAM e il Protocollo ITACA, volti a valutare opzioni progettuali nel costruito, mediante criteri di sostenibilità prestazionale. Nel contesto australiano, il *Investment Framework for Environmental Resources* (INFFER, 2024) è impiegato per pianificare e prioritizzare investimenti pubblici nella gestione delle risorse naturali e ambientali, basandosi anch'esso su una logica costi-benefici. Sebbene alcuni di questi protocolli siano stati adattati alla scala di quartiere o urbana, hanno limitata rappresentazione degli aspetti sociali. Tra questi, il Protocollo ITACA a scala urbana si basa su una definizione multidisciplinare di sostenibilità, su dati open-access e indicatori con calcolo semplificato e scalabili. Dunque rappresenta un riferimento significativo per il Framework, in quanto include aspetti di governance, tra cui la qualità del processo di pianificazione, la partecipazione dei cittadini, la qualità urbana e architettonica (ITACA, 2016). La ponderazione dei criteri è calcolata empiricamente in funzione della scala, della durata e magnitudo dell'impatto.
Come suggeriscono Attaianese and Acierno (2017), questi protocolli dovrebbero essere considerati non solo strumenti di certificazione, ma anche dispositivi capaci di orientare il progetto verso una maggiore consapevolezza sociale, attraverso l'integrazione di metodi partecipativi e criteri eterogenei. Inoltre, tali strumenti presentano limiti, quali incoerenza nei punteggi e scarsa aderenza all'identità locale o alla fattibilità istituzionale. Il Framework introdotto nel prossimo paragrafo affronta tali criticità introducendo pesi definiti dagli stakeholder locali e integrando criteri provenienti dall'ingegneria, dalle scienze sociali, dall'architettura e dalla pianificazione.

Metodologia
Il Framework FLOODS.ACT è stato costruito attraverso un processo articolato in più fasi. In primo luogo, è stata condotta una revisione della letteratura per definire le Dimensioni e i Criteri rilevanti. Successivamente, tali risultati sono stati sottoposti a una validazione tramite interviste con esperti, il cui contributo è stato integrato nel Framework. Gli intervistati hanno suggerito modifiche quali l'aggiunta, l'eliminazione o l'aggregazione di alcuni criteri. Questo processo iniziale di identificazione di Dimensioni e Criteri principali è descritto in dettaglio in Vanelli, Lavagna and Minifie (2024). In seguito, per formalizzare il Framework e strutturarlo secondo un sistema operativo di ponderazione e valutazione, la gerarchia è stata ulteriormente rivista e adattata per rispondere ai requisiti metodologici. Ad esempio, la categoria *Governance Capacity* è stata suddivisa in *Governance Legitimacy* e *Feasibility*, al fine di ottenere una distribuzione più equilibrata dei criteri all'interno di ciascuna Dimensione. Il Framework è stato quindi dettagliato mediante indicatori specifici, rispetto ai quali è possibile valutare scenari progettuali alternativi. In terzo luogo, la versione preliminare del Framework è stata verificata tramite casi studio selezionati. Questa fase ha previsto l'organizzazione di Focus Groups con la partecipazione di esperti, membri della comunità, autorità locali e architetti. Il Framework preliminare e i dettagli relativi al Focus Group condotto in Australia sono descritti in Vanelli, Lavagna and Minifie (forthcoming). Gli obiettivi del Focus Group erano di: discutere e validare il Framework nel contesto locale; esplorare la sua applicazione nei processi decisionali esistenti; attribuire i pesi ai Criteri. A seguire, il Framework è stato rielaborato e il feedback integrato. Le modifiche hanno riguardato: la semplificazione e chiarificazione delle denominazioni dei Criteri; la verifica di eventuali ridondanze e sovrapposizioni, in particolare tra le Dimensioni di *Flood Risk Reduction* e C*o-benefit Provision*, e tra *Governance Feasibility)* e *Governance Legitimacy*; l'articolazione di *Steps, Phases*, *Loops* come presentato a seguire.
Il Framework è stato poi testato attraverso due casi studio – il bacino del fiume Seveso in Italia e quello del Maribyrnong in Australia – utilizzando scenari sviluppati a partire da workshop e interviste con agenti locali. Il caso del Seveso riguarda inondazioni ricorrenti in un'area altamente urbanizzata e inquinata, interessata da interventi pubblici su larga scala. Il caso del Maribyrnong è invece legato all'evento alluvionale dell'ottobre 2022, che ha colpito oltre 500 abitazioni nei sobborghi di Melbourne. I profili dei due casi sono introdotti nelle pubblicazioni sopracitate.

