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Multicriteria analysis as a method for engaging stakeholders and citizens in activities aimed at supporting climate resilience and adaptation to climate change – Gdansk Coastal City Living Lab case study

Abstract
In this study, we aimed to present solutions to mitigate the effects of climate change, summer torrential rain, and pluvial flooding. Within the Gdańsk living lab, a multicriteria analysis (MCA) was performed to assess the implementation of ecosystem-based adaptation (EBA) options for the city of Gdańsk. The results show an assessment of the stakeholders' acceptability and local knowledge of selected EBA options including rainwater gardens, water parks, retention ponds, green roofs, green walls, community gardens, urban farming and tree plantation. All the proposed EBAs were generally accepted during an online living lab stakeholder meeting. However, EBA solutions that were less intrusive on the natural landscape were preferred over large structures. Yet during the consecutive physical workshop with identified stakeholder composition, there was a higher level of approval for large structures to reduce the level of flood risk, indicating that face-to-face meetings significantly influence the choice of measures during MCA procedures. This has highlighted the importance of physical meetings of MCA for selecting proper implementation options.

Keywords
Climate change • resilience • multicriteria analysis• living lab • ecosystem-based adaptation

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Introduction

One of the most important issues in evaluating resilience for built environments in times of increasing risks of coastal hazards is understanding how they are impacted by climate change and how communities can protect the city's natural ecosystems from greater destruction (Dau et al. 2023; Anton, Paranunzio & Gharbia 2023). The impacts of climate change on human and natural systems are causing loss and damage to ecosystems, infrastructure, the environment, the economy and society. Coastal areas are exposed to sea level rise, erosion, coastal flooding and salinization among others (Doust et al. 2021; Oppenheimer et al. 2019). Consequently, adaptation to climate change − alongside mitigation − is an essential response. According to the Intergovernmental Panel on Climate Change (IPCC), adaptation can be defined as a 'process of adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2014). The goal of adaptation is to increase adaptive capacity and enhance resilience (Spiegelhalder et al. 2022).

Adaptation depends on whether it takes place in human-controlled or natural systems (Rusinga et al. 2014). In human-controlled systems, such as built environments and tightly managed natural systems, adaptation is driven by private interests, such as individual households and firms and/or public interests including various levels of government. Whether driven by private or public interests, adaptation can be planned, because of a conscious political decision. More recently, adaptation has been considered incremental or transformational. Incremental adaptation aims to maintain the essence and integrity of a system or process at a given scale, while transformational adaptation changes the fundamental attributes of a system in response to climate and its impacts (IPCC 2014; Spiegelhalder et al. 2022). In research, several climate change adaptation priorities can be identified, including assessing the effectiveness of adaptation responses, enhancing the understanding of limits to adaptation, enabling individuals and civil society to adapt, improving methods for synthesizing different forms of evidence or forms of adaptation and improving the dynamics of responses (Berrang-Ford et al. 2021).

Smart Control of the Climate Resilience in European Coastal Cities is a 4-year EU-funded project that hosts 10 coastal communities establishing a Coastal City Living Lab (CCLL) to propose sustainable solutions to CCLL-specific climate hazards. As a social innovation, the co-creative MCA was developed which aims to be a co-creative scientifically informed stakeholder-included process of democratically selecting the best-suited EBA options for each study area. The aim of the article is to present the Gdańsk MCA case study results. This study was conducted in the Gdańsk CCLL where the previously identified climate-related hazards affecting the city are coastal floods and land floods. During the Gdańsk MCA process, one online and one physical meeting was organized in which various stakeholders representing the quadruple helix took part. The stakeholders were familiar with or were specialists in ecological systems and represented various local and state institutions.

Literature review

Climate change adaptation encompasses a range of actions, that is, physical, structural, social and institutional. For example, physical and structural adaptation activities include engineering within the built environment, such as coastal protection, flood shelters, storm sewers and wastewater management, technological innovations including information

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and communication technologies, and traditional technologies, services such as emergency and health services and ecosystem-based adaptations or ecosystem-based approach (EBA). Social adaptation refers to education and behavioural activities such as participation, awareness raising, early warning and response systems, household evacuation, withdrawal and migration. Institutional adaptation includes economic solutions, such as insurance, subsidies, and taxes, laws and regulations including water regulation agreements, land assessment and zoning and policies and programmes such as adaptation plans and mainstreaming (IPCC 2014; Spiegelhalder et al. 2022; 100 Resilient Cities 2024).

