Interreg Baltic Sea Region

Co-funded by the European Union

SUSTAINABLE WATERS City Blues

CITY BLUES JOINT OPERATIONAL MODEL FOR IMPLEMENTING NATURE BASED SOLUTIONS

Concept and Key Performance Indicators (KPI)

D1.3 Critical KPIs for the joint operational model design process

October 2024

AUTHORS

Ivar Annus, Katrin Kaur, Kerta Kõiv, Kristjan Suits, Murel Truu *Tallinn University of Technology*

Cristian Tosa, Gopalakrishnan Kumar *University of Stavanger*

Salla Leppänen, Anna Vilhula*, Tampere City Government*

Therése Ehrnstén, *Malmö City Government*

Maarja Täht, *Tartu City Government*

Kristiina Mardi, Mathias Joachim Skov Pristed *Aarhus City Government*

Project has received funding from the EU's Interreg Baltic Sea Region programme.

Summary

The document outlines the development of Key Performance Indicators (KPIs) for the Joint Operational Model (JOM) within the City Blues project, focusing on different stages of the Nature-Based Solutions (NBS) cycle. It presents a structured approach to measuring success across various urban NBS implementation stages, from Sewered City to Water Sensitive City.

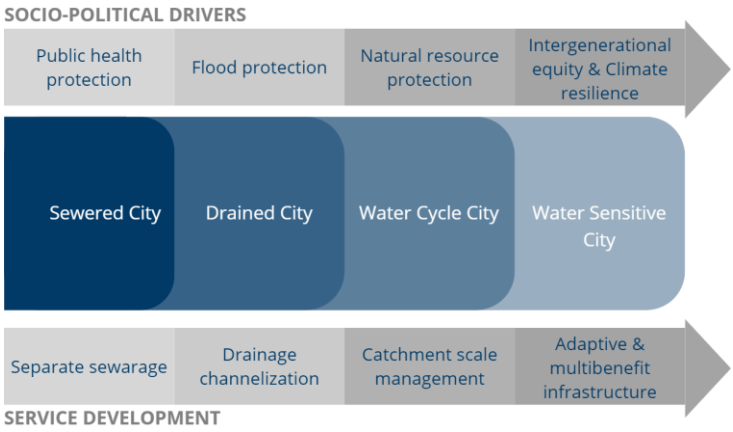


Figure 1 Cities transition in urban water management (Adapted from [1])

The KPIs are categorized into **process KPIs**, which monitor the actions and steps taken during NBS implementation, and **result KPIs**, which assess the outcomes and impacts of these actions.

The document emphasizes the need for both types of KPIs to ensure that cities are not only following the right procedures but also achieving tangible benefits such as improved urban resilience, ecosystem services, and stakeholder engagement. Through a detailed analysis and collaboration with cities, the final KPI framework integrates insights from Nordic NBS community workshops and city-level practices to help guide the effective deployment, monitoring, and scaling of NBS across urban environments.

Contents

Concept for the joint operational model

City Blues project has set an ambition to develop a **Joint Operational Model (JOM) for the development of Nature Based Solutions (NBS) for resilient urban watersheds**. This needs to serve as guidance source for local governments, infrastructure and public service providers to help select suitable strategies in implementing NBS. As the initial idea the JOM aimed to cover themes like planning of NBS, risk management, maintenance plans, citizen and stakeholder engagement, governance models and actual pilots and be visualized as a process chart.

To proceed with the development of the JOM it needs to be acknowledged that **all 5 pilot cities participating in the project differ by their previous experiences with climate extremes, their entry level capacities and knowledge pool on NBS, their financial capacity in investing into NBS and related developments**. Moreover, while cities have similarities in their local governance models, the socio-political contexts as well as legislative frameworks differ significantly. When aiming to develop a joint model that represents the different operations in cities implementing NBS, all such differences should be acknowledged.

Moreover, to make the operational model relevant for Baltic Sea Region (BSR) cities beyond consortium, the pertinence should be recognised by cities with no previous experience with NBS as well as by cities leading the way in NBS implementation in BSR. Therefore, the concept of JOM builds on different available models of urban transformation towards sustainable water management as presented by Sayers [2] and Brown [1] as well as the theory for reinventing organizational models as described by Laloux [3]. We illustrate the concept of JOM as a transformative process cycle as shown in Figure 2.

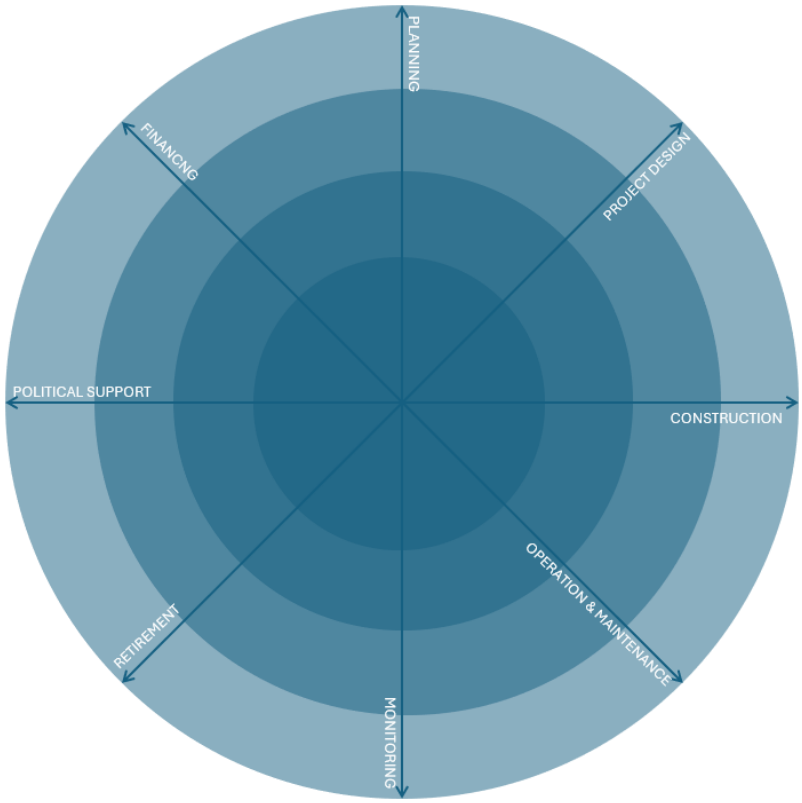
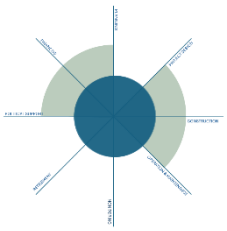
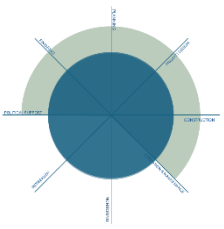
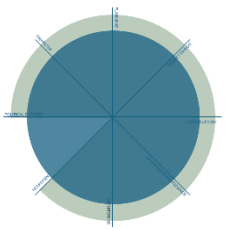
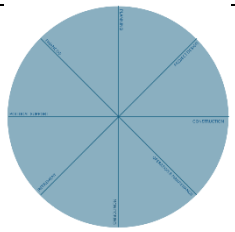


