



Research Articles

Integrating service design principles in NbS implementation: Insights from Szombathely (Hungary)[☆]Francisca Tapia^{a,b,*}, Andras Reith^{c,d}^a Marcel Breuer Doctoral School, Faculty of Engineering and Information Technology, University of Pécs, Hungary^b Advanced Building and Urban Design, Orlay Street 2/b, H-1114 Budapest, Hungary^c Advanced Building and Urban Design, Orlay Street 2/b, H-1114 Budapest, Hungary^d BIM Skills Lab Research Group, Department of Engineering Studies, Faculty of Engineering and Information Technology, University of Pécs, Boszorkány Street 2, 7624 Pécs, Hungary

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ABSTRACT

Nature-based Solutions (NbS) have become crucial for enhancing urban resilience to climate change; an increasing focus has been put by scholars and practitioners in strategies to enhance their implementation. This research presents the case study of the Dési Huber István Elementary School, in Szombathely (Hungary) where a green and blue infrastructure (GBI) NbS was implemented as part of the JustNature project. This case study applied a methodological framework that integrated the principles of Service Design (SD) in the early phases of NbS implementation. The research presents how SD can enhance NbS early implementation, investigating the question: How can a service design approach support and sustain NbS implementation in educational environments?

By integrating SD principles, the study contrasts conventional top-down approaches with co-design processes, revealing that the latter can foster a more inclusive and participatory NbS design, boosting stakeholder engagement and adjusting NbS to local needs. The research highlights the importance of involving students, teachers, and the local community in the process. Based on the findings, key recommendations for effective NbS implementation in educational environments are proposed, categorized into learning integration (interactive stations, curriculum integration), student empowerment (Green Teams, environmental councils), infrastructure development (multifunctional outdoor classrooms, eco-friendly systems), and community engagement (inter-generational partnerships, living laboratory practices). This study contributes to the growing body of knowledge on innovative approaches to urban climate resilience and sustainable design practices. It also emphasizes the crucial role of educational institutions in fostering environmental awareness through practical NbS projects, which can range from urban forests and green walls to ecosystem-based management approaches. The significance of this research lies in its potential to inform both educational policy and urban planning practice, promoting resilient, sustainable, and educationally enriching urban environments.

1. Introduction

Nature-based solutions (NbS) have taken a leading role in climate change mitigation and adaptation actions. As an umbrella concept, NbS encompasses diverse interventions, from urban forests and green roofs to ecosystem-based management approaches like wetland restoration and sustainable agriculture [1]. In urban environments, these solutions

offer particularly significant benefits, enhancing resilience through climate change adaptation, biodiversity enhancement, and improved well-being [2]. The concept has notably developed through international cooperation and public policy applications, giving it a pragmatic character and placing a strong emphasis on its implementation. Ensuring NbS effective implementation is crucial for delivering the expected environmental and societal outcomes in a cost-effective way,

Abbreviations: GBI, Green blue Infrastructure; H2020, Horizon 2020 framework programme; JN, JustNature; NbS, Nature-based Solution; SD, Service Design; SECAP, Sustainable Energy and Climate Action Plan; SSME, Service Sciences, Management and Engineering.

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while also addressing the complexity and multidimensionality of climate change-related challenges, such as extreme heat events, flooding from intense precipitation, air pollution, and biodiversity loss [3]. These challenges are notably exacerbated in urban scenarios, for which cities must apply integrated resilience strategies [4].

Within the broad range of NbS applications, educational settings have emerged as crucial spaces for their implementation, with school courtyards and gardens serving as vital platforms for promoting ecological transition and sustainable practices [5]. These spaces not only provide environmental benefits but also serve as living laboratories for environmental education and eco-friendly behavior development [6]. Green spaces in school environments contribute to biodiversity by creating habitats for local flora and fauna, while simultaneously improving human well-being through reduced heat stress, enhanced air quality, and creation of spaces for social interaction and learning. Furthermore, it provides evidence on the relationship between successful urban NbS implementation and strong community involvement from the outset to ensure long-term acceptance and maintenance [7]. Framed in this context, this document presents the case study of the Dési Huber István Elementary School in Szombathely, Hungary.¹ This NbS intervention entailed the implementation of a living schoolyard with green multifunctional NbS that involved a multi stakeholder approach and the application of an integrated implementation framework that utilizes Service Design tools.

The Szombathely intervention exemplifies how educational spaces can serve as important fields of action for green and just transitions [5]. The Dési Huber István Elementary School project implements NbS that includes shading structures, Kneipp path tracks, and the conversion of 400 m² of asphalt to permeable surfaces. The project has three objectives: urban heat stress mitigation, environmental education enhancement, and social cohesion promotion through the engagement of students, teachers, parents, and elderly residents as part of the city's urban goals. As a five-year initiative, it aims to improve environmental awareness, community health, and climate resilience, serving as a blueprint for future urban educational interventions.

A multifunctional design approach was adopted in Szombathely, integrating Service Design (SD) principles into the early design phases. NbS initiatives frequently face significant barriers in integrating different stakeholders, as well as in assuring their effectiveness and a sufficient understanding of costs and benefits [8]. Traditional design methodologies often struggle addressing these complexities, particularly regarding multifunctionality, contextual integration, and co-impacts [9]. Service Design's emphasis on user-centered and collaborative approaches [10] offers promising solutions to overcome these challenges by providing structured frameworks for stakeholder engagement, knowledge co-creation, and iterative development processes. This approach is particularly valuable given the high levels of complexity and uncertainty in NbS projects, and the need to progress despite imperfect information and limited standardization [8].

A qualitative case study methodology is used to present Szombathely's intervention, which is detailed in section 3 of this paper. The process is structured in three sequential phases that respond to the interventions' implementation, beginning with a comprehensive literature review that established a robust theoretical framework for examining both the challenges in NbS implementation and the potential of SD tools to address these limitations. The second phase involved the selection and adaptation of five SD tools for application in the Szombathely case study, specifically targeting the early implementation stage of the schoolyard regeneration project. The selection criteria encompassed the contextual factors of Szombathely, project timeline constraints, resource availability, and stakeholder involvement. The service design workshops aim to enhance the NbS design process by improving user

interaction and experience with the solutions, while also addressing key aspects of operations and maintenance for long-term sustainability. Building upon established service design methodologies [10], we developed and adapted a specialized toolkit for NbS implementation in educational settings, which comprises five key instruments: Service Brainstorming, Personas, Motivation Matrix, Actor Network Mapping, and Expert Interviews. Finally, the implementation of these tools was done through a series of three collaborative workshops conducted from October 2023 to January 2024, whose results are documented in this paper.

Overall, the results of this intervention indicate that the integration of digital and traditional design methods facilitated a comprehensive capture of insights, enabling a thorough examination of the NbS implementation process in the Szombathely schoolyard regeneration project. The content analysis of the Szombathely case study demonstrates the value of integrating Service Design tools in NbS, especially during the design phase. The co-design process for the living schoolyard project showcased innovative ideation, stakeholder mapping, and operational insights crucial for successful NbS interventions such as educational gardens with composting areas, native plant beds, a green wall system, and permeable surfaces with learning stations. These features were designed to provide ecosystem services while improving biodiversity and climate resilience. This approach provides a versatile framework for urban planners, policymakers, and researchers, highlighting the importance of stakeholder engagement in NbS design and maintenance. While primarily focused on early implementation stages, the methodology has potential implications for the entire NbS process.

2. Theoretical framework

1.1. The potential of living schoolyards as NbS implementation sites in urban environments

NbS interventions are characterized by a high degree of complexity, with management approach being a critical aspect. Eggermont et al. [11] and Somarakis et al. [12] propose a three-tier classification system for NbS, which provides a comprehensive framework for urban planners and policymakers to strategize NbS implementation across diverse urban contexts. This system delineates NbS into three distinct categories: Type 1 encompasses minimal or no intervention, exemplified by protected urban biotopes; Type 2 involves moderate intervention, such as urban forests, necessitating the management of multi-functional ecosystems; and Type 3 requires substantial intervention to create new ecosystems, as illustrated by living schoolyards or urban area regeneration projects.

Green or re-naturalized schoolyards are considered an innovative NbS implementation site ([55], as part of the green infrastructure and re-greening NbS initiatives, affirming their capacity of delivering significant social and ecological advantages as NbS that enhance urban sustainability [13,55,58]. By treating schoolyards as 'living' ecosystems that combine grey, green, and blue infrastructure, cities can better adapt to climate change. This approach not only helps the environment but also makes these spaces more liveable and functional for their main users – children and teenagers [55]. These innovative urban interventions demonstrate remarkable multifunctionality, addressing various environmental and social challenges simultaneously. The implementation of permeable surfaces in schoolyards enhances urban water management by increasing the absorptive capacity of cities and mitigating rainwater runoff [14]. Furthermore, these green spaces play a crucial role in urban climate adaptation by attenuating heat island effects and serving as community thermal refuges during extreme heat events, primarily through the provision of shade and cooler microclimates [15]. Living schoolyards also contribute significantly to urban biodiversity conservation and environmental education. By creating diverse habitats within urban landscapes, these spaces facilitate biodiversity gains and provide opportunities for on-site nature-based

¹ The intervention is part of the JUSTNature (JN) project, funded by the European Commission (EC) under the Horizon 2020 program (2021–2025).

learning, potentially nurturing the next generation of urban environmental advocates [16]. The benefits extend beyond ecological considerations, with studies indicating improvements in student well-being and academic performance [17]. Additionally, these green interventions act as natural buffers, reducing the school community's exposure to various forms of pollution, including noise, visual disturbances, and air pollutants, particularly by filtering contaminants from nearby traffic [18].

Living schoolyards as urban NbS have gained significant attention, particularly in low- and middle-income countries [55]. Studies show multiple benefits including improved climate resilience [3], enhanced biodiversity [19], and positive impacts on children's cognitive development [20]. However, implementation faces various challenges [2,21] and requires careful consideration of stakeholder needs [22]. Successful projects need comprehensive planning with robust maintenance strategies [23]. Importantly, greened schoolyards can reduce health inequities between low and high-income neighborhoods [24], promoting equal opportunities regardless of gender [25] or socioeconomic status [26,27].