According to Spiegelhalder et al. (2022), several measures can be distinguished in terms of strategies and actions aimed at mitigating climate change-related impact, namely, hard measures, soft measures, EBAs and hybrid forms. Hard measures assume, prevent or contain hazards using dikes, seawalls or breakwaters. Soft measures refer to adaptative behaviour including land use planning and subsidies. The aim of any EBA is to ensure ecosystem service provision and preserve and promote biodiversity (Munang et al. 2013). This approach includes adaptation interventions implemented at the level of the ecosystem, ecological structure, functions and services (Wamsler et al. 2016). EBA also refers to practices that promote socio-ecological resilience by supporting ecosystem services, through ecosystem management that help people to adapt to climate change and lower their vulnerability (Ojea 2015). The examples of adaptation measures can be street tree planting, green roofs or increases in green urban areas. Hybrid measures assume a combination of the previously implemented hard measures with more ecosystem-friendly adaptation options (Andreadis et al. 2021) such as seawall and green dike construction and planning, permeable pavements and green roofs.

An ecosystem service (ESS) is any benefit to people that is provided by the natural environment and a healthy ecosystem. In a more academic sense (Haines-Young & Potschin 2018), 'an ecosystem service is defined as the contribution that ecosystems make to human well-being'. An ecosystem according to this definition is a living system as in ecology (eco), and, therefore, not only limited to the natural world, such as specific habitats. However, (ecologic) ecosystems can also be considered as urban or other infrastructural systems that include human societies interactive with their natural surroundings, such as living labs. As such, services are products of those ecosystems, whether natural, semi-natural or highly modified, that most directly affect human well-being (Etxebarria et al. 2022). Achieving the benefits of ecosystem services requires the engagement of various stakeholders.

In this context, involvement refers to the active participation of relevant and interested parties in the MCA process. Stakeholders or individuals and groups that share a common interest in the identification, assessment and selection of adaptation options can directly or indirectly influence – or be influenced – by decisions. Stakeholders could be such groups as decision-making 'interest groups' policymakers, experts, planners and analysts and political parties, civil society organizations and residents (Lahdelma, Salminen & Hokkanen 2000; Alves et al. 2020; Baills, Garcin & Bulteau 2020; Etxebarria et al. 2022).

Research methods

To identify stakeholder-desired investments to support climate change mitigation, ten living labs were set up as part of the Horizon 2020 Smart Control of the Climate Resilience in European Coastal Cities project. More precisely, SCORE outlines a co-creation strategy, developed via a network of 10 Coastal City Living Labs (CCLLs), to enhance coastal city climate resilience rapidly, equitably and sustainably through an ecosystem-based approach and sophisticated digital technologies (Etxebarria et al. 2022).

A Living Lab is a place for citizens, scientists, entrepreneurs and authorities represented by businesses and organizations to co-create ideas, tools and technologies to address local challenges. It is a place for innovation that helps to change the expectations of stakeholders and communities (Malmberg & Vaittinen 2017; Lie, Van Paassen & Witteveen 2023). According to Bronson, Devkota & Nguyen (2021, p. 2) 'Living Labs are a mechanism or approach that brings a diversity of stakeholders together to arrive at user-centric solutions and innovations and thus they could present a viable method for solving complex issues'.

Within the framework of the established laboratories, a MCA was conducted in Gdańsk. MCA was the method selected to carry out a participatory assessment in each place (Zopounidis & Pardalos 2010). The appropriate method used in the project was MCA, which aimed to involve local and regional stakeholders from each of the 10 CCLLs in the assessment of their consecutive adaptation solutions through workshop activities. MCA is an appropriate participatory evaluation method because it allows the integration of stakeholders at different stages, including the evaluation and prioritisation of adaptation measures. MCA is a useful, participatory tool for solving complex decision-making problems, allowing individuals to compare different solutions, according to predefined criteria, and to obtain an overall score for each solution, thus enabling to prioritise them (Etxebarria et al. 2022; Riera-Spiegelhalder et al. 2023). According to Hajkowicz & Collins (2006) MCA consists of three components, that is, a set of options which need to be scored, a set of criteria measured in different units and a set of performance measurements for each option against each criterion. Munaretto, Siciliano & Turvani (2014) mention that the key output of a MCA is the single most preferred option or a set of ranked solutions. The process of MCA is composed of the following steps, that is, understanding the local adaptation context, identifying a list of preliminary options, screening or feasibility assessment, defining evaluation criteria; scoring or assessment of options, weighting of evaluation criteria and ranking and prioritization of options and sensitivity analysis (Etxebarria et al. 2022).

Findings

The objective of using the MCA method in Gdańsk during the workshop was to suggest and assess EBA implementation in three districts (Wrzeszcz district; old historic central area; Orunia district) effective against summer torrential rain and pluvial flooding. The workshops aimed to assess the stakeholders' acceptability and local knowledge of different EBA options, namely, rainwater gardens, filter strips, water parks and retention ponds, green roofs and walls, community gardens and urban farming, tree plantations, protection and restoration of grasslands/open green spaces. The objective was to rank the different adaptation strategies and to consecutively share the ranked results with the local municipality and relevant stakeholders, to be potentially included in the region's climate action plans.