Figure 2 Concept of incremental transformations in cities operational model aiming to implement NBS in urban environments. Different shades show transformation stages cities go through when streamlining the use of NBS.

JOM will highlight and describe the important steps in NBS project cycle relevant for different transition stages of cities. As a simplification the first iteration of JOM will include 4 transition stages explained in Table 1.

Table 1 Transition stages of operational models

Transition stage	Sewered city	Drained city	Water cycle city	Water sensitive city
Description	No experience yet with NBS / green infrastructure	First pilots built and successfully operating. Recognition that budgets are limited and not all problems are equal.	Key locations have been identified for most efficient NBS implementation. Recognition that engineering / nature alone have limitations, hybrid solutions are needed.	Urban communities can cope with extremes and adapt to changes in climate, (urban) environment etc.
Motivation in implementing NBS	Desire to promote opportunities and manage risks adaptively.	Desire to manage flooding efficiently.	Desire to reduce flood damages, to control flood flows and be protected against flooding.	Desire to persist with extremes and urban uncertainties.
Objective	Demonstrate the benefits of NBS.	Identify the most impactful NBS.	Implement the most impactful NBS.	Be prepared for the uncertainties of future urban challenges.
Focus	Ignite and inspire Financing pilots Design demonstrators Implement / construct demonstrators Gaining political support	Methods (analyses, modelling) Learn and adjust Comprehensive planning & large-scale modelling Political support & public acceptance (institutionalization of NBS in urban design)	Securing financing Prove that NBS work Establishment of operation and maintenance practices Political support for large scale structural approaches to be implemented (levees, controls). Organized governance to achieve this.	Balanced and sustainable operational model Future oriented and flexible multi-purpose solutions
Growing effort related the governance (example)				

Joint operational model (JOM) will be fully developed in the further stages of City Blues project. The first concept was developed to map and systemize the Key Performance Indicators describing the NBS implementation.

Methods for identifying the Key Performance Indicators (KPIs) for NBS implementation

Literature review

Result KPIs for NBS implementation

Several studies are available on Key Performance Indicators (KPIs) for nature-based solutions (NBS), focusing primarily on their effectiveness in mitigating climate change. KPIs help quantify the benefits of NBS by assessing ecosystem services, climate adaptation, and urban resilience. Indicators like carbon sequestration, water quality improvement, and biodiversity metrics [4], [5], [6] are essential for evaluating the ecological impact of NBS and their capacity to adapt to climate change. Similarly, KPIs related to flood risk reduction and community engagement reflect the social and resilience benefits of NBS. Specifically in terms of hydro-meteorological risk management, different KPIs have been developed that allow to assess the performance of NBS related to risk reduction, but also improving ecosystem service provision as well as reinforcing local economies [7].

Recent studies have identified several categories of KPIs that can guide the design and implementation of NBS, ensuring they meet ecological and social objectives. Chapelli et al. [8] have recently defined 7 critical design criteria for planning NBS for effective flood mitigation. Mosca [9] has proposed a conceptual framework for optimization of environmentally sustainable NBS and identified data and tools how to effectively quantify this using most relevant parameters for urban heat island reduction, carbon storage, stormwater retention etc. Design criteria serving as KPI have been also developed for assessing the effect of green and blue infrastructure for the mental health and wellbeing of elderly [10].

Process KPIs for NBS implementation

Less research is available on the operational cycle of NBS and how to measure success of NBS implementation on the operational level. Despite this growing popularity, there is considerable uncertainty in selecting appropriate criteria and indicators for effectively monitoring and evaluating the success of NBS implementation in cities. Some approaches exist to propose indicators across project cycle and describe a selection criteria for assessment targets and determine appropriate data to quantify them [11]. However not much research has been done on measuring the NBS process (governance) effectiveness across project cycle, as it is more practical concern rather than actual research topic. However, when aiming to support cities in progressing towards more streamlined application of NBS, the KPI can assist in planning the next actions and progressive governance.

Gathering Stakeholder Insights

Feedback from the City Blues cities

As part of the KPI identification, an exercise was designed to gather insights from City Blues cities. Each city was asked to identify their practices in setting objectives and measuring success across the different stages of the nature-based solutions cycle. The cities were tasked with filling in tables that addressed several key questions across all project stages, such as gaining political support for NBS, financing and planning their implementation and more.

The cities were asked to:

- Bold the three focus stages for their NBS implementation process.
- Define their objectives for each project step, outlining what they aim to achieve at each project step (e.g. planning, design, construction etc.).
- Identify near-term actions needed to meet these objectives, specifying the concrete steps they will take.
- Describe how they measure success, outlining the key performance indicators (KPIs) or metrics used to track progress toward achieving their objectives.