Despite the recognized potential of living schoolyards as NbS sites for implementations in urban settings, their practical implementation remains challenging [28]. The focus on engineering aspects has sometimes led to the neglect of biodiversity conservation in GBI implementation (European Commission, 2021). The implementation of schoolyards as NbS faces numerous challenges, particularly in low- and middle-income countries. Infrastructure deficits and failures extend to the inadequate management of insufficient urban vegetation [5]. The unreliable supply of water and electricity impedes the development of hybrid nature-based solutions, which may require automated watering systems during certain periods [55]. Moreover, the scarcity of adequate and well-maintained building spaces in schools suitable for pedagogical activities and diverse community needs, including universal access and age- and gender-specific areas for recreation, compounds the implementation difficulties [55]. While school environments are increasingly recognized as priority areas for increasing children's exposure to GBI, studies analysing the spatial and temporal patterns of GBI in school environments remain scarce, especially those considering the design and implementation process in all urban contexts and elements [5]. Given the significant beneficial effects of urban green spaces on children's health and development [2,29], there is a pressing need for upscaling nature-based interventions within and around schools. The implementation of schoolyards as NbS is further hindered by various factors,

including policy implementation lags [23] and the need for a balanced approach that considers both immediate urban needs and long-term ecological benefits. To realize the full potential of GBI interventions, particularly among decision-makers, a comprehensive strategy that addresses these multifaceted challenges is essential [30]. This approach should integrate scientific knowledge, policy frameworks, and practical considerations to overcome the barriers to successful implementation of schoolyards as effective NbS in urban environments. Fig. 1 provided an overview of benefits and NbS implementation of living schoolyard challenges.

1.2. Service Design: A multidisciplinary co-creation methodology

Co-creation methodologies, particularly those employed in Horizon 2020 (H2020) NbS projects, aim to address complex urban environmental challenges through the integration of diverse stakeholder perspectives [31]. These approaches enhance knowledge dissemination, align societal requirements, and facilitate successful NbS implementation [32]. The NbS co-creation process involves a reflective, participatory approach that engages stakeholders in the development of viable interventions [33]. Co-creation represents a significant evolution in collaborative development methodologies, originating in the business sector as an approach to integrate diverse stakeholder perspectives with technical expertise [34]. Since 2007, the concept has undergone substantial transformation, particularly in urban planning contexts, evolving from basic user-centered design approaches to a comprehensive framework that fosters collective innovation and meaningful stakeholder engagement [35]. Within this framework, co-design emerges as a crucial component, functioning as a strategic mechanism for expertise integration by facilitating the synthesis of perspectives from researchers, designers, and end-users in solution development [35].

NbS systems require diverse stakeholder participation, including researchers, practitioners, engineers, and the public [54]. While organizations support co-design methods for knowledge generation [36], managing diverse participants without standard frameworks remains challenging [54]. Co-design goals in the NbS context demonstrate strong alignment with Service Design principles, emphasizing user-centricity, iterative development, and holistic thinking [35]. Service Design (SD) is a multidisciplinary field that synthesizes applied behavioural sciences, technology, and design principles to develop user-centric solutions,

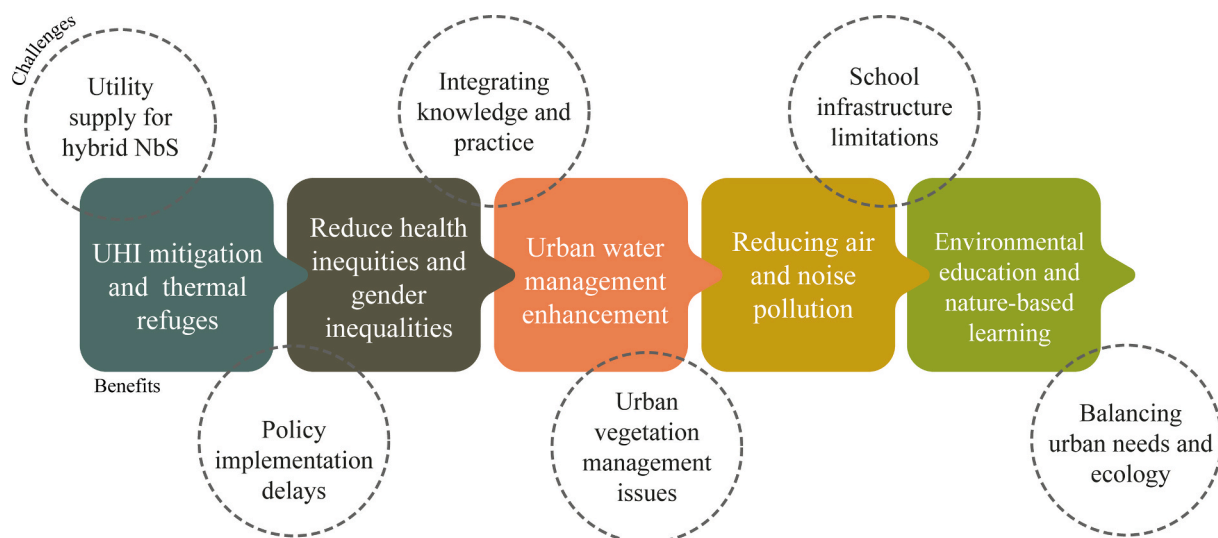


Fig. 1. Living schoolyards benefits and NbS implementation challenges in urban environments. , Kanai et al. (2024), , Sanz-Mas et al. (2024), and . Source: Authors (2024), adapted from [5][25][24]

encompassing both tangible and intangible outcomes [44]. Originating from Service Sciences, Management and Engineering (SSME), SD has evolved to incorporate a diverse range of disciplines, focusing on the intricate interactions between service providers and users [37]. At its core, SD employs a human-centred methodology that facilitates the co-design of solutions through extensive stakeholder engagement [44]. In the context of NbS, designers play a crucial role in conceptualizing services that address both environmental challenges and community needs. This process involves mapping complex processes and allocating resources effectively.

The participatory nature of SD enhances the efficacy and contextual relevance of NbS projects by aligning solutions with local requirements. As [37] note, SD strikes a balance between usability, aesthetics, and user perspectives. The discipline aims to create efficient, distinctive, and

impactful services through a combination of exploratory, generative, and evaluative methodologies [44]. In SD, physical products often serve as conduits for delivering more comprehensive service experiences, with value creation centered on enhancing user interactions [38]. SD draws inspiration from human-centered design, emotional design, and design thinking, fostering collaboration through participatory and co-design principles [35]. The framework emphasizes the dynamic interplay between service providers, users, and the services themselves, focusing on the shared experiences that shape the design process. Value in SD is co-generated through user experiences, making it inherently context-specific and adaptable to diverse needs [61]. This co-creation approach not only enhances user well-being but also aligns with the strategic objectives of service providers, creating a synergistic relationship between all stakeholders involved in the design process. In this

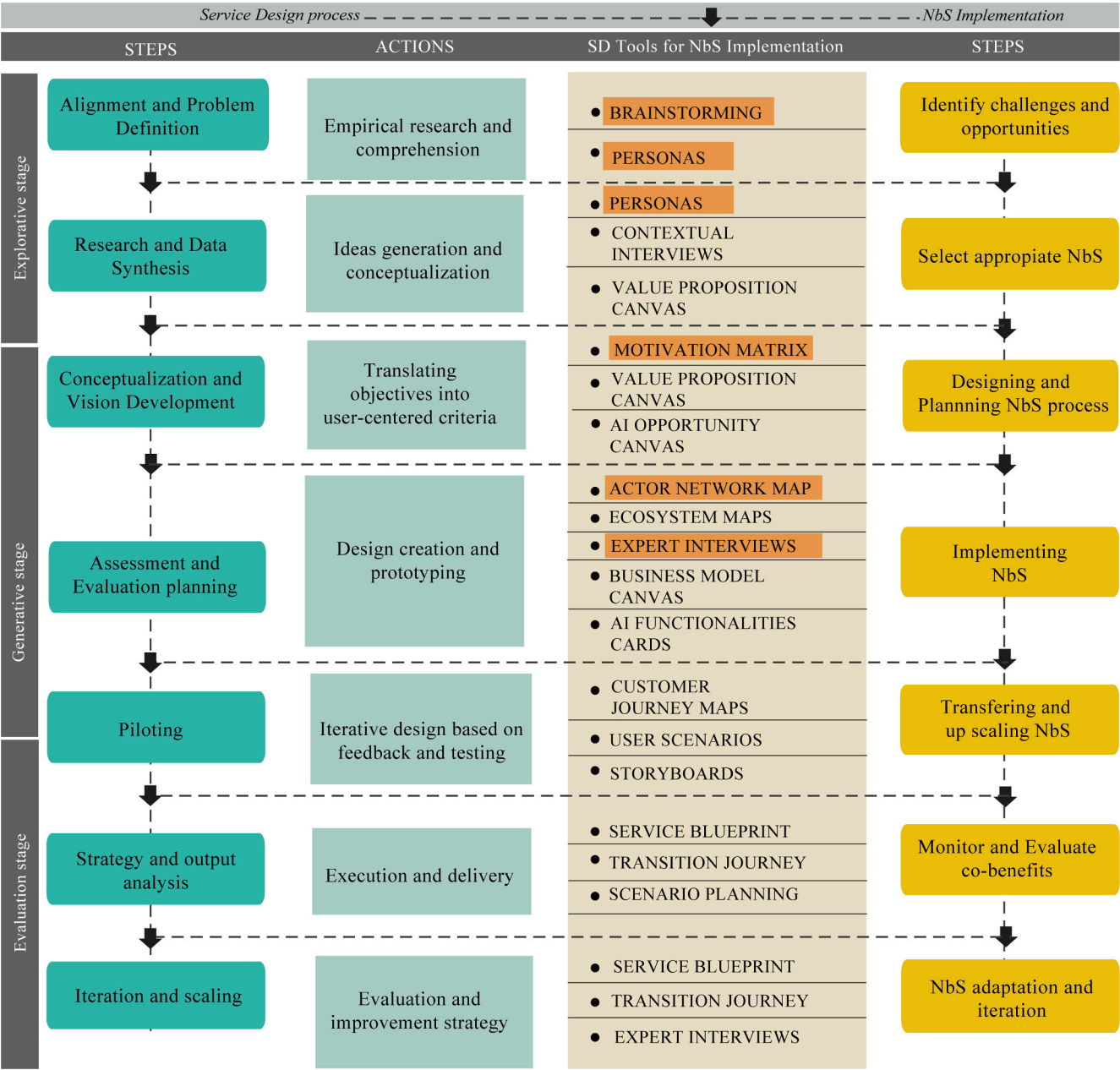


Fig. 2. Service Design methodology and tools framework for NbS implementation, with the five case study tools highlighted in orange.). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: Authors (2024)

Table 1
Research methodological sources for Service Design.

Source	Key Contributions	Potential Impact on NbS Implementation
[44] <i>This is Service Design Thinking: Basics, Tools, Cases</i>	Establishes fundamental service design principles and methodological frameworks. Presents comprehensive toolkit for user-centered design approaches in complex system interventions.	Provides systematic methodology for stakeholder engagement and collaborative design in NbS projects. Offers practical frameworks for aligning diverse stakeholder interests throughout implementation phases.
[45] <i>This is Service Design Doing</i>	Advances practical application of service design methods through real-world case studies and implementation strategies. Emphasizes iterative prototyping and testing approaches.	Demonstrates practical application of service design principles in complex projects, particularly relevant for NbS implementation in urban contexts. Offers validated methodologies for stakeholder engagement.
[60] <i>Service Design Tools Platform</i>	The <i>Service Design Tools</i> platform, created by Roberta Tassi in collaboration with POLI.design and Domus Academy Research Center (2009), is curated by Oblo studio and organizes design tools by project stages and user types. Aims to support methodological development and provide a comprehensive resource for promoting service innovation in both public and private sectors	Enables systematic tool selection for different NbS project phases. Supports evidence-based decision-making and stakeholder engagement throughout the implementation process.