The EBA feasibility assessment and the final selection of the evaluation criteria were undertaken in the online session (23rd of November 2023). Sixteen stakeholders participated in the workshop. The following entities took part in this process: Gdańsk Waters, Gdańsk Municipality, Agency for Regional Atmospheric Monitoring of the Gdańsk Agglomeration (ARMAAG), University of Gdańsk and Technical University of Gdańsk. All of them belong to the quadruple helix group in the following proportions: citizens 37,5%, government 25%, industry 12,5%, and academia 25%. The stakeholders were asked to grade each of the four general criteria, that is, acceptability, technical feasibility, ease of

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Table 1. Ecosystem-based adaptation solutions and scoring suggested by participants during the online workshop organised by the Gdańsk team

No. of EbA option	Name of EBA option	Stakeholder acceptability	Technical feasibility	Ease of Implementation	Financial Feasibility	Total	AVERAGE	Ranking
1	*Rain gardens*	*3,88*	*3,88*	*4,06*	*4,13*	*15,9*	*4.0*	*3*
2	*Water parks and retention ponds*	*3,94*	*3,25*	*3,94*	*3,88*	***15.0***	*3,8*	5
3	*Filter strips*	*3,25*	*3,31*	*4,5*	*4,44*	*15,5*	*3,9*	4
4	*Green roofs and green walls*	*4,00*	*3,25*	*4,19*	*3,88*	*15,3*	*3,8*	5
5	*Urban farming and community gardens*	*3,81*	*3,56*	*4,31*	*4,49*	*16,2*	*4.0*	3
6	*Planting trees*	*4,13*	*3,94*	*4,56*	*4,31*	***16,9***	*4,2*	1
7	*Introduction and/or renovation of open green spaces*	3,81	4,06	4,38	4,25	16,5	4,1	2

Source: SCORE, Gdańsk CCLL

Table 2. Criteria for ecosystem-based adaptation options formulated by participants during the online workshop organised by the Gdańsk team

1	**Reducing the risk/ damage associated with heavy rains**	To what extent do you think the solution contributes to reducing the risk/damage associated with heavy rains?
2	**Protection and use of urban and housing infrastructure**	To what extent do you think the solution will contribute to increasing the protection and use of urban and housing infrastructure?
3	**Protection and use of cultural heritage (infrastructure, traditions).**	To what extent do you think the solution will contribute to the protection and use of cultural heritage?
4	**Reduction of public and private costs after implementation**	Do you think the solution will reduce public and private costs after implementation?
5	**Increased recreational opportunities**	To what extent do you think the solution will contribute to increasing the recreational opportunities of Gdańsk?
6	**Increased biodiversity**	To what extent do you think this solution will contribute to the increase in biodiversity?

Source: SCORE, Gdańsk CCLL

implementation, financial feasibility, with each criterion to receive points for each stakeholder ranging from one to five points: with one indicating the lowest support and five the highest support.

The summated individual votes were subsequently averaged, giving the mean (Table 1). All the proposed preliminary EBAs scored means of 15 points or over of maximally 20. This makes them all feasible for implementation based on the general feasibility criteria as supported by the available stakeholder group. Retention ponds received 15 points while planting trees received 16.9 points. All the proposed EBAs were generally accepted as able to contribute to the main hazard, that is, pluvial summer flooding.

During the online meeting, six specific criteria were described and presented (Table 2). These criteria allowed individual EBA options to be weighed up during the next physical workshop.

The physical workshop on the 5th of December 2023 brought together stakeholders from the different municipalities and different administrative levels, and academics, researchers, representatives of the private sector and civil society. The following entities took part in this process: Gdańsk Municipality, Regional Directorate for Environmental Protection, Agency for Regional Atmospheric Monitoring of the Gdańsk Agglomeration (ARMAAG), Institute of Meteorology and Water Management – National Research Institute, Port of Gdańsk, University of Gdańsk and the Technical University of Gdańsk. All of them belong to the quadruple helix group in the following proportion: citizens 12,5%, government 50%, industry 12,5%, and academia 25%.

Different kind of hazards, study areas and preliminary EBA selection was repeated, followed by further explanation of the continuous MCA procedure, during which typically, the voting and weighing preferences were collected in a combination of mobile phone Google forms and a printed voting form. The total number of cast votes was 16. The voting and weighted ranking yielded the following result (Table 3).