This exercise helped City Blues cities reflect on their practices, clarify their goals, and success measures for each stage of NBS project development. As City Blues cities are in different stages of maturity in their NBS implementation, it helped to understand the possible transition across the different development stages.

Nordic NBS conference

The insights from the Nordic NBS community were successfully integrated into the City Blues JOM KPIs through a workshop held at the Nordic NBS Conference in September 2024 in Malmö (Figure 3). An interactive session organized by the City Blues project brought together city planners, municipal officials, environmental experts, and community stakeholders from the Nordics to discuss the key components for integrating nature-based solutions into urban planning and development. Participants explored essential elements such as policy frameworks, funding mechanisms, stakeholder engagement, technical expertise, and monitoring and evaluation.

Building on the experiences of the City Blues project, the workshop aimed to identify practical strategies for mainstreaming NBS in urban environments, facilitating collaboration, and sharing knowledge to enhance urban resilience and sustainability. As a result of the brainstorming the groups in the workshop were asked to outline the critical KPIs to identify the success or failure of the NBS implementation considering a specific city development stage (Figure 1).

Figure 3 Workshop in Malmö helped to identify the KPIs for the Nordic operational model for implementing NBS

The Malmö workshop focused on identifying critical KPIs and challenges across different transition stages for nature-based solutions (NBS), emphasizing the need for multidisciplinary collaboration, political support, and public acceptance.

- **Sewered City**: The key KPIs discussed included assessing capacity for change (e.g., partners needed, partners available), changes in media attention, the number of NBS-related documents and strategies, and budget allocation over time. Additionally, the need to map those areas affected by flood risks, track training efforts, and evaluate budget versus results was highlighted. Important insights included establishing baseline KPIs, fostering multidisciplinary work groups, and identifying a "thriving force" (e.g., disaster, pollution) to ignite NBS adoption.
- **Drained City**: The focus was on including NBS throughout planning processes, ensuring multidisciplinary groups across departments, and having annual reports and maintenance programs in place. KPIs included stakeholder involvement, knowledge among politicians, and public participation in NBS planning. Upscaling methods, experimentation, and public acceptance were prioritized for success.
- **Water Cycle City**: KPIs emphasized cost-related aspects such as insurance, maintenance, and funding diversification. Also, political support, long-term funding, and NBS performance were key objectives. Near-term actions focused on showcasing successful NBS examples, securing resources, and initiating monitoring and modelling.

- **Water Sensitive City**: The focus here was on the flexibility and multipurpose nature of NBS, with KPIs tracking the co-benefits provided, adaptability to new risks, and budget increases. Emphasis was placed on long-term planning, monitoring, fast recovery, and scalable, future-proof designs.

The overall themes included the need for capacity building, political and public support, and scaling NBS from pilot interventions to integrated, routine processes, results summarized in Table 2.

Table 2 Results of Malmö workshop

Challenge	Defined critical KPI-s	Additional comments
Sewered city	• KPI for capacity (do you have the capacity to change) – measure partners involved in the project • Change in media attention • Number of documents and strategies on NBS • Budget and priority – proportion to NBS over the years • Mapping people affected by flooding risk, change in risk • How much trainings on NBS • KPI for failure – budget allocation vs results (a lot of resources but no results, was it worth it?)	Important is to set the baseline for KPIs. Important to have multidisciplinary work groups (engineers, ecologists, planners etc.) Cities learning from each other, inspire politicians and planners Need for a thriving force – disaster, pollution etc. something that ignites the process. 1. Ignition, 2. Inspiration, extension for multi-competence (international), 3. Political support, 4. Pilots and learning, 5. Strategize
Drained city	• NBS is included (shown) throughout the planning process • Objectives in strategies/plans have included in all relevant departments • Maintenance and evaluation program have put in place • Annual report for NBS for different planning objectives • Innovation funding • Number of projects that had stakeholder involvement • How many politicians have knowledge on NBS? • How many NBS have been planned with public participation?	Focus should be set on: 1. Methods for upscaling/building capacity including knowledge at all levels (university, municipality, planners…). From single interventions to routine processes 2. Multidisciplinary groups with all critical actors (structured, learning from results) 3. Keep on experimenting 4. Public acceptance 5. Learn from failures Tasks: 1. Scaling mission – what is needed for upscaling? 2. Spread knowledge at universities, planning departments, contractors, politicians 3. Document the knowledge in guidelines, planning documentation 4. Get the acceptance from the general public
Water cycle city	• Cost of insurance • Area of flooded land • Ease of getting acceptance from landowners (KPI is rate of % answers/feedback) • Share of budget allocated for maintenance of NBS • Diversification of funding sources • Cost of maintenance • Number of checks vs number of actions (rate of failure) • Water quantity and quality • Biodiversity changes (if the frogs you brought to the pond are still alive)	Objectives are: 1. Continue having political support 2. Secure long-term funding 3. Sustain the performance and experience of the NBS 4. Prove that the NBS work Near-term actions to achieve it: 1. Need to show that NBS work 2. Show real-life good examples that NBS work 3. Success stories, collaboration with academies, showcase multiple positive effects of NBS 4. Secure resources and time, put it into the routine 5. Start monitoring and modelling, include more consultants 6. Define goals for environmental and social scale Discussion – who will take responsibility, there is no one person.