Source: Authors (2024).

research, co-design serves as a stage where Service Design methods can be applied to develop continuous stakeholder and end-user engagement processes, utilizing various tools and semi-structured interviews for data collection and analysis. This case study proposes an integrative Service Design framework for NbS implementation (Fig. 2); it presents a structured process for the design and implementation of NbS, organized in three main stages: exploratory, generative and evaluation. In the left column, the service design process is described, consisting of specific steps such as problem definition, data synthesis, vision development, evaluation planning, pilot testing and finally analysis and scaling up of results. Each of these steps includes clear actions such as empirical research, conceptualization of ideas, prototyping, implementation and continuous improvement.

By involving stakeholders from the outset and throughout the process, Service Design has the potential to enhance the efficacy and sustainability of NbS interventions, ensuring both environmental benefits and local stakeholder support, thus maximizing their long-term impact [39]. The synergy between NbS and SD principles manifests in a systems perspective that prioritizes multi-functionality and user interactions, adaptability to dynamic urban conditions [40], and the promotion of multidisciplinary integration, combining elements of marketing, user experience, and design thinking [62]. Furthermore, this approach fosters continuous innovation through the exchange of information between organizations and communities, facilitating adaptability in dynamic urban environments [10].

The proposed framework emphasizes continuous stakeholder engagement throughout the implementation process, with a particular focus on co-design methodologies. This framework serves as a comprehensive guideline, integrating rigorous technical assessments with valuable stakeholder input by synthesizing urban data and landscape plans for NbS projects, such as the schoolyard intervention in Szombathely. The iterative nature of SD facilitates rapid prototyping and adaptation to changing conditions [10,40]. Furthermore, continuous stakeholder involvement in the design process promotes community ownership and shared responsibility for NbS outcomes [41]. Service Design facilitates collaboration among a diverse range of stakeholders, including municipalities, academic institutions, private sector entities, and local communities. Interdisciplinary, human-centered approaches effectively integrate expert assessments, stakeholder participation, and political engagement to develop robust strategies and sustainable maintenance plans for NbS [42]. Service Design is fundamentally about bringing together designers and stakeholders to create user-focused solutions through journey mapping and delivery system development [37]. A systems perspective aids in managing the complexity of NbS, while user-centered approaches—inherent to SD—tailor solutions to local needs [43].

This study highlights five key service design (SD) tools employed during the NbS co-design process in Szombathely to enhance decision-making and evaluate alternative scenarios: brainstorming, personas,

motivation matrices, actor mapping, and expert interviews. These tools were selected and adapted to address the specific challenges of stakeholder engagement, scenario analysis, and collaborative design within the NbS context. As shown in Table 1, the selection of tools was informed by foundational literature in the field of service design. For example, Stickdorn and Schneider’s *This is Service Design Thinking* (2012) provided a comprehensive toolkit and systematic methodology for user-centered design, particularly valuable for aligning diverse stakeholder interests in complex systems. Similarly, Stickdorn’s *This is Service Design Doing* (2018) emphasized iterative prototyping and testing, offering practical applications and strategies that guided the development of these tools in real-world settings. Additionally, resources like the Service Design Tools Platform [60], curated by Roberta Tassi, provided structured guidance on selecting and applying SD tools for specific project phases, enabling evidence-based decision-making throughout NbS implementation.

Despite these foundational contributions, it should be noted that literature on the application of SD tools in the NbS domain remains limited. This gap underscores the novelty and necessity of tailoring and evolving these tools for the unique requirements of NbS projects. Building on these foundational works, this study adapted and re-developed the tools to address specific challenges encountered in the Szombathely case study. For instance, brainstorming sessions were tailored to elicit collaborative problem-solving among diverse stakeholders, while personas were designed to represent varying community needs and priorities in the urban NbS context. Motivation matrices were adapted to clarify stakeholder roles and foster commitment, actor mapping was refined to manage multi-stakeholder dynamics, and expert interviews were structured to extract actionable insights for implementation.

These tools facilitate a comprehensive analysis of NbS configurations, enabling public and private stakeholders to collaboratively assess how GBI implementation aligns with community needs and intended uses [70]. As Dushkova et al. (2024) argue, “implementing this approach necessitates a paradigm shift from traditional grey infrastructure to an integrated methodology that combines green and grey solutions”, this is adaptive and holistic design approach fosters inclusivity and active participation from all stakeholders. The Szombathely case study underscores the significance of these five SD tools in co-design, demonstrating their efficacy in enabling the collaborative creation of multifunctional NbS that address environmental, social, and economic needs in complex urban settings. The adapted methodologies and their application are discussed in detail in the methodology section of this study, highlighting how these tools were systematically modified to ensure relevance and effectiveness in the NbS context.

3. Methodology

This case study examines Szombathely Municipality’s living schoolyard initiative at Dési Huber István Elementary School, part of the

city's vision to become climate-conscious by 2030. The project implements Nature-based Solutions through installations like green walls and dedicated fauna habitats. Through workshops conducted in late 2023 and early 2024, the study explores how service design tools facilitated GBI implementation while addressing environmental challenges and sustainability goals. Our research contributes significantly to the expanding literature on co-design methodologies in NbS integration within urban development. This approach serves as an appropriate design framework for implementing integrated and participatory NbS interventions. The study specifically examines climate change mitigation and environmental education within educational institutions, while the implemented service design tools effectively support both the final NbS design and the development of sustainable operation and maintenance models for the interventions.

This study utilized a qualitative methodology comprising three distinct phases. The first phase consisted of a literature review examining Service Design principles and tools. This review drew from seminal works in the field, including [44] and [45] foundational frameworks on service design tools and practice, [10] user-centered approaches, and Morelli and Tollestrup's (2007) stakeholder engagement methodologies. This review identified 17 potential SD tools applicable to NbS implementation (Fig. 2). These tools were systematically evaluated based on their effectiveness in facilitating collaboration processes. An analysis of Service Design tools conducted during this research is presented in Annex C, which includes a detailed matrix documenting each tool's description, application context, and relevance to NbS implementation. This analysis informed the strategic selection of specific tools deployed in this case study. From these analysis, five tools were selected based on the project timeline and co-design phase requirements. The selection process was further informed by recent contributions from Service Design Tools Platform [60], based on The Service Design Tools project—a research conducted by Roberta Tassi for her graduation thesis Communication Design and Service Design in collaboration with POLI design and Domus Academy Research Center—along with Giordano et al.'s (2018) work on stakeholder mapping in environmental contexts and [46] expert interview frameworks.

The second phase involved a tool selection process based on multiple criteria: alignment with the Szombathely context, stakeholder engagement requirements, project timeline constraints, and tool accessibility. This analysis was guided by Cooper's (1998) user-centered design principles and Long's (2009) persona development frameworks. Five tools emerged as particularly suitable for the initial intervention planning and design stages (Table 2). The theoretical foundation for this selection drew from Manzini et al.'s (2004) collaborative design

approaches and Goodwin's (2009) user research methodologies. In the final phase, these tools underwent careful adaptation to address the specific requirements of the schoolyard implementation case. This adaptation process incorporated user-friendly visual elements and detailed instructions, following best practices from participatory design literature [63]. The methodology utilized both digital platforms (e.g., Miro) and traditional methods to optimize stakeholder engagement and data collection. Comprehensive templates for each tool are available in Annex A, while the semi-structured interview is in Annex B.

The implementation of five Service Design tools was conducted through three co-design workshops held between October 2023 and January 2024. These workshops aimed to establish a structured and accessible framework for designing NbS interventions, focusing specifically on the regeneration of a primary schoolyard in Szombathely. The participants included four representatives: a City Project Manager, a Councillor for Environmental and Climate Affairs from the Municipality of Szombathely, a school representative, and a workshop facilitator. The methodology emphasized participatory design, aligning conceptualization, design, and management of interventions with local needs and municipal design guidelines.

The schoolyard intervention targeted multiple demographics—schoolchildren, parents, and nearby elderly residents—creating a multigenerational space aimed at fostering ecological awareness and climate resilience. Over a planned five-year period, the project seeks to instill a shift in attitudes toward nature, raise awareness of climate challenges, and enhance community health. This approach not only addresses environmental goals, such as heat resilience, but also tailors solutions to the unique behavioral and developmental needs of younger populations. The resulting interventions contribute to the ecological value of urban spaces while promoting interaction with natural elements in an educational and recreational setting.

The methodology implementation utilized Miro as the primary digital collaboration platform to facilitate remote workshop activities and visual teamwork. This platform was selected for its robust capabilities in supporting real-time collaborative design activities and its ability to accommodate multiple stakeholders simultaneously. Templates for each adapted tool are provided in Annex A, illustrating their systematic redesign for workshop implementation, resulting in the creation of a service design toolkit for NbS co-design. The adaptation of these tools, while grounded in established service design literature, underwent significant modifications to align with the specific requirements of NbS implementation. This process involved the development of comprehensive guidelines, user-friendly visual elements, and detailed instructions tailored to facilitate stakeholder engagement. The

Table 2
Service Design Tools.

SD Tool Name	Description	Main goal in co-creation	Role in NbS	Co-Creation Stages Applicability	Original Name, Inspiration, and Source
Service Brainstorming	Group ideation technique to inspire creativity and generate diverse ideas during brainstorming sessions.	Discover shared values and needs.	Stimulates diverse ideation and identifies a wide range of potential NbS solutions.	Co-assessment, Co-design	Idea Generation [44] or Brainstorming [60]
Personas	Fictional profiles based on real data that represent target groups and their needs, behaviors, and motivations.	Engage and empathize with stakeholders.	Bridges gaps between stakeholder expectations and NbS design.	Co-assessment, Co-design	Personas [44,67–69] or Dynamic Personas [60]
Motivation Matrix	Visual tool that maps relationships and values among stakeholders, enabling alignment and coordination.	Design action plans and achieve long-term goals.	Establishes shared understanding and sustainable co-creation among stakeholders.	Co-assessment, Co-design	Motivation Matrix [63], Impact Journey/User Journey [60], or [66].
Actor Network Mapping	Visualizes formal and informal relationships between stakeholders to analyze influence, power, and dynamics.	Engage stakeholders and clarify roles.	Maps key roles, relational dynamics, and power structures in NbS projects.	Co-assessment, Co-design, Co-implementation	Actor Network Mapping [63], Stakeholder Map [44,60].
Expert Interviews	Structured interviews conducted with stakeholders or experts to uncover behavior, attitudes, and operational insights.	Discover specific needs and contextual values.	Provides direct feedback, behavioral insights, and identifies NbS-specific challenges.	Co-assessment, Co-design, Co-implementation, Co-monitoring	Contextual Interviews [44] or Expert interview [46].