Il Framework
Il Framework FLOODS.ACT si basa su un sistema di analisi multicriterio per valutare risposte sistemiche all'adattamento ai rischi alluvionali alla scala di bacino o sottobacino, assegnando punteggi prestazionali a insiemi di azioni. Include misure esistenti e di progetto, strutturali, non strutturali, grigie, verdi, pubbliche o private, comprese strumenti normativi ed economici. Il Framework consente di confrontare alternative progettuali, tenendo conto del contributo alla riduzione del rischio alluvionale. La sua struttura è articolata in *Phases, Steps e Loops* (Figura 1), sulla base di una combinazione di fonti teoriche, interviste e risultati dei Focus Groups. I passaggi sono elencati nella Tabella 1. Inoltre, si propone l'istituzione di un *Community Partnership Panel* (CPP), ispirato al modello in via di sperimentazione a Melbourne, con l'obiettivo di formare e coinvolgere attivamente gli stakeholder nelle fasi di definizione e valutazione degli scenari.

Phases, Steps e Loops
L'applicazione del Framework è stata strutturata in quattro Fasi, a partire dalla Fase 1-Analisi, che include l'analisi del rischio (*Hazard Assessment*); l'analisi delle caratteristiche spaziali e sociali dell'area (*Socio-Spatial Screening*); e la validazione della modellazione del rischio (*Field Validation*). I primi due passaggi possono essere condotti internamente dalle autorità competenti o affidati a consulenti tecnici. Il terzo passaggio è stato introdotto in risposta ai suggerimenti del Focus Group sul caso Maribyrnong. La tempistica di questa fase può variare in base al contesto, ma si ipotizza

una durata massima di un anno, in linea con i tempi richiesti per l'aggiornamento dei modelli di rischio nel caso studio australiano.
La Fase 2-Pianificazione degli Scenari Progettuali introduce un approccio più partecipativo, per ovviare alle pratiche top-down tradizionali, articolandosi in sviluppo degli Scenari e delle sue condizioni (*Conditional Scenario)*. Il Framework è supportato dall'*Atlas for Flood Adaptation Design Action*, un repertorio di azioni a supporto delle fasi partecipative, testato nel bacino del Maribyrnong per la co-creazione degli scenari. La Ponderazione dei criteri (*Weighting*), consente di definire pesi contestuali per la valutazione. Nel Framework, i pesi non sono predefiniti da esperti, ma stabiliti dagli stakeholder locali tramite il metodo Playing Cards, in modo da riflettere valori e priorità del contesto. Questo passaggio può essere svolto prima dei workshop o in parallelo, senza influenzare la definizione degli scenari. Segue l'analisi di fattibilità tecnica, normativa ed economica (T*echnical and Feasibility Planning),* e si conclude con la presentazione degli scenari per ulteriore confronto. Integrando i risultati dei workshops, la fattibilità tecnica si inserisce a valle del co-design per non limitare le alternative. Anche in questa Fase, si prevede una durata di circa un anno, per consentire più cicli di confronto e allinearsi ai tempi delle autorità competenti, come nel Maribyrnong.
La Fase 3-Valutazione degli scenari si concentra sull'analisi delle alternative progettuali, attraverso l'attribuzione di punteggi (*Scoring)* agli scenari applicando il protocollo valutativo, per ottenere la graduatoria (*Ranking)* che riflette la ponderazione e aggregazione dei punteggi per ciascuna dimensione. Lo scenario con punteggio più alto rappresenta l'alternativa preferibile. A seguire, una consultazione (*Reporting)* propone i risultati della valutazione, secondo modalità analoghe alle consultazioni pubbliche. Gli scenari finali sono sottoposti ad approvazione formale (*Approval)*, al di fuori del perimetro del presente Framework, per proseguire poi alle fasi preparatorie e implementazione.
Poiché i processi decisionali non sono mai completamente lineari, ma richiedono aggiustamenti continui, il Framework introduce dei *Loops*. Ad esempio, il Passaggio 3 può comportare una rivisitazione della modellazione del rischio o l'aggiornamento dei gruppi vulnerabili. Considerata la natura strutturata ma intensiva della Fase 2, che prevede un forte coinvolgimento, ci si attende che la Fase 3 benefici di un ampio consenso. Tuttavia, il Framework è pensato come adattivo: un evento significativo può innescare una revisione retrospettiva delle fasi precedenti, per garantirne l'adeguatezza e l'attualità.