Challenge	Defined critical KPI-s	Additional comments
Water sensitive city	• How multipurpose are the solutions (nr of co-benefits, including water and people related) • Flexibility of the design • How well are NBS handling new/different risks (e.g. changes in design rainfall) • Increase in budget allocation for NBS • Changes in political support (changes how NBS are incorporated in zoning plans, urban planning, building regulations etc.)	Is able to recover fast, has flexible and scalable solutions. Focus should be set on: 1. Long term planning 2. Monitoring 3. Project design 4. Loss and damage modelling (modelling also the trends of the monitored results, improving the existing models?!?) 5. Ability to recover fast 6. Future scenarios 7. Flexible, multipurpose solutions 8. Scalable design

Analysis

The first draft of the Joint Operational Model (JOM) concept was initially developed through a thorough literature review and analysis of best practices in nature-based solutions implementation. This draft outlined key stages of the NBS cycle and included preliminary objectives and actions for each stage, such as gaining political support, securing financing, and ensuring effective monitoring. City Blues cities were then asked to provide their input through an exercise where they responded to the draft by detailing their own practices. This included defining their city's objectives for each project step, identifying near-term actions to achieve those objectives, and describing how they measure success. The cities' responses were gathered and analysed to identify common patterns, gaps, and best practices. These findings were then presented to the Nordic NBS community during a workshop, where further insights and feedback were gathered. Based on this collaborative process, the results were refined, and a comprehensive list of KPIs was created to measure success across the NBS cycle. The final KPIs reflected both the initial research and the practical experiences of the cities, ensuring that the JOM concept was both evidence-based and aligned with real-world needs.

Overall, when identifying the KPIs for the operational model stages it is important to distinguish whether we measure the success of the process or the aimed result. Process KPIs focus on the activities and steps taken to implement NBS, such as stakeholder engagement, policy integration, or securing project funding. These indicators help track whether the necessary actions are being carried out efficiently and within timelines. On the other hand, result KPIs measure the actual outcomes and impacts of these efforts, such as improvements in water quality, biodiversity, or community resilience. By separating these two types of KPIs, cities can ensure that not only are the right processes in place, but they are also achieving the intended environmental and social benefits. This distinction provides a more comprehensive understanding of both progress and effectiveness, allowing for better adaptive management and strategic adjustments.

Process KPIs for NBS implementation across project stages and governance transformations

Gaining and maintaining political support for NBS implementation

Political support is a prerequisite for the entire process, as it enables decision-makers to prioritize NBS, allocate funding, and create favourable regulatory environments. Without political backing, it can be difficult to proceed with planning, designing, and securing financing.

City Blues partner cities have been working strategically to gain and maintain political support for nature-based solutions (NBS) in urban planning and water management. Here's an overview of their approaches, with some examples:

- **Tampere** has successfully integrated NBS into various water management and urban development strategies. Their objective is to maintain this political support by revising and upgrading strategic documents regularly. For example, they measure success by annually reporting to environmental accounts on how many new NBS projects have been implemented and their associated costs. This continuous monitoring keeps NBS central to the city's strategy.
- In **Tartu**, the focus is on encouraging more politicians to actively support NBS by making them understand the benefits. They introduce their NBS ideas to local politicians, using successful examples from other cities to build credibility. The city measures success by tracking the number of politicians who support NBS, aiming to grow political advocacy over time.
- Like Tampere, **Aarhus** has successfully integrated NBS into urban development and water management strategies. They ensure political support is maintained by revising and upgrading strategic documents regularly. Aarhus also oversees the implementation of agreed action plans and monitors whether the schedules are kept, helping them to stay on track with their NBS initiatives.
- **Stavanger** aims to secure political commitment for prioritizing NBS in urban planning while fostering public awareness and support for NBS projects. Their approach includes presenting evidence-based research to decision-makers, organizing public consultations to gather input, and running communication campaigns to highlight the benefits of NBS. Stavanger measures success by the number of policies and regulations favouring NBS, the increase in budget allocation for NBS projects, and public awareness indicators such as survey results and positive social media mentions.
- In **Malmö**, the integration of NBS into urban strategies has been successful, and the goal is to maintain political support through periodic revisions of strategic documents. Success is measured through the monitoring of the city's environmental strategy, with indicators such as the proportion of overflows and the percentage of combined sewage and stormwater systems. Although explicit NBS indicators are still in development, their focus on environmental monitoring ensures NBS remains central to the city's climate adaptation efforts.

Each city employs a tailored approach, with some focusing on integrating NBS into strategic documents and others prioritizing political engagement or public awareness. Next the critical KPIs for different city development stages are presented.

Table 3 Critical KPI for measuring success in gaining and maintaining political support

- **KPI prioritized by at least 3 cities**
- **KPI prioritized by at least 2 cities**
- KPI prioritized by at least 1 city
- KPI proposed, but not highlighted on behalf of cities

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	In a sewered city, NBS are not yet viewed as a feasible alternative in urban environments. The need for these solutions is only recognized by experts, and political support is minimal. At this stage, NBS need to be introduced and demonstrated to gain traction.	• **Presence of NBS in municipal policy agendas: Inclusion of NBS in local policy discussions signals initial steps toward recognizing their value for urban environments.** • **Number of pilot projects initiated and funded: Political willingness to fund NBS pilot projects is a key indicator of emerging support.** • Measure the number of partners involved in NBS projects (e.g., city departments, external stakeholders) to assess the city's ability to implement change and build a multidisciplinary support base. • *Number of public statements or speeches in favour of NBS: Early advocacy from political leaders reflects a growing interest in promoting NBS.* • *Track changes in media coverage related to NBS initiatives, reflecting increased public awareness and potential political interest.* • *Count the number of trainings and capacity-building sessions conducted for city staff and stakeholders, reflecting the readiness of the city to support and implement NBS.*
Drained city	In a drained city, there is some political support for NBS, and these solutions have been integrated into strategic documents. However, the city struggles to implement these strategies due to limited political commitment, insufficient resources, or competing priorities.	• **Percentage of budget allocated for NBS: An increased budget allocation for NBS projects indicates a transition from experimental pilots to more formalized funding.** • **Number of policy revisions or updates incorporating NBS: The revision of existing policies to include NBS demonstrates growing political commitment.** • Number of cross-sectoral collaborations initiated: Collaboration between various government departments and stakeholders reflects political momentum and support for a more integrated approach.
Water cycle city	In a water cycle city, political support for NBS is well-established, and these solutions are integrated into various strategic documents. However, the city still faces challenges in prioritizing NBS over other land-use conflicts and in sustaining operations and maintenance due to limited budgetary commitment.	• **Number of comprehensive urban plans integrating NBS: Endorsement of urban plans that incorporate NBS as a core element demonstrates strong political backing.** • Institutionalization of NBS through legislation or ordinances: The adoption of laws and regulations formalizing NBS is a key indicator of long-term political commitment. • Political support for integrating green and grey infrastructure: Implementation of large-scale NBS projects that work alongside traditional engineering solutions reflects strong political endorsement for hybrid approaches. • *Public support: Ease of getting acceptance from landowners*
Water sensitive city	In a water sensitive city, there is full political support for NBS, with these solutions fully integrated into strategic documents. Political commitment is realized through adequate budget allocations, support for private sector involvement, and comprehensive governance for the entire NBS project lifecycle—from planning to maintenance.	• **Political approval for city-wide NBS governance frameworks: Institutionalizing NBS into formal governance structures ensures long-term sustainability through clear procedures, positions, and budgeting.** • **Increased budget allocations for both NBS maintenance and new developments: A growing financial commitment to both existing and new NBS projects indicates the maturity of political backing and commitment.**