Source: Authors (2024).

methodological framework was specifically designed to accommodate the requirements of the NbS project framework during the co-design phase, operating within the broader context of the JUSTNature project. As one of seven case studies within the JUSTNature framework, the templates were systematically adapted to address the specific requirements of NbS implementation.

The **Service Brainstorming** tool was developed based on established methodologies [44,60] and specifically adapted for NbS implementation. This adaptation incorporated landscape and conceptual design elements for the schoolyard, utilizing a structured matrix with designated spaces for documenting potential functions and services. While conventional brainstorming methodologies typically focus on general service innovation [10], our adaptation emphasized environmental and educational outcomes specifically within the context of living schoolyards. This methodology enabled a systematic ideation process, facilitating stakeholder exploration of innovative approaches to integrating GBI for educational purposes. The process employed a structured ideation template, as recommended by Morelli and Tollestrup (2007), which resulted in the identification and prioritization of solutions that effectively aligned with both local educational requirements and municipal sustainability objectives. As [44] mentioned, ideation techniques act as “icebreakers,” relaxing the participants so they can take part in the session more fully. In this research, the tool was the first step to start the workshop session.

The second tool, **Personas**, adapted from Cooper's (1998) foundational work on user archetypes and further developed through Goodwin's (2009) persona methodology, was specifically modified to address NbS project requirements. This adaptation enhanced traditional user archetypes by incorporating environmental consciousness and sustainability parameters, facilitating more precise and context-specific design solutions. The modified framework integrated structured data collection regarding demographic characteristics (age, gender, socioeconomic status), interaction patterns with the schoolyard environment, usage frequency, occupational contexts, transportation preferences, and primary activities within urban-educational settings, aligned with [10] user-centered design principles. The systematic implementation of this tool enabled a comprehensive analysis of key stakeholder groups (students, educators, and community members). Through rigorous qualitative analysis [45], the resulting research-based personas effectively captured essential behavioral patterns and motivational factors. This detailed stakeholder characterization guided the development of targeted, human-centered solutions that effectively addressed both educational requirements and environmental objectives within the school community.

The **Motivation Matrix**, inspired by Manzini et al.'s (2004) collaborative design approach, was restructured to specifically address the multifaceted nature of NbS projects. This modified version particularly emphasized the temporal aspects of environmental interventions and their long-term impacts on educational communities. The redesigned template of this tool highlights main sections: the input from the previous Personas tool, the services related to each persona from the initial brainstorming, the benefits and potential challenges, and finally the frequency of interaction and participation of actors within the schoolyard NbS implementation. This tool was particularly effective in delineating the values and goals of various participants, such as environmental educators, urban planners, and student representatives. By categorizing these values based on their importance and temporal relevance, the matrix elucidated priorities and fostered strategic decision-making. In the Szombathely case, this approach facilitated cooperation and negotiation among stakeholders, ensuring an equitable distribution of the schoolyard's multifaceted environmental and social benefits.

The **Actor Network Mapping** tool, adapted from established stakeholder mapping methodologies [63,64], was specifically enhanced to analyze the complex stakeholder dynamics in NbS educational implementations. This adaptation maintained fundamental power

structure analysis principles while incorporating layers for environmental impact assessment and community engagement within the JustNature framework. The redesigned template introduced a three-tiered spatial context analysis (city, neighborhood, and building scales), with the NbS schoolyard project positioned centrally. Stakeholder connections, including previously identified personas, were mapped across these spatial contexts to visualize relationships and dependencies.

This systematic mapping approach proved instrumental in identifying decision-making hierarchies and influence networks within the project ecosystem. Through detailed visualization of stakeholder interactions and power dynamics, the tool facilitated effective project governance and stakeholder management throughout Szombathely's schoolyard regeneration process. The mapping exercise particularly excelled in highlighting potential synergies and areas requiring careful conflict management, thereby supporting informed decision-making in the co-creation process.

The **Expert Interviews** methodology, adapted from [46] qualitative research framework, was specifically modified to address NbS challenges during operation and maintenance. The interview protocol was enhanced to capture both technical implementation aspects and pedagogical considerations, reflecting the specific requirements of the Szombathely case study [45]. This methodological adaptation facilitated the collection of targeted insights that effectively bridged theoretical knowledge with practical implementation challenges.

The interview process involved key stakeholders with expertise in GBI maintenance and implementation, particularly those affiliated with municipal authorities or relevant maintenance organizations. Following [10] approach to stakeholder engagement, these semi-structured interviews were designed to gather comprehensive insights into maintenance planning, operational requirements, and long-term sustainability considerations. The integration of results directly contributed to the development of community engagement strategies and automation systems, ensuring practical applicability of the findings.

The expert interviews methodology was designed to systematically examine the practical maintenance aspects of NbS interventions in urban settings. The interview protocol was developed based on insights from prior Actor Network Mapping and Motivation Matrix workshops, ensuring continuity in the research process. The interviews focused on several interconnected areas: data-driven maintenance assessment, performance metrics monitoring, conditional maintenance protocols, and stakeholder participation strategies. This comprehensive approach allowed for detailed exploration of both technical and social aspects of NbS maintenance.

The interview structure was carefully crafted to investigate environmental dependencies, maintenance expertise requirements, and automation possibilities. Special attention was given to distinguishing between specialized and general maintenance tasks, while also examining resource optimization through potential outsourcing and automation opportunities. The protocol particularly emphasized collaborative maintenance strategies and the integration of stakeholder participation in maintenance activities. Analysis of the interview data directly informed practical recommendations for the Szombathely schoolyard project, contributing to the development of community engagement strategies and automation systems. This methodological approach ensured that the findings maintained practical applicability while addressing both immediate operational needs and long-term sustainability goals for the NbS intervention.

While maintaining a standardized core structure across all seven case studies in the JUSTNature project, the interview protocol was customized to address location-specific actors and interventions. This approach aligns with Morelli and Tollestrup's (2007) recommendations for context-sensitive research design. In the Szombathely case study, these expert interviews proved instrumental in understanding the complexities of stakeholder engagement, particularly concerning the specific needs of young users. The gathered data informed the development of

feasible, locally appropriate solutions that effectively balanced educational objectives with ecological principles. All interviews were documented through audio recordings with participant consent, enabling thorough analysis and interpretation of the collected data.

The co-design process involved two distinct participant groups. **Group A** included the City Project Manager, Councillor for Environmental and Climate Affairs, primary school representative, and workshop facilitator. This group participated in Workshop sessions 1 and 2, applying fundamental Service Design methods such as Service Brainstorming and Personas to develop initial concepts and analyze stakeholder engagement. **Group B**, formed by the City Project Manager, Managing Director of Green Building Initiatives, and workshop facilitator, joined during Workshop session 3 (as detailed in Table 4). This group provided expertise during the professional consultation phase and expert interviews.

To facilitate collaboration among the international research participants listed in Table 4, who were geographically distributed across different locations, the workshops adopted a hybrid approach. The Miro platform, a digital whiteboard solution designed for interactive collaboration [47], served as the primary tool for brainstorming, mapping, and design discussions [57]. Microsoft Teams [56] complemented this setup by providing video and audio-conferencing capabilities. It's important to note that while the workshops were conducted remotely, participation was strictly limited to the research team members identified in Table 4. This digital infrastructure enabled effective collaboration and continuous feedback among the designated participants, despite their geographical separation.

In October 2023, Group A participated in a 30-minute Service Brainstorming exercise as part of the initial co-design session. This exercise generated conceptual ideas for potential services and functionalities specific to the schoolyard NbS intervention in Szombathely. Following this, Group A engaged in a two-hour workshop where they utilized additional Service Design tools—Personas, a Motivation Matrix, and an Actor-Network Mapping. These tools were strategically employed to construct a comprehensive stakeholder network and identify the values and needs across diverse target groups. To ensure clarity and alignment of objectives, brief presentations elucidating the workshop goals preceded both sessions, establishing a contextual

framework for the participants. All sessions were recorded with participants' consent, allowing for detailed documentation and analysis of the inputs provided during the workshops. Fig. 3 shows a graphic glimpse of the results from Szombathely Workshop session 1 and 2 – Four tools presented in sequence: Service Brainstorming, Personas, Motivation Matrix, and Actor-network Mapping. The figure was created using screenshots of tools developed in Miro and scaled in Adobe Illustrator for optimal viewing.

In January 2024, following a comprehensive analysis of data gathered from previous methodological tools, a final workshop session 3 was convened with Group B, incorporating an expert interview session. This 45-minute interview centered on the future maintenance and operation of GBI within educational institutions, with a particular emphasis on schoolyards as spaces for cultural and educational activities. The session involved a series of seven meticulously crafted questions addressing critical aspects of NbS implementation. The significance of this interview was underscored by the expertise of the participants, notably the school city officer and the managing director of GBI and Landscape in Szombathely, whose roles were crucial in the current operation and implementation of GBI within the urban context.

The interview was built upon insights gleaned from preceding sessions, aiming to identify operational processes and potential enhancements for future implementation phases of the schoolyard regeneration project. Throughout these workshops, five SD tools, adapted specifically for the NbS context and terminology, were employed. These tools, drawing inspiration from the methodologies outlined by Stickdorn and Schneider (2012) and the Service Design Tools platform—developed in 2009 by Roberta Tassi at the Politecnico di Milano—played a crucial role in facilitating stakeholder collaboration. They ensured that the co-creation process for the schoolyard NbS was both context-sensitive and transparent for all participants. The employed tools—Service Brainstorming, Personas, Motivation Matrix, Actor Network Mapping, and Expert Interviews—steered the NbS co-design process by seamlessly integrating designers' landscape solutions with the school community's engagement needs. This approach prioritized fostering attitudinal shifts, heightening awareness of nature and climate issues, and aligning with Szombathely's environmental and urban objectives.