Water parks and retention ponds received the most points (348.70), while green roofs and green walls received the least scoring points (236.10). The personalised weighting of the specific criteria showed that pluvial risk/damage reduction got the most average support (29%) and protection of cultural heritage

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Table 3. EBA solutions and scoring suggested by participants during the physical workshop held in Gdańsk

No. of EbA option	Name of EbA option	Perception of flood risk/damage reduction	Protection/ use of urban/ housing infrastructure	Protection/ use of cultural heritage (infrastructure, traditions)	Reduction of public and private costs after implementation	Increase recreational opportunities	Maintain and enhance biodiversity	Final scoring	Initial Ranking	Final Ranking
		29.00	**20.00**	**9.00**	**16.00**	**11.00**	**16.00**			
1	*Rain gardens*	*98.60*	*72.00*	*36.00*	*64.00*	*33.00*	*48.00*	*303.60*	*4*	*4*
2	*Water parks and retention ponds*	*124.70*	*80.00*	*36.00*	*64.00*	*44.00*	*64.00*	**348.70**	*1*	*1*
3	*Filter strips*	*107.30*	*74.00*	*27.00*	*48.00*	*22.00*	*48.00*	278.30	*5*	*5*
4	*Green roofs and green walls*	*84.10*	*60.00*	*27.00*	*32.00*	*33.00*	*48.00*	**236.10**	*7*	*7*
5	*Urban farming and community gardens*	*81.20*	*56.00*	*27.00*	*48.00*	*33.00*	*48.00*	245.20	*6*	*6*
6	*Planting trees*	*104.40*	*70.00*	*27.00*	*64.00*	*44.00*	*64.00*	309.40	*3*	*3*
7	*Introduction and/or renovation of open green spaces*	*116.00*	*82.00*	*36.00*	*64.00*	*44.00*	*64.00*	342.00	*2*	*2*

Source: SCORE, Gdańsk CCLL

and traditions received the lowest average support (9%). The personalised weighting did not change the ranking as the specific criteria were valued of importance within a narrow range (9–29%), indicating that no extreme outliers beyond this range were oberved, either from personalised weighting or general criteria.

During the physical workshop, there was a higher level of approval needed for large structures to reduce the level of flood risk compared to the results from the online meeting. Compared to the online meeting, this post-voting opportunity to exchange ideas is an essential part of the co-creation MCA process. This has highlighted the relevance of implementing the MCA in the form of a physical meeting of participants where opinions and ideas should and can be exchanged through appropriate moderation.

Conclusions

In this study, we discussed the EBAs and the methods used. One of the significant challenges, that was also emphasized during the physical meeting, is the necessity to carry out investments in a narrow area, without considering the broader environmental context. For instance, a representative of the Regional Directorate for Environmental Protection (RDOŚ) pointed out a recently transformed garden as part of the Brzeźnieński Park, which negatively drained the water from the adjacent soil on which the historic border of older trees. This was due to the lack of financial resources and holistic planning. Also, the problem is the lack of a detailed inventory of natural resources that are being implemented, meaning that sometimes the support for biodiversity is absent or excluded. In other words, the implementation plan lacks detail and cannot be efficient in supporting the ecosystem services foreseen.

The future challenge for reducing flood risk will be the high density of buildings and the use of concrete surfaces in many places. With the current infrastructure situation for the built environment in the city of Gdańsk, it is impossible to return to the times when there were many retention areas in the city. Therefore, it is necessary to use the smallest possible areas to increase urban water retention. Gdańsk and its various institutions try to prevent the negative effects of extreme climate events by large sums of financial investments. Compared to other cities, Gdańsk and its various institutions try to prevent the negative effects of extreme climate events in accordance with EBA.

The study carried out in Gdańsk, and other experience gained during the project and literature review have led to several conclusions referring to MCA. The advantages of using the MCA method are that it brings together the diverse expertise and scientific knowledge of the stakeholders, who represent different perspectives, interests and values. A highly regarded benefit is the transparency of the process, the expression of opinions in a direct way which enables a better understanding of problems and the suggestion of positive solutions. During the workshop some experts highlighted that the MCA is a highly effective method for everyone to show their preference - even citizens - and which allows other evaluation criteria to be added. Considering quantitative and qualitative criteria, this method allows for mutual learning through dialogue and joint conflict resolution. The MCA method also has some imperfections or limitations. The selection of stakeholders and their degree of involvement can

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be problematic. Experts in workshops may suggest exemplary solutions. Meanwhile, in planning practice, feasible (field and thus practical) solutions are considered. The transparency of the process may mean that stakeholders are not always willing to share their knowledge, such as due to conflicting interests, which may manifest itself in biased statements. The method may also be technically too complex for some participants due to the weighting of criteria. Therefore, the results may be subject to some error (Hajkowicz & Collins 2006; Munaretto, Siciliano & Turvani 2014; Etxebarria et al. 2022).

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