Financing NBS

Securing funding should occur early in the process, after political support is obtained. Without adequate financing, planning and design efforts might stall, and the actual implementation could be delayed. Financial commitments ensure that resources are available for all stages of the NBS lifecycle.

The financing of NBS varies across the City Blues partner cities, with each city employing different strategies to secure and allocate funding for these projects. Cities employ multiple methods to finance NBS, often blending public and private funding sources. For example, Tampere collects a statutory stormwater fee to finance NBS, primarily in new development areas. All cities work actively with securing funds from EU- projects, aiming to minimize its own financial contribution. In addition to this Malmö, Aarhus and Stavanger blend public, private, and project-based funding to support NBS. Cities like Aarhus, Malmö and Tampere also encourage developers to contribute to NBS in new development areas as part of city plans. All cities are also interested in exploring innovative financing mechanisms, herein also support from EU funded projects is exploited.

Success in financing NBS is not explicitly measured by City Blues partner cities, however, could be assessed by tracking the number of new NBS projects implemented and the total cost of their implementation, by the number of funding applications submitted and approved, and the amount of funding received for NBS projects.

Table 4 Critical KPI for measuring success in NBS financing

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	At this stage, NBS is not yet widely implemented, and the focus is on securing initial funding for pilot projects to demonstrate their potential.	**- Amount of funding secured (e.g., from grants)** **- Number of pilot projects funded**
Drained city	Political support is growing, and the aim is to increase investment in NBS. The focus shifts to larger-scale funding to implement NBS projects as well as finance related governance tools (baseline inventories, modelling etc).	**- Total annual cost of implemented NBS** - Number of successfully funded proposals or grants - Number of financial disputes and claims related to NBS contracts - *Total annual cost related to NBS governance & management*
Water cycle city	NBS is integrated into city strategies, and the objective is to ensure consistent financing for their construction and operation. Financing does not only cover the creation of the NBS, but adequate maintenance and monitoring.	- **Percentage of budget allocated to NBS** (incl their operations) - Investments in operation and maintenance of NBS (maintenance infrastructure, monitoring equipment etc.) (eur / (ha x service life)) - *Number of public-private partnerships (PPP)*
Water sensitive city	Full financial commitment for NBS is realized, including for long-term sustainability and private sector involvement in financing.	**- Increase in budget allocations for NBS implementation and maintenance** - *Number of innovative financing mechanisms adopted (e.g., green bonds)* - *Total funding secured through public-private partnerships (PPP)*

Planning NBS

This stage involves assessing the specific needs and objectives for the NBS, understanding the local ecological and social context, and setting goals. Planning is critical for defining what success looks like, aligning stakeholders, and determining site suitability.

In cities like Tampere, the impact of new developments on the hydrological cycle is a key focus. The city aims to analyse these effects and develop catchment-specific masterplans for older urban areas to enhance stormwater management through NBS. These masterplans will identify areas where NBS, such as green streets and swales in renovated parks, can mitigate stormwater challenges.

In Aarhus, land-use planning already considers the impact of construction on the hydrological cycle. The city plans to further expand NBS as part of comprehensive urban planning, particularly in flood-prone areas. The master and sub-planning processes determine how stormwater management is incorporated into city planning. Catchment-specific masterplans are also being developed for existing urban spaces, identifying areas needing better stormwater management. The order of implementation for these plans will be decided annually. Aarhus also focuses on re-wetting former agricultural lands, restoring streams and rivers, establishing wetlands, and increasing NBS coverage in streets and parks through green streets or swales.

Stavanger prioritizes the renovation of streets and parks to increase NBS coverage, focusing on green infrastructure like swales and depaved areas.

Malmö aims to make the city greener and more resilient by integrating NBS into rebuilding and redesigning projects where space and feasibility allow.

Tartu is still in the process of mapping current and future climate-related problems, with the goal of highlighting these issues and possible NBS solutions. The city plans to integrate these solutions into ongoing projects.

City Blues partners measure the success of NBS planning in different ways. Tampere evaluates progress based on whether its zoning program has allocated space for stormwater management and if stormwater masterplans have been finalized. Aarhus and Malmö assess how well NBS are integrated into formal planning documents and the number of high-risk areas prioritized for NBS implementation.