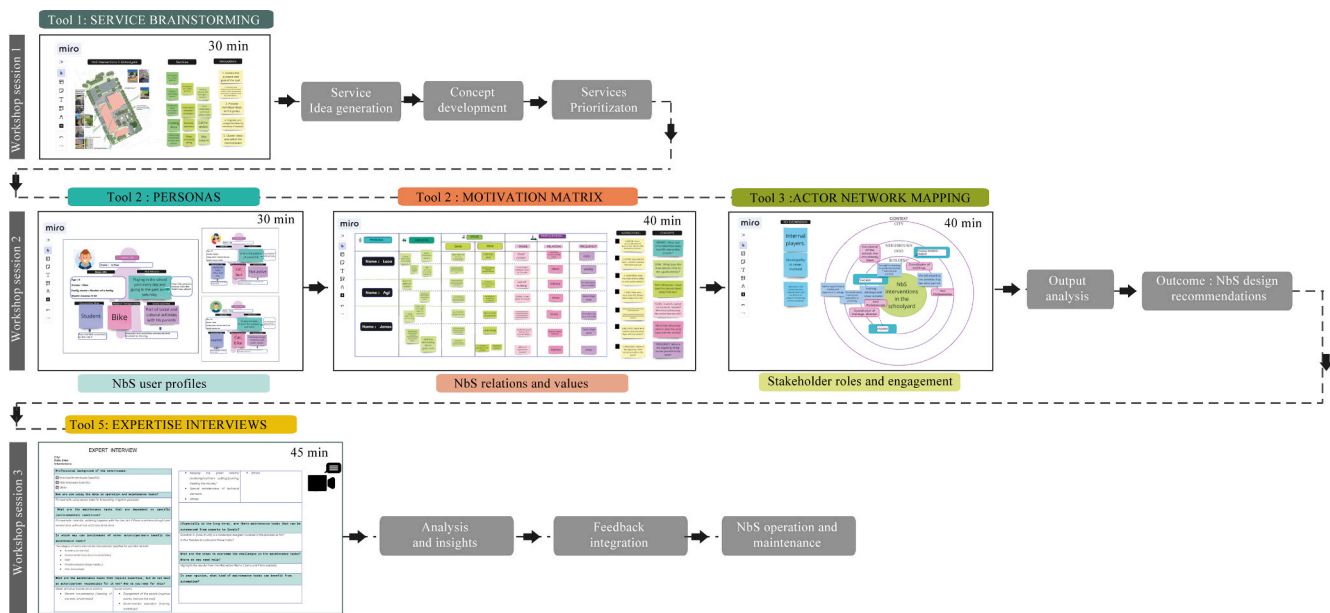


Fig. 3. Results from Workshop 1 and 2 – Four tools numbered starting from Service Brainstorming, Personas, Motivation Matrix and Actor-network mapping.).
Source: Authors (2024)

4. Framing the case study: Szombathely’s green urban adaptation and sustainable goals

4.1. Szombathely urban structure

Szombathely, one of Hungary’s oldest cities, has a rich history and a well-developed urban infrastructure. With a population of 78,025, the city spans 9,752 ha and reflects nearly two millennia of growth, transitioning from the Roman settlement of Savaria to its modern role as the administrative center of Vas County [71]. Szombathely’s urban structure is characterized by a compact layout with a mix of medium and high-rise buildings in the city center and a combination of high-density and low-rise housing in the outskirts [71]. The city faces environmental challenges such as traffic-induced air pollution, uneven green space distribution, and the urban heat island (UHI) effect. Szombathely experiences a typical Hungarian continental climate, with an annual average temperature range of 21.4 °C and precipitation averaging 596 mm. Urbanization has contributed to increased air conditioning demand, exacerbating greenhouse gas emissions and intensifying urban heating. To address these issues, Szombathely has initiated several environmental management strategies, including promoting sustainable transportation, selective waste collection, and public awareness campaigns.

4.2. Szombathely’s urban initiatives and programs

Szombathely has implemented forward-thinking programs to enhance urban sustainability and climate resilience. The **Sustainable Energy and Climate Action Plan (SECAP)** [59] is a cornerstone of its environmental strategy, leveraging the city’s 268.9 ha of public green spaces, approximately 30,000 trees, and 11 large parks. The plan outlines ambitious goals such as increasing the tree population by 50 % and integrating NbS like rain gardens and green roofs to manage urban water resources and combat the UHI effect. To strengthen its urban ecosystem, Szombathely launched several initiatives, including the “Wildflower Szombathely” program to enhance biodiversity, systematic removal of invasive tree species, and the “1000 Trees” program to expand urban greenery. These efforts are complemented by water conservation measures, such as community cisterns and park water absorption enhancements. Table 3 illustrates the **Sustainable Urban Development**

Strategy (SUDS) 2021–2027, which prioritizes environmental protection, traffic pollution reduction, and renewable energy adoption. The city’s comprehensive framework includes initiatives such as Szombathely’s “**Greening City**” program, which promotes sustainable energy solutions and urban green networks. This aligns with the broader **Szombathely2030 program**, which envisions the city as a “green intelligent city.” These strategic initiatives focus on integrating NbS into urban planning, improving public spaces, and enhancing urban quality of life.

4.3. Assessing and implementing NbS in Szombathely’s urban green spaces

According to the SECAP, Szombathely, despite its favorable ranking among Hungarian cities in terms of green space quantity, faces challenges in optimizing the quality and effectiveness of its GBI. The city’s abundant green areas have not fully mitigated the urban heat island effect or enhanced its appeal to residents and businesses, primarily due to suboptimal microclimatic impacts and development pressures on smaller urban green spaces. The city’s green space development is further hindered by inadequate emphasis on creating beneficial green areas in new residential developments. To address these issues, Szombathely has identified two key strategies for enhancing its green space network: utilizing inner city blocks and leveraging the city’s waterways. These strategies aim to provide a localized response to global environmental sustainability challenges, addressing both ecological concerns and broader urban development objectives. The enhancement of green spaces is recognized as crucial for maintaining Szombathely’s livability and attractiveness, ensuring the city can meet the evolving needs of its population and business community. To further improve its green and blue infrastructure, Szombathely plans to implement a comprehensive green space assessment system, evaluating the quality, accessibility, and ecological value of existing green spaces, while identifying potential areas for new green development. Within these goals, the city has explored and created partnerships with local and international stakeholders to develop innovative NbS projects such as vertical gardens, schoolyards, green roofs, and pocket parks to maximize the use of limited urban space. This integrated approach aims to enhance the city’s environmental performance while simultaneously improving public health, fostering social cohesion, and boosting economic vitality.

Table 3
Szombathely Strategic Sustainable Goals Target Matrix. Goals related to Nbs in educational environments are highlighted with an orange dotted line.

STRATEGIC GOALS						
1. Ecosystem Development		2. Renewable Energy City		3. Sustainable Transport	4. Attractive Community	
RELATED SUB-GOALS						
Develop a research ecosystem supporting corporate automation and digitalization.		Build renewable energy infrastructure and promote circular economy.		Improve transport infrastructure for community use.	Enhance social, health, and childcare services, including elderly care.	
Enhance local business competitiveness		Transition public services to renewable energy		Develop eco-friendly public transportation	Expand community green spaces and foster community development	
Enhance infrastructure and revitalize brownfield sites		Upgrade parks and green spaces with innovative solutions		Implement multimodal transport and parking improvements	Promote active lifestyles through sports, recreation and cultural programs	
Prosperous city		Green city		Digital city	Retaining city	Service-oriented city

Source: Elaborated and translated by the authors based on the “Sustainable Urban Development Strategy 2021-2027” document (in Hungarian) from Szombathely County [53].

Szombathely Municipality is committed to implementing innovative NbS as part of its vision to become a leading climate-conscious city by 2030. The municipality's dedication to environmental sustainability and climate resilience is exemplified through its participation in the JUST-Nature project. This initiative aims to foster a just, low-carbon transition in European cities. Six city administrations and one city-owned company are involved, with their representatives collaborating with researchers to design and implement nature-based interventions. Szombathely, as one of the participating cities, is implementing a schoolyard greening initiative at Dési Huber István Elementary School. This institution is situated in a residential educational zone on the outskirts of the city center (Fig. 4).

The NbS intervention aims to alleviate heat stress, address social issues and encourage climate-friendly behavior by improving outdoor wellbeing, biodiversity and ecosystem health. The project includes elements such as shading installations, asphalt removal, replanting, raised beds, green surfaces and walls, and habitats for local wildlife, addressing urban problems such as heat stress and air quality. It also encourages environmental education and community engagement, especially among young people, promoting long-term environmental stewardship. Workshops conducted between October 2023 and January 2024 facilitated stakeholder collaboration through service design tools, ensuring the integration of blue-green infrastructure into Szombathely's urban strategy. While Szombathely's extensive green infrastructure and urban sustainability programs provide important context, this research case study focuses specifically on implementing NbS to transform a local primary school's grounds into a living schoolyard that benefits both students and the community. The case study investigates how these broader urban strategies align with localized initiatives to enhance climate resilience, foster ecological awareness, and strengthen community engagement. By examining the schoolyard's redevelopment within Szombathely's comprehensive sustainability framework, we demonstrate how targeted NbS projects can effectively contribute to achieving city-wide environmental objectives.

5. Results and discussion

5.1. Workshop findings in Szombathely case study

The Szombathely case study applied co-design methodologies to thoroughly explore local needs and challenges for the schoolyard NbS project at Dési Huber István Elementary School (Fig. 5). A series of workshops, conducted between October 2023 and January 2024, utilized five key Service Design tools. These tools were instrumental in facilitating collaboration between stakeholders from both the public and

private sectors of Szombathely, leading to a participatory and transparent design process for the NbS intervention. Each tool was strategically selected to contribute unique insights to the participatory design process: Service Brainstorming facilitates creative ideation and collaborative solution-finding, particularly valuable for identifying innovative NbS interventions. Personas enable deep stakeholder understanding through data-based user profiles, ensuring design decisions align with community needs. The Motivation Matrix maps stakeholder relationships and values, crucial for sustainable co-creation and long-term project success. Actor Network Mapping visualizes power dynamics and institutional relationships, essential for effective project governance. Expert Interviews provide detailed operational insights and technical expertise necessary for NbS maintenance.

The implementation of these tools was conducted through three structured co-design workshop sessions between October 2023 and January 2024, engaging a diverse range of stakeholders from both public and private sectors in Szombathely. The landscape design concept plan for the living schoolyard served as visualization reference and support material for all tools. The plan shown in Fig. 5, developed by Hungarian landscape architects and the municipality of Szombathely, features NbS interventions including urban agriculture areas, a central garden with raised beds, a Kneipp nature path, a green wall, and a renewed sports field with an education trail—all designed to showcase and develop social and cultural services.

The initial session, held on October 10, 2023, focused on the Service Brainstorming tool facilitated through the Miro digital platform. Group A, comprising a city project manager, school representative, and councilor, participated in a 30-minute collaborative ideation process. Participants systematically generated, clustered, and prioritized intervention strategies, establishing a comprehensive foundation for subsequent workshop phases. The second session, conducted on November 10, 2023, engaged Group A in the application of three complementary tools: Personas, Motivation Matrix, and Actor Network Mapping. The session was facilitated through the Miro platform, with detailed explanations provided for each tool's methodology and objectives. The Personas tool helped identify and understand key user groups, ensuring that the design catered to a variety of stakeholders' needs. The Motivation Matrix allowed participants to visualize relationships between different actors and prioritize their contributions. Actor Network Mapping further deepened the analysis by mapping the roles and relationships of various stakeholders, which provided clarity on responsibilities and collaborations necessary for the project's success.

The final phase of the workshops took place on January 12, 2024, with an Expert Interview that involved city officials and park management representatives. This session was critical in refining the project's



Fig. 4. Szombathely map highlighting the urban area, city centre, and primary school of NbS intervention. .