Il Protocollo Valutativo
Il *Value Protocol* è lo strumento sviluppato per valutare la performance degli scenari alternativi. Esso si articola in cinque Dimensioni, organizzate in Criteri e Sotto-Criteri (Tabella 2). La Dimensione A: Riduzione del Rischio Alluvionale (*Flood Risk Reduction*) si riferisce alla valutazione tecnico-economica delle azioni, premiando quelle che combinano più strategie di FRM (Dieperink *et al.*, 2016). La Dimensione B: Qualità spaziale e progettuale (*Spatial and Design Quality*) definisce il valore del progetto come parte integrante dell'adattamento, basandosi sull'esperienza olandese *Room for the River* (Busscher, van den Brink and Verweij, 2019), e valuta la multi-scalarità delle azioni progettuali. La Dimensione C: Fattibilità di Governance (*Governance Feasibility*) misura la possibilità di implementazione secondo i meccanismi e le strutture di governance esistenti, e valuta la coesistenza tra adattamenti pubblici e privati (Tompkins and Eakin, 2012; Alexander, Priest and Mees, 2016; Juhola *et al.*, 2022). La Dimensione D: Legittimità di Governance (*Governance Legitimacy*) verifica la coerenza tra scenari e profilo di rischio locale, nonché la presenza di strumenti partecipativi e possibilità di ricorso (Barquet and Cumiskey, 2018). Infine, la Dimensione E: Co-benefici (*Co-benefit Provision*) valuta il contributo alla riduzione di rischi multipli e la generazione di benefici ambientali, economici e sociali (Alves *et al.*, 2019).
I Criteri sono articolati in Indicatori, valutati su una scala -1, 0, 3, 5, ispirata al Protocollo ITACA e successivamente convertita su scala 1–100. Ogni Dimensione può ricevere un massimo di 20 punti. Un punteggio negativo indica mal-adattamento o mancato rispetto di standard minimi; 0 indica

prestazione neutra o non applicabile; punteggi positivi riflettono performance migliorative. Per le azioni esistenti, alcuni indicatori (come costi o co-benefici) possono avere valore zero, se già assorbiti. Quando due indicatori corrispondono allo stesso sotto-criterio, essi sono ponderati equamente. Le soglie di riferimento derivano da standard esistenti, oppure da benchmark specifici testati durante la ricerca. Ad esempio, gli indicatori di costo premiano gli scenari compatibili con i budget disponibili. Ogni Indicatore è descritto con richiesta, descrizione, livello di applicazione (per azione o per scenario), scala e istruzioni per l'assegnazione del punteggio (Tabella 3). Rispetto ai co-benefici, la loro valutazione è ampiamente trattata in letteratura (vedi European Commission. Directorate General for Research and Innovation, 2021). Per mantenere la fruibilità del Framework sono stati inclusi solo i co-benefici ritenuti più rilevanti da interviste e connessi a incentivi per iniziative private, con la possibilità di adattare gli indicatori in seguito, in funzione di uno specifico contesto.

Conclusioni

Il framework proposto costruisce le basi sociotecniche e istituzionali per l'azione condivisa con diversi agenti locali, favorendo l'espressione di forme progettuali alternative e mettendo in discussione le pratiche di governance del rischio alluvionale. La costruzione del framework ha previsto una fase iniziale di revisione della letteratura e dei documenti tecnici, seguita da interviste e validazioni con stakeholder. Questo processo ha contribuito a trasformarlo in uno strumento multidisciplinare e applicabile, in grado di integrare competenze tecniche, saperi locali e processi partecipativi. L'ipotesi di istituire un *Community Partnership Panel* rappresenta un'opportunità per generare una visione condivisa e una responsabilità collettiva. Il Framework FLOODS.ACT, sebbene più complesso e impegnativo rispetto ai processi convenzionali, mette a disposizione strumenti flessibili che possono essere utilizzati in modo modulare o integrati in pratiche già esistenti. I decisori possono adottarlo nella sua interezza o selezionare alcuni passaggi per migliorare la partecipazione. Il Protocollo supporta la valutazione degli scenari attraverso cinque dimensioni, che possono anche servire da checklist per rafforzare aspetti come fattibilità, consenso e inclusività. L'evoluzione futura del framework dovrebbe esplorarne l'integrazione strutturale e la sostenibilità nei contesti specifici di FRM.

Nota

[1] Misura, termine tecnico diffuso, implica una logica risolutiva. Si adotta qui azione, per superare l'idea di un rischio alluvionale risolvibile.

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