Table 5 Critical KPI for measuring success in NBS planning

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	At this stage, NBS is not widely adopted, and planning efforts focus on piloting and demonstrating NBS.	- **Number of pilots of NBS projects planned** - **Number of feasibility studies conducted for NBS** - Advised usage of NBS in comprehensive plans
Drained city	NBS is recognized and integrated into some strategic documents, but planning focuses on expanding support.	- **Number of catchment areas identified for NBS implementation** **- Number of high-risk flood areas prioritized for NBS** - Number of strategic plans updated to incorporate NBS
Water cycle city	NBS is well-integrated into urban planning, but cities aim to resolve land-use conflicts and prioritize areas for implementation.	- NBS requirements/preference in planning (e.g. green factor tool, legislation) - Percentage of urban development plans incorporating NBS - Number of NBS projects approved in high-risk areas *- Level of stakeholder engagement in NBS planning*
Water sensitive city	NBS is fully integrated into planning processes, with a focus on long-term resilience and sustainability.	- Comprehensive urban NBS strategies adopted (thematic plans for green-blue infrastructure established)

Designing

After planning, the design phase translates goals and site assessments into detailed, practical solutions. This stage includes technical and ecological design aspects and integrates stakeholder input. It also aligns with budgetary constraints set during financing.

The design of NBS across City Blues partner cities is guided by specific objectives and a structured approach. In cities like Tampere, Aarhus, Tartu, Stavanger, and Malmö, the design process follows NBS guidelines, aiming to balance functionality, aesthetics, and environmental impact. The primary goals include setting retention targets for water management (both quantity and quality), and secondary goals enhancing biodiversity, ensuring safety, and promoting circular economy principles and long-lasting lifecycles.

Stakeholder involvement is also a key objective, with cities encouraging residents and experts to provide input during the planning stages. In all cases, the design process strives to not only solve environmental issues like stormwater management but also provide additional value to citizens by integrating nature into urban spaces.

Table 6 Critical KPI for measuring success in NBS design

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	At this stage, NBS is a new concept, and the focus is on piloting basic designs that demonstrate feasibility.	- **Number of pilot NBS designs** **- Achievement of basic functionality goals (e.g., water retention, flood control)** - Stakeholder input and approval of design concepts
Drained city	NBS is recognized and integrated into some strategic areas. Design needs to focus on improving functionality and environmental benefits.	**- Average performance of NBS in terms of water quality improvements or flood mitigation** - Percentage of NBS designs that meet specific water management or biodiversity targets *- Number of design iterations to address feedback and functionality challenges (including design failures)*
Water cycle city	NBS designs at this stage should aim to integrate multifunctional amenities (e.g., recreation, biodiversity, aesthetics) with core functionality.	- **Stakeholder satisfaction scores for the overall design quality** - Percentage of NBS designs that incorporate multifunctional amenities (e.g., recreational spaces, aesthetic improvements) - Number of NBS projects achieving both functionality and amenity targets (e.g., flood risk reduction, biodiversity, heat island reduction)
Water sensitive city	NBS designs are fully optimized for long-term resilience, sustainability, and integration with urban infrastructure.	- Long-term monitoring data showing NBS performance in achieving ecological and social benefits (e.g., biodiversity, stormwater management, urban cooling) - Number of NBS designs incorporating adaptive management for changing climate conditions - Lifecycle analysis of NBS performance, cost and associated amenities (e.g., carbon footprint versus maintenance costs versus community benefits)

Constructing

This stage is the physical implementation of the designed solutions. It involves coordinating materials, labour, and ecological considerations to ensure that the NBS is constructed according to the planned design. Successful construction lays the foundation for the future functioning of the NBS.

The construction phase of NBS projects across the City Blues partner cities, including Tampere, Tartu, Aarhus, Stavanger, and Malmö, is guided by specific objectives that focus on efficient implementation and minimizing disruption to surrounding communities. Each city aims to implement NBS according to annual investment or development plans, ensuring that projects are completed on time and within budget while adhering to high-quality construction standards and the designs tailored for the specific site.

The main objectives during NBS construction are minimize disturbance to the surrounding area and restore the environment after construction, ensure efficient and cost-effective project delivery and maintain strict adherence to design specifications and ensure high-quality outcomes. Success in NBS construction is measured using several indicators, including:

- The number of NBS projects implemented each year and specific metrics like kilometres or meters of restored rivers, or the number of wetlands and ponds established.
- The percentage of projects completed on time and within budget, reflecting the efficiency and cost-effectiveness of the construction process.

Table 7 Critical KPI for measuring success in NBS construction

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	At this stage, NBS construction focuses on pilot projects. The priority is to build basic infrastructure to demonstrate feasibility.	- **Number of NBS projects constructed** *- Percentage of projects completed on time* *- Number of complaints related to construction*
Drained city	NBS construction is expanded but must still align with strategic documents and investment plans. The focus is on scaling NBS efficiently while minimizing disruptions.	- **Percentage of projects completed within budget** *- Accident rates*
Water cycle city	Construction at this stage should ensure NBS are multifunctional, combining core infrastructure with amenities like recreational spaces, while maintaining cost and quality.	- Number of non-compliance issues during quality control
Water sensitive city	The focus is on optimizing construction processes for long-term resilience and sustainability, including the ability to adapt to changing urban conditions.	- Number of NBS constructions based on circular economy and principles of sustainable environmental construction *- Percentage of projects using NBS standard components in constructions (streamlined construction)* *- Optimized construction processes (life cycle cost or disturbance related)*

Operating and maintaining

After construction, ongoing operation and maintenance are necessary to ensure that the NBS continues to function effectively. This stage includes activities like periodic maintenance, addressing invasive species, or adjusting flow regime through manual or automated control. Neglecting maintenance can undermine long-term success.

The primary objective of NBS operation and maintenance across the partner cities is to ensure that NBS are easily maintainable and operate reliably. In cities like Tampere and Malmö, NBS sites are maintained in accordance with predefined maintenance programs and site-specific instructions. Establishing long-term maintenance and monitoring programs is critical to ensuring the continued functionality and effectiveness of NBS. Additionally, involving local communities in stewardship activities is encouraged to support ongoing maintenance efforts.

Success in NBS operation and maintenance is measured through several indicators:

- The number of NBS maintained or fixed annually.
- Maintenance quality tracking via photographs of maintained sites, providing visual proof of upkeep.
- The existence of documented maintenance and monitoring plans for each NBS project.
- The number of trained municipal staff and community volunteers involved in maintaining and monitoring NBS.