Source: Authors' elaboration based on Google Earth imagery (2024) and official data from the Municipality of Szombathely (2024)

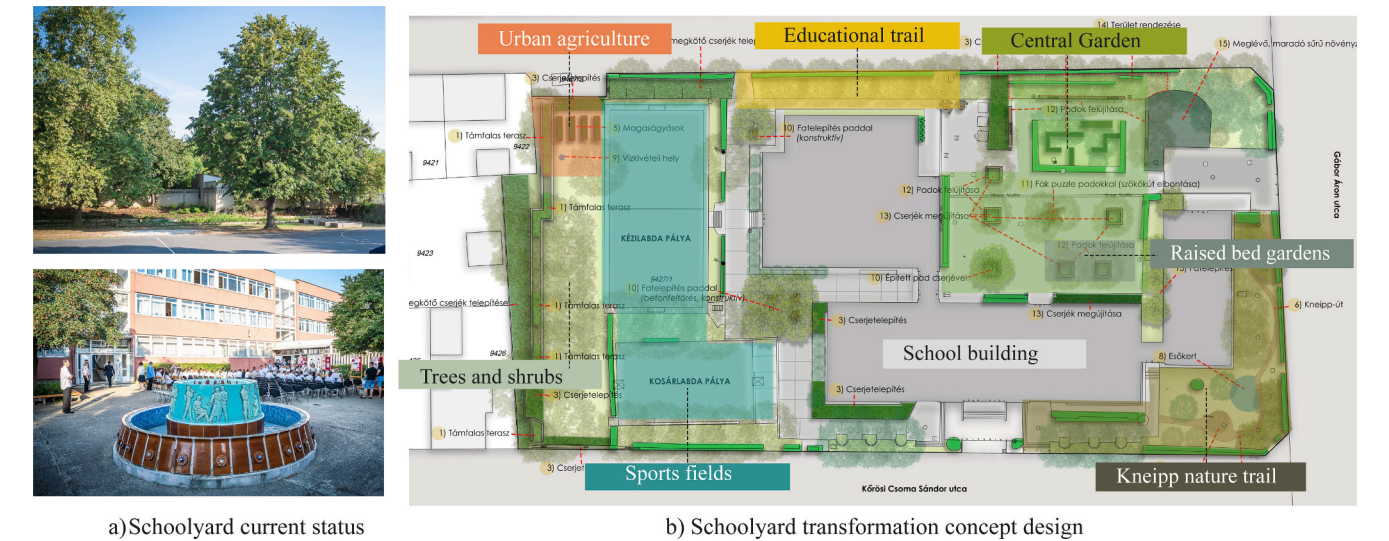


Fig. 5. Conceptual Landscape Design for Dési Huber István Elementary Schoolyard.). Source: Elaborated by Authors based on the Urban Planning Department, Municipality of Szombathely, Hungary data (2024)

Table 4
Tools' characterization.

SESSION	TOOL	DATE	GROUP	PARTICIPANTS	DURATION
Workshop session 1	Service Brainstorming	10.10.2023	A	- City Project Manager (Municipality of Szombathely) - Councilor for Environmental and Climate Affairs (Municipality of Szombathely) - School Representative - Workshop facilitator (Authors)	30 min
Workshop session 2	Personas	10.11.2023	A	- City Project Manager (Municipality of Szombathely) - Councilor for Environmental and Climate Affairs (Municipality of Szombathely) - School Representative - Workshop facilitator (Authors)	30 min
	Motivation Matrix	10.11.2023	A	- City Project Manager (Municipality of Szombathely) - Councilor for Environmental and Climate Affairs (Municipality of Szombathely) - School Representative - Workshop facilitator (Authors)	40 min
	Actor Network Mapping	10.11.2023	A	- City Project Manager (Municipality of Szombathely) - Councilor for Environmental and Climate Affairs (Municipality of Szombathely) - School Representative - Workshop facilitator (Authors)	40 min
Workshop session 3	Expert interview	12.01.2024	B	- City project Manager (Municipality of Szombathely) - Managing Director, Green Building Initiatives (Municipality of Szombathely) - Workshop facilitator (Authors)	45 min

Source: Authors (2024).

details, integrating technical expertise into the design process, and addressing practical challenges related to implementation and long-term sustainability. Table 4 summarizes the workshops, detailing the tools used, participants involved, and time allocated for each session. The iterative nature of the co-design process, with feedback loops and constant adjustments, ensured that the interventions were well-informed, realistic, and supported by those responsible for their execution. This approach not only improved the design quality but also fostered a strong sense of ownership among stakeholders, which is essential for the NbS intervention's long-term success and maintenance.

In the case study of the Dési Huber István Elementary schoolyard in Szombathely City, the first tool—**Service Brainstorming**—generated a diverse array of functionalities and services for the schoolyard as a NbS intervention to enhance its impact on the school and community. Participants assessed each proposed idea based on its practicality and innovative potential. An analysis of feasibility and innovation served as a strategic tool to categorize interventions, with the x-axis representing feasibility (from low to high) and the y-axis representing innovation (from low to high), as shown in Fig. 6. The brainstorming tool yielded

several high-feasibility, high-innovation interventions, including “Food waste reduction campaigns” and “Garden plot planting workshops.” These were identified as prime candidates for immediate implementation due to their practicality and creativity. Other ideas, such as the “Call for artists” intervention, showed high innovation but lower feasibility, suggesting potential implementation challenges. More moderately innovative yet highly feasible interventions—like “Enhance planting activities” and “Install food waste stations”—were labelled as “quick wins” for the project, balancing immediate urban needs with innovative NbS approaches. This exercise underscored the value of service brainstorming in aligning NbS interventions with local needs, fostering stakeholder engagement, and maximizing the schoolyard's multifunctionality.

The second tool, **Personas**, was utilized to identify and characterize key stakeholders for the proposed NbS interventions. This exercise facilitated the development of three fictional personas by workshop participants: P1 (a student), P2 (a parent), and P3 (a teacher), representing diverse demographics and roles within the school community. Each persona was meticulously crafted with attributes such as age,

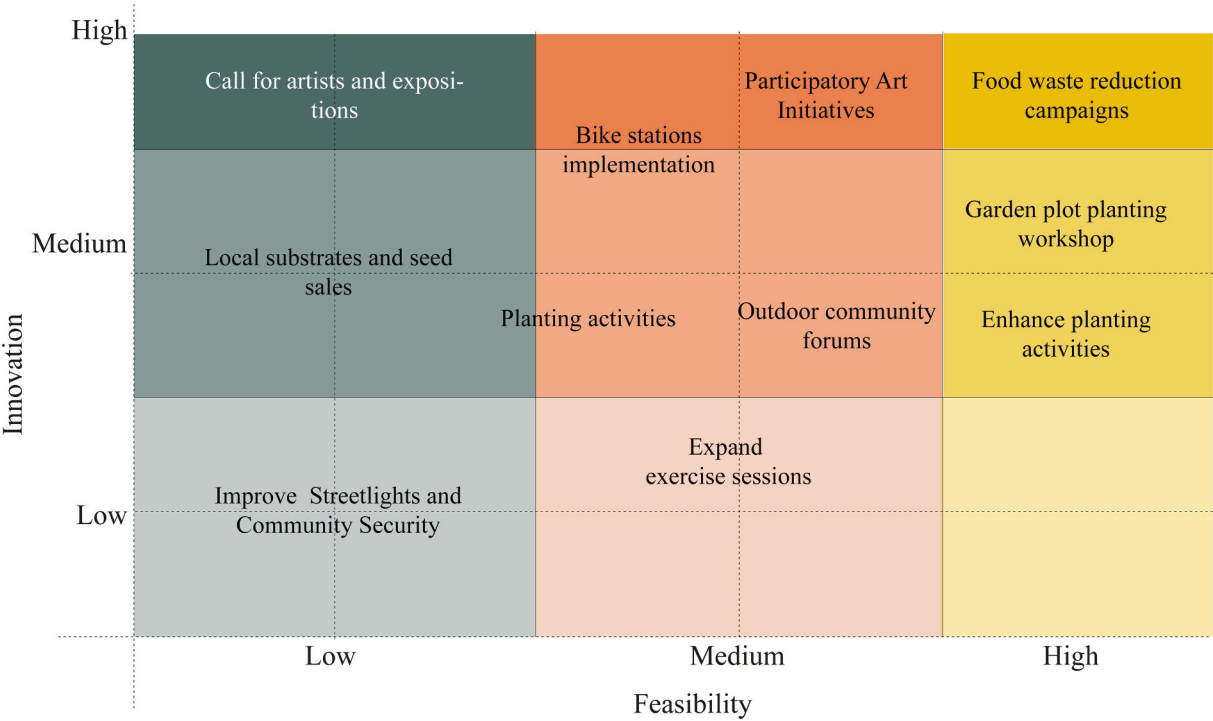


Fig. 6. Service Brainstorming Szombathely case analysis based on feasibility and innovation.). Source: Authors (2024)

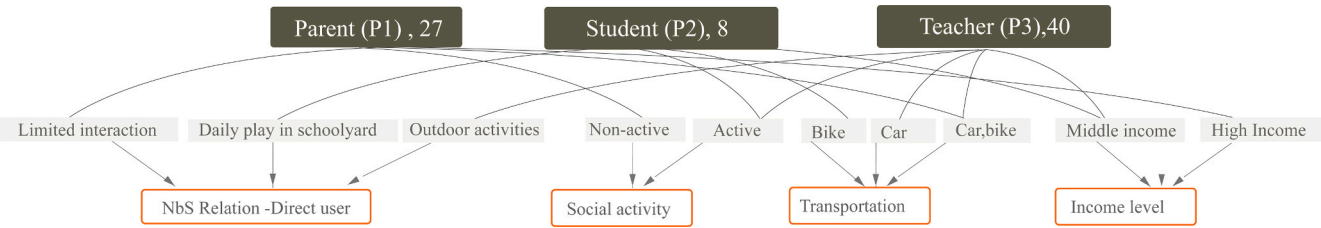


Fig. 7. Schematic analysis of four personas by their connection to the schoolyard project, income, social activity, and transport preferences.). Source: Authors (2024)

gender, occupation, relationship to the NbS intervention, transportation preferences, and social activity engagement, providing a comprehensive understanding of the stakeholder ecosystem. P1, a young student, was characterized by frequent daily interactions with the schoolyard, exemplifying the role of students as primary users of the space. P2, a parent, represented a more indirect but supportive figure, embodying the perspective of those who may engage with the schoolyard less frequently but play a crucial role in supporting new initiatives. P3, a teacher, highlighted a more involved stakeholder, engaging with the space both as an educator and as someone interested in the multifunctional benefits the NbS could provide. As shown in Fig. 7, the **Personas** tool revealed two prominent stakeholder groups: educators/students and parents. Educators and students were identified as critical actors due to their regular presence and interaction in the courtyard, while parents, particularly represented by P2, were recognized as essential supporters of new NbS initiatives. The personas provided actionable insights into the specific needs and behaviors of each group, informing the design process in a manner sensitive to the varied ways stakeholders interact with the schoolyard space.