Table 8 Critical KPI for measuring success in NBS operations and maintenance

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	At this stage, the focus is on establishing basic maintenance protocols for pilot NBS projects to ensure their continued functionality.	**- Percentage of NBS requiring corrective actions (e.g., fixes or reconstructions)** **- Number of NBS sites maintained per year** - Availability of basic maintenance plans for pilot sites
Drained city	NBS implementation is scaled up, requiring more structured maintenance programs to ensure their reliability and sustainability.	- **Percentage of NBS sites maintained in accordance with the maintenance program** **- Number of NBS sites demonstrating continued functionality over time** - Percentage of NBS malfunctioning due to failures in design and/or construction - Number of staff trained in NBS maintenance - Frequency of site inspections and maintenance activities
Water cycle city	At this stage, NBS are more integrated into urban infrastructure, requiring advanced maintenance programs and community engagement for stewardship.	*- Number of community partnerships supporting NBS maintenance* *- Satisfaction scores from community and stakeholders regarding maintenance efforts* *- Number of NBS integrated with the urban water system monitoring platforms*
Water sensitive city	NBS are fully optimized, with long-term maintenance programs designed for resilience, climate adaptation, and ongoing community involvement.	- Percentage of NBS sites incorporating adaptive operation and maintenance strategies - Number of community-driven NBS stewardship initiatives established

Monitoring

Monitoring is an ongoing process that should begin during the operation and maintenance phase but has to continue for years or decades to assess performance against KPIs. It provides essential feedback on the effectiveness of the solution, allowing for adjustments and ensuring long-term sustainability.

The monitoring of NBS performance is critical to ensuring that these solutions function as intended and provide the desired benefits, such as stormwater management, water quality improvement, and biodiversity enhancement. The cities of Tampere, Aarhus, Stavanger, and Malmö have adopted various approaches to monitor the effectiveness of their NBS projects. The primary objective of monitoring is to verify that NBS are functioning as designed. This involves collecting data on key parameters, such as water retention, nutrient removal, and biodiversity levels. The monitoring data also support adaptive management, allowing cities to adjust maintenance or design practices based on actual performance. This ensures that NBS remain effective over time and can inform future planning efforts.

Most typical KPI used in NBS monitoring is nutrient and Total Suspended Solids (TSS) removal, which indicates how effectively NBS are improving water quality. Also, NBS are monitored for the effectiveness in controlling water retention time as well as the system's capacity to manage stormwater. In some cases, also biodiversity metrics, including the number of flora and fauna species in NBS sites is monitored, however these are often reported through state monitoring programs.

The success of monitoring as such is measured using KPI as:

- Frequency of data collection and reporting, with some cities conducting monthly or quarterly reports.

- The use of innovative monitoring technologies and the number of adaptive management actions taken in response to monitoring data are also indicators of success.

Table 9 Critical KPI for measuring success in NBS monitoring (focusing on the governance aspects of the monitoring activities)

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	In the early stages, monitoring programs are just being developed, with the focus on establishing basic protocols and governance.	- **Number of NBS sites with basic monitoring protocols established**
Drained city	Monitoring becomes more structured, ensuring that data collection is consistent and feeding into governance frameworks.	- **Percentage of NBS projects monitored annually** - Frequency of monitoring data used for policy revisions or updates *- Number of staff trained in monitoring techniques*
Water cycle city	Governance for monitoring is fully integrated, with systems in place for long-term data collection, analysis, and review.	*- Frequency of data collection and reporting (e.g., quarterly or annual reports)* *- Number of standardized monitoring guidelines implemented* *- Number of community or stakeholder feedback reports incorporated into monitoring*
Water sensitive city	NBS monitoring is optimized for resilience and adaptability, with governance systems designed for long-term sustainability.	- Number of adaptive management decisions made based on monitoring reports - Number of NBS projects with citizen science or community-based monitoring programs *- Percentage of NBS projects using innovative monitoring technologies (e.g., remote sensing)*

Retirement or repurposing

Urban NBS are typically heavily engineered systems. However, they are also evolving ecosystems where different ecological processes like natural succession in vegetation, soil formation and development, species adaptation as well as evolvement of microbial and fungal activity take place. As NBS mature, feedback loops between vegetation, soil, and water cycles can amplify or stabilize ecological processes, but **can also lead to changes in terms of intended functionality.** At a certain point, it may become necessary to retire or repurpose the NBS to ensure that it continues to provide value to its surrounding environment and community.

Cities have very little experience in retirement and repurposing of NBS. Currently the aim is to maintain solutions so that the system does not need to be totally replaced frequently but to cope with small-scale repairs.

Table 10 Critical KPI for measuring success in NBS retirement and repurposing

Transition stage	Rationale	Key Performance Indicators (KPI)
Sewered city	At this stage, the focus is on minimizing risk of needing to retire pilot NBS by maintaining basic functionality through small-scale repairs, ensuring systems last as long as possible.	- Failures in designed performance - Average lifespan of NBS systems before major intervention *- Frequency of maintenance interventions*
Drained city	As NBS becomes more established, cities should begin planning for the eventual repurposing of systems, particularly those that are no longer fully functional due to ecological changes.	- NBS repurposing is based on comprehensive risk assessment (with consideration to designed lifespan).
Water cycle city	NBS at this stage are more complex, requiring adaptive management strategies to extend functionality and account for ecological succession, soil development, and species adaptation.	**- Number of NBS renewed annually to ensure their initial functionality** *- Ratio of transitioned and utilized NBS (loss of natural character)*
Water sensitive city	In this stage, cities prioritize resilience, focusing on long-term strategies for retiring or repurposing NBS systems to ensure sustainability and continued community and environmental value.	**-** Availability of long-term strategies for retiring or repurposing NBS systems

Failure to implement timely repurposing or adaptive management can lead to degraded functionality, loss of public trust, and reduced political backing. By demonstrating proactive management, including small-scale repairs, repurposing, and long-term planning for system transitions, cities can show their commitment to sustainable urban solutions, thus preserving political support and reinforcing public engagement with NBS. This, in turn, ensures ongoing investment and broad acceptance of these solutions in the urban landscape.