The **Motivation Matrix**, employed as the third service design tool, connected the previously developed personas with the services offered by the NbS intervention, revealing key values and participation levels

for each stakeholder group. The analysis highlighted the distinct roles and motivations of three main personas: **P3 (Teacher)**, **P1 (Student)**, and **P2 (Young Parent)**. Teachers emerged as daily facilitators, playing a fundamental role in integrating the NbS intervention into the school curriculum. They actively organize activities such as planting sessions and food waste reduction campaigns, utilizing the courtyard as a “living laboratory” for practical environmental education. Their primary motivation stems from the opportunity to provide students with hands-on learning experiences and enhance their understanding of ecology and sustainability. Students, as daily users of the schoolyard, demonstrated high engagement with planting activities and outdoor events. These interactions offer them experiential learning in biodiversity and environmental stewardship. The educational and playful aspects of the interventions drive student participation, making them essential to the success of the NbS initiative. Parents, while occasional participants, provide crucial support during workshops and special events. They value the new interactive opportunities offered by the NbS intervention, particularly for children and family engagement during weekends and school breaks. Their motivation lies in the enhancement of the school environment and the chance for shared learning experiences with their children.

A key finding from the Motivation Matrix was the potential of the

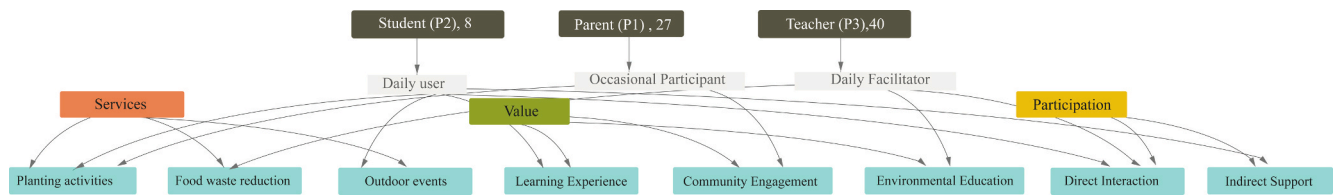


Fig. 8. Motivation Matrix summary. Shows four personas, their services, values, and participation in the schoolyard project.
Source: Authors (2024)

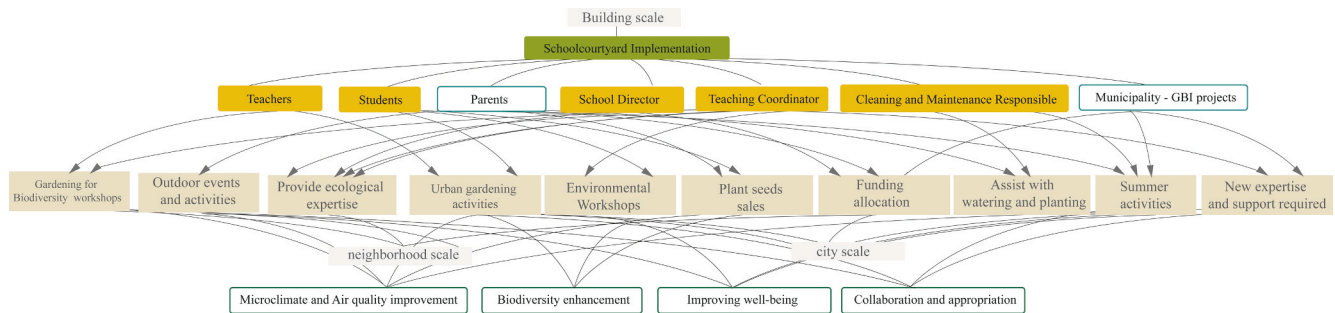


Fig. 9. Actor Map analysis, showing connections between the central site and key urban stakeholders.
Source: Authors (2024)

schoolyard to serve as a flexible learning space, adapting to seasonal changes and meeting the evolving needs of both the school community and nature as shown in Fig. 8. Notably, teachers and students emerged as the primary promoters of the regeneration process, underscoring the importance of well-organized and consistent activities to ensure meaningful engagement from all stakeholders. The tool's results emphasize the importance of considering diverse stakeholder motivations in designing and implementing successful NbS interventions in educational settings.

The **Actor Network Mapping** tool, built upon the motivation matrix, revealed the complex relationships among stakeholders in the NbS project. This analysis highlighted the School Courtyard as the central hub, showcasing how various actors interact and contribute to the project's success. As shown in Fig. 9, key findings from the Actor Network Mapping highlighted the crucial roles of different stakeholders. Teachers stood out as essential daily facilitators, conducting workshops and organizing outdoor activities while providing ecological expertise. Their direct connection to the intervention underscored the need for ongoing support and training to enhance their skills in managing the ecological aspects of the schoolyard. Students, comprising both children and teenagers, actively engaged in gardening activities and workshops, emphasizing their crucial role in the intervention's success through hands-on learning experiences in sustainability and biodiversity. Teenagers took on additional responsibilities as peer mentors, helping younger students and contributing to environmental education programs.

A significant finding was the valuable contribution of elderly community members, particularly grandparents, who emerged as important stakeholders in the project. Their involvement in gardening activities not only supported children's learning but also enhanced their own well-being, fostering intergenerational learning and enhances the collaborative spirit of the intervention. As documented by Heliker et al. (2001), elderly participants (aged 63–90) reported improved subjective well-being, satisfaction, and spiritual fulfillment through their involvement in gardening projects. Their traditional knowledge and experience in

local gardening practices proved invaluable for both educational and maintenance aspects of the schoolyard. Parents and grandparents, while less frequent participants, were identified as important contributors to watering, planting, and workshop activities. The School Director emerged as a critical administrative actor, responsible for allocating funding, coordinating activities, and securing necessary expertise. This role is vital for ensuring the financial and organizational support required for the project's success. A notable addition to the stakeholder network was the Training Coordinator, tasked with scheduling summer activities and special events, including intergenerational workshops where elderly community members share their gardening knowledge with students. This role bridges the gap between regular school operations and specialized programs, maximizing engagement during school breaks. The Cleaning Person's role in maintaining the schoolyard was also highlighted, with the recognition that additional support may be needed due to the increased complexity of an NbS intervention.

The Actor Network Mapping exercise revealed several challenges and areas for improvement. There is a clear need for additional resources and expertise in ecological management, particularly for teachers and cleaning staff. The School Director's role in seeking partnerships with local environmental organizations and securing external funding was emphasized as critical for scaling the project's impact. Additionally, the analysis underscored the importance of fostering collaboration across all roles to ensure the proper functioning of the schoolyard as a dynamic and sustainable NbS intervention. Overall, the Actor Network Mapping tool proved invaluable in illustrating the importance of a well-coordinated, multi-stakeholder approach to the NbS intervention in Szombathely. By identifying key relationships and roles, it provides a clearer path for implementing and sustaining the schoolyard project. These insights offer valuable lessons that can be applied to similar educational contexts across the region, emphasizing the need for comprehensive stakeholder engagement and ongoing support to maximize the potential of NbS interventions in school environments.

The fifth service design tool employed in the Szombathely case study

was **Expert Interviews**, which provided crucial insights into the city's approach to urban green space management, particularly focusing on the NbS intervention in the schoolyard. A semi-structured interview with the Managing Director of Szombathelyi Parks and recreation revealed several operational challenges and areas for improvement in maintaining such spaces. The interview findings highlighted significant challenges in urban green space maintenance, particularly regarding plant irrigation and health management. A key issue identified is accurately determining watering needs for young trees, essential for their longevity. While advanced agricultural techniques like colour spectrum analysis have been explored, their urban application remains problematic. Currently, maintenance requirements are primarily assessed through visual inspections, a method that, while widely used, lacks precision and is labour-intensive. This situation underscores the complexity of urban green space management and emphasizes the need for more advanced, yet implementable solutions within the framework of NbS interventions.

Collaborative maintenance initiatives, such as the "Adopt a Park" program, face sustainability issues. Despite initial high community involvement, the program struggles with maintaining long-term engagement, especially as demographic changes occur and responsibilities for park maintenance are not clearly transferred. This underscores the need for a more structured approach to sustained community involvement in urban green space maintenance. The interview also revealed a significant gap in specialized expertise for critical maintenance tasks. Tree pruning, for instance, requires specialized permits and skills, but there is currently no designated entity responsible for these tasks. This **lack of a clear expertise management system** raises concerns about the city's ability to maintain complex green spaces like the schoolyard in the long term. To address this gap, training and certification programs for municipal staff, as well as the establishment of formal partnerships with specialized companies, are recommended. A recurring theme in the interview was the **low prioritization of green spaces** in Szombathely's urban development projects. Green spaces are often overlooked in favour of building infrastructure during both the planning and execution stages, resulting in inadequate attention to their long-term maintenance needs. The interview emphasized the necessity for a shift in urban design approaches to integrate green spaces more meaningfully into the city's broader development agenda.

Regarding **automation** in green space maintenance, the interview revealed both opportunities and challenges. While robotic lawnmowers offer a promising solution for reducing manual labour, they are currently banned in Szombathely due to various regulatory and technical obstacles. Similarly, the use of drones for plant protection is restricted in residential areas, limiting the city's ability to employ cutting-edge technologies for more efficient maintenance. Interestingly, there's a growing trend away from automatic watering systems, with a preference for more sustainable methods like local water retention. These findings from the Expert Interviews tool complement and reinforce the insights gained from the Actor Network Mapping tool used

earlier in the process. The Actor Network Mapping had already identified key stakeholders such as teachers, students, parents, and school administrators, highlighting their roles and interactions within the schoolyard NbS intervention. The Expert Interviews further emphasized the operational challenges these stakeholders might face in maintaining and sustaining the intervention as shown in Fig. 10.

The Expert Interviews tool complemented the Actor Network Mapping by providing a more in-depth operational perspective on the challenges of implementing and maintaining NbS interventions in the schoolyard. It highlighted the alignment between the lack of specialized expertise identified in interviews and the need for additional support and training for key stakeholders, as revealed by the Actor Network Mapping. The tool also emphasized the practical difficulties in sustaining community engagement and addressing technical challenges in plant care. These insights are valuable for developing comprehensive and sustainable strategies for NbS interventions in educational settings, ensuring that the roles and relationships identified through Actor Network Mapping can be effectively supported and maintained over time.

Following the workshops and subsequent analysis, new insights and requirements were synthesized to inform the NbS intervention design for landscape planning and operational model development. Table 5 presents the key findings derived from the five analytical tools employed during the workshop sessions. This research contributes to an innovative NbS co-design framework that supports future implementations. The methodological approach facilitated strategic planning and creative problem-solving while ensuring NbS solutions aligned with local community needs, ultimately promoting sustainable and context-appropriate urban green and blue infrastructure.