Critical KPI-s

The Table 11 summarizes the most significant **process KPIs** that were identified for the project cycle, and these correspond mostly to the first stages of the operational cycle of NBS. In discussions with the cities, it was understood that while it is possible to identify and measure different operational performance indicators for also the later stages of operation cycle, it is more relevant there to focus on the results.

In the initial stages of the NBS cycle—*political support*, *financing*, and *planning*—KPIs such as the **number of NBS projects**, **budget allocations**, and **presence in policy and planning documents** are critical for tracking progress and building foundational support. These KPIs reflect the extent to which NBS are gaining political traction, financial backing, and integration within city strategies. However, it can be challenging to measure these indicators accurately, as NBS are often embedded within broader climate adaptation and resilience efforts rather than receiving specific budget lines or policy references. As a result, measuring success at this stage may require interpreting data from overarching climate policies, which can dilute the visibility of NBS-specific achievements.

As the NBS cycle progresses into more operational stages like *designing*, *construction*, *operation and maintenance*, and *monitoring*, it becomes more relevant to shift the focus to **functionality and performance KPIs**. Here, indicators such as the efficiency of stormwater management, biodiversity benefits, and resilience under climate stressors become essential in assessing the real-world impact of NBS. Additionally, examining whether and how NBS are embedded in long-term **maintenance plans and monitoring programs** ensures that these solutions are not only implemented but are also actively managed, adapted, and improved over time. Tracking these functional and performance based KPIs enables cities to understand the practical contributions of NBS and to adaptively manage their impact on urban ecosystems and community resilience.

For measuring the progression of a city in terms of the transition stages, most performance indicators remain relevant from previous stages, however as the operational model progresses, the previously focused KPI will function as background statistics rather than critical KPI.

The KPI identified have currently not been quantified with any limit values. As a current format, the KPI identified can serve as self-assessment metrics for cities aiming to implement NBS.

Table 11 Critical KPIs for Sewered city, Drained city, Water cycle city and Water sensitive city.

Sewered city	Drained city	Water cycle city	Water sensitive city
• Presence of NBS in municipal policy agendas: Inclusion of NBS in local policy discussions signals initial steps toward recognizing their value for urban environments. • Number of pilot projects initiated and funded: Political willingness to fund NBS pilot projects is a key indicator of emerging support.	• Percentage of budget allocated for NBS: An increased budget allocation for NBS projects indicates a transition from experimental pilots to more formalized funding. • Number of catchment areas identified for NBS implementation	• Number of comprehensive urban plans integrating NBS: Endorsement of urban plans that incorporate NBS as a core element demonstrates strong political backing.	• Secured budget allocations for NBS implementation and maintenance

List of references

[1] "Urban water management in cities: historical, current and future regimes | Water Science & Technology | IWA Publishing." Accessed: Oct. 18, 2024. [Online]. Available: https://iwaponline.com/wst/article-abstract/59/5/847/15553/Urban-water-management-in-cities-historical?redirectedFrom=fulltext

[2] P. Sayers *et al.*, "Strategic flood management: ten 'golden rules' to guide a sound approach," *International Journal of River Basin Management*, vol. 13, no. 2, pp. 137–151, Apr. 2015, doi: 10.1080/15715124.2014.902378.

[3] F. Laloux, *Reinventing Organizations: A Guide to Creating Organizations Inspired by the Next Stage of Human Consciousness*. Nelson Parker, 2014.

[4] F. Horneman, S. Torresan, E. Furlan, D. N. Nguyen, A. T. Asresu, and A. Critto, "Indicators and metrics to evaluate the effectiveness of nature-based solutions for climate risk management and adaptation: A systematic review," Copernicus Meetings, EGU23-8034, Feb. 2023. doi: 10.5194/egusphere-egu23-8034.

[5] F. Mosca, M. Canepa, and K. Perini, "Strategies for adaptation to and mitigation of climate change: Key performance indicators to assess nature-based solutions performances," *Urban Climate*, vol. 49, p. 101580, May 2023, doi: 10.1016/j.uclim.2023.101580.

[6] "Indicators to measure the climate change adaptation outcomes of ecosystem-based adaptation | Climatic Change." Accessed: Oct. 18, 2024. [Online]. Available: https://link.springer.com/article/10.1007/s10584-019-02565-9

[7] G. Caroppi *et al.*, "A comprehensive framework tool for performance assessment of NBS for hydro-meteorological risk management," *Journal of Environmental Planning and Management*, vol. 67, no. 6, pp. 1231–1257, 2024, doi: 10.1080/09640568.2023.2166818.

[8] N. A. Chappell and K. J. Beven, "Nature-based solutions for effective flood mitigation: potential design criteria," *Environ. Res. Lett.*, vol. 19, no. 7, p. 074006, Jun. 2024, doi: 10.1088/1748-9326/ad4fa2.

[9] F. Mosca, "A Conceptual Framework for the Optimization of Environmentally Sustainable Nature-based Solutions," *Journal of Digital Landscape Architecture*, vol. 2024, no. 9, pp. 173–181, 2024, doi: 10.14627/537752017.

[10] M. B. Andreucci, A. Russo, and A. Olszewska-Guizzo, "Designing urban green blue infrastructure for mental health and elderly wellbeing," *Sustainability (Switzerland)*, vol. 11, no. 22, 2019, doi: 10.3390/su11226425.

[11] A. Rödl and A. Arlati, "A general procedure to identify indicators for evaluation and monitoring of nature-based solution projects," *Ambio*, vol. 51, no. 11, pp. 2278–2293, Nov. 2022, doi: 10.1007/s13280-022-01740-0.