5.2. Recommendations for implementing NbS in educational environments

The co-design methodology applied in the Szombathely case study has yielded valuable insights that contribute to a comprehensive framework for NbS implementation in school environments. This framework, informed by Service Design tools, aims to enhance the effectiveness, sustainability, and long-term engagement in NbS interventions for urban green spaces, with a specific focus on schoolyards. The following recommendations are organized into four thematic areas.

• Technological Innovations and Data-Driven Solutions

The framework emphasizes the integration of technology to support educational, maintenance, and community objectives. **Interactive, data-driven learning stations** equipped with sensor-based systems enable real-time monitoring of plant health, water usage, and local biodiversity (United States Department of Agriculture, n.d.). These stations facilitate data-driven maintenance strategies while providing hands-on learning opportunities for all age groups. The involvement of

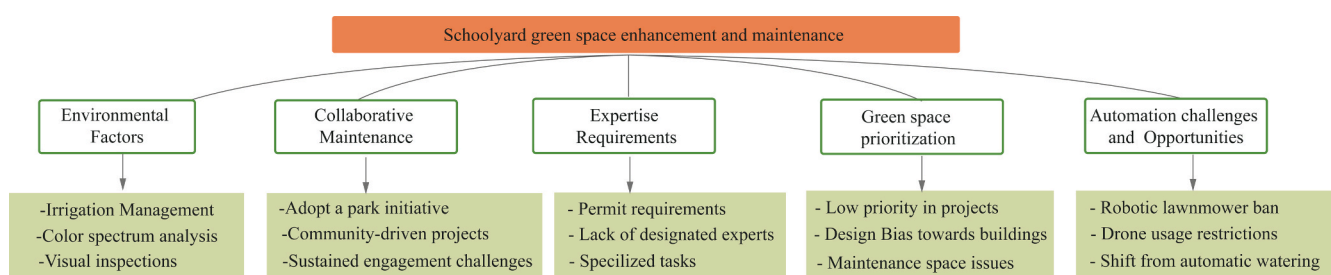


Fig. 10. Key components for enhancing NbS implementation in Szombathely, based on expert interviews.).

Source: Authors (2024)

Table 5
Key summarized results from the five tools utilized in the workshop sessions.

Tool Name	Findings/Insights	Relevance and Key Applications
Service Brainstorming Personas	Identified NbS interventions by feasibility and innovation (e.g., “Food waste reduction campaigns,” “Garden plot planting workshops,” “quick wins”). Developed three personas: P1 (Student) , P2 (Parent) , P3 (Teacher) , revealing stakeholder needs, motivations, and engagement.	Strategic prioritization of interventions aligned with local needs. Fostered stakeholder engagement and enhanced multifunctionality . Guided tailored intervention design by addressing specific stakeholder motivations and interaction patterns .
Motivation Matrix	Connected personas to NbS services, highlighting stakeholder roles and motivations (e.g., students’ experiential learning , teachers’ practical education).	Defined stakeholder values and participation levels, emphasizing seasonal adaptability and multifunctional design .
Actor Network Mapping	Mapped relationships among stakeholders, emphasizing the School Courtyard as a central hub. Identified resource and expertise gaps in ecological management.	Highlighted coordination needs and provided a roadmap for addressing gaps, fostering multi-stakeholder collaboration .
Expert Interviews	Addressed operational challenges (e.g., watering needs , expertise gaps , community engagement). Identified obstacles to automation .	Provided actionable recommendations for sustainable operations, aligning stakeholder roles with technical and maintenance requirements.

Source: Authors (2024).

elderly community members in **data interpretation and knowledge-sharing sessions** enriches intergenerational learning by connecting scientific insights with life experiences [48]. Furthermore, **child-friendly, eco-friendly automation systems** are proposed for school grounds maintenance, ensuring safe and sustainable operation while serving as educational tools within local regulatory frameworks. The engagement of teenagers in programming and managing these systems enhances their technical skills and fosters environmental responsibility [49].

• Educational Programs and Stakeholder Engagement

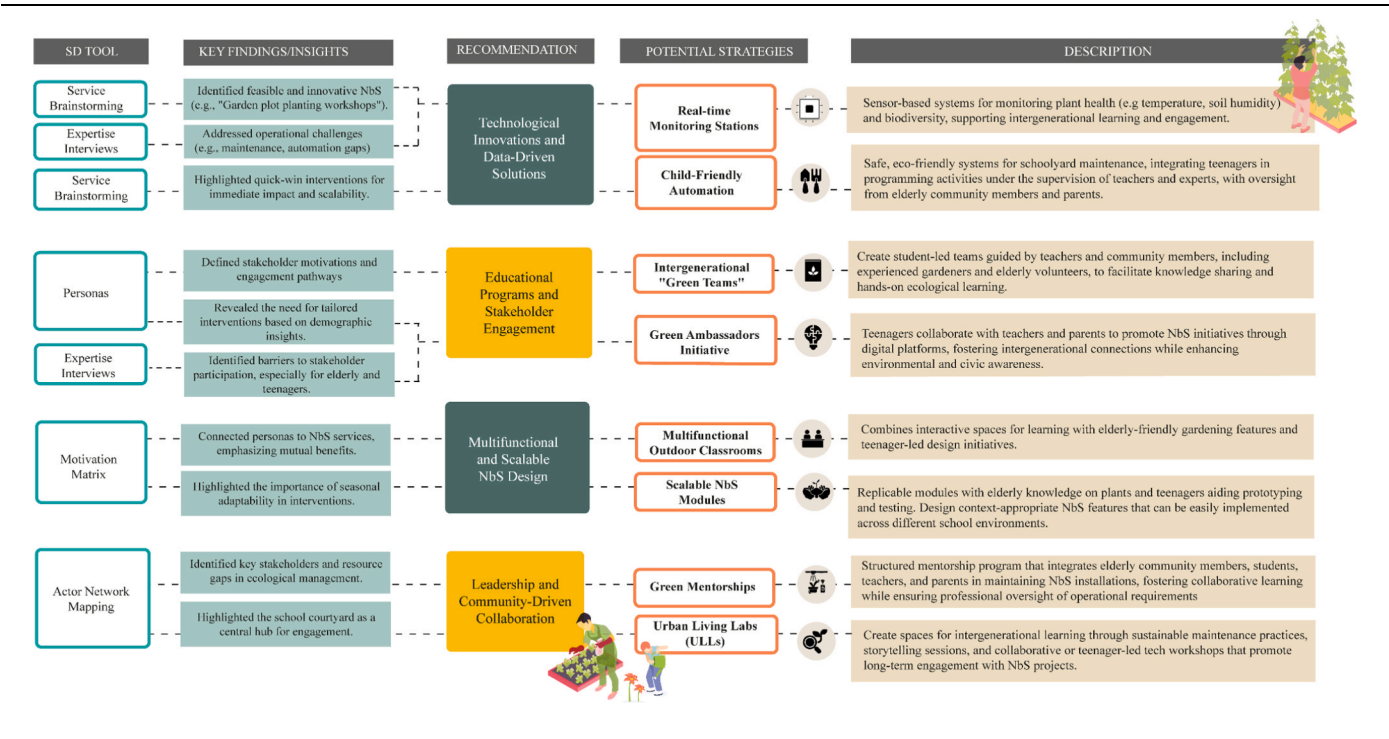
Curriculum-integrated green space programs form the cornerstone of educational engagement, incorporating NbS features into various subjects to foster long-term student involvement and

environmental awareness. **Student-led “Green Teams”** incorporate intergenerational collaboration, where elderly community members contribute expertise in gardening, maintenance techniques, and cultural traditions [50]. Teenagers serve as “Green Ambassadors,” leveraging their digital literacy to promote environmental awareness and facilitate community outreach. Intergenerational activities with the support of teachers and parents, including gardening workshops and biodiversity monitoring, promote shared learning experiences. Research indicates these programs foster mutual respect, reduce social isolation among the elderly, and improve teenagers’ sense of civic responsibility [65] (.

• Multifunctional and Scalable NbS Design

Multifunctional outdoor classrooms serve dual purposes as NbS implementations and dynamic learning environments, aligning with

Table 6
Key Insights from Service Design Tools and Implementation Strategies for NbS in School Environments.



Source: Authors (2024).

broad urban planning initiatives. These spaces incorporate features encouraging intergenerational use, such as raised gardening beds for elderly accessibility and interactive design elements for teenager engagement. The development of **scalable, replicable NbS modules** ensures context-appropriate features implementable across different school environments while maintaining compliance with local regulations and environmental constraints. Community volunteers and elderly participants can contribute to the design and maintenance through their knowledge of local plants and ecosystems, while teenagers assist in prototyping and testing scalable solutions, bridging traditional wisdom with innovative approaches.

• Leadership and Community-Driven Collaboration

The framework promotes **student environmental councils** to enhance participation in NbS decision-making processes, fostering leadership skills and sustained engagement. Including elderly representatives in these councils encourages diverse perspectives and strengthens decision-making processes. **Intergenerational learning partnerships** are institutionalized through structured programs like “Green Mentorships,” pairing students with elderly mentors and parents for collaborative design and maintenance of green spaces. The implementation of **urban living labs (ULLs)** provides physical spaces for stakeholder collaboration and problem-solving [51]. These labs serve as community engagement hubs [52], hosting elderly-led storytelling sessions about local green spaces’ historical and ecological significance, alongside teenager-led technology workshops focused on digital tools for NbS design. These collaborative efforts build robust stakeholder networks, promoting ownership and long-term commitment to NbS initiatives while improving elderly participants’ well-being, developing teenagers’ skills, and enhancing cross-generational environmental stewardship.

By integrating these recommendations, the framework presents a multifaceted strategy for urban NbS initiatives in school settings, addressing key challenges in green space management, community participation, and maintenance. This approach ensures that NbS interventions serve multiple purposes: enhancing environmental resilience while simultaneously promoting educational opportunities and community engagement. Table 6 presents an overview of key insights derived from Service Design Tools and their application in implementing Nature-based Solutions within school environments.

6. Conclusions

The Szombathely schoolyard case study demonstrates the significant impact of integrating Service Design tools in NbS implementation. Through a systematic application of five complementary SD tools, we developed a comprehensive framework that bridges theoretical concepts with practical implementation. The Service Brainstorming sessions proved particularly effective in generating innovative solutions, categorizing interventions by feasibility and innovation potential, which led to the identification of strategic “quick wins” and long-term transformative projects. Personas development revealed nuanced insights into stakeholder needs, with distinct profiles for students, parents, and teachers informing the design of targeted interventions that resonated with each group’s motivations and capabilities. The Motivation Matrix emerged as a crucial tool for understanding stakeholder interactions, revealing how students’ experiential learning needs could align with teachers’ practical education goals. This alignment proved fundamental in designing sustainable engagement strategies. Actor Network Mapping identified critical relationships centered around the school courtyard, highlighting resource gaps and expertise needs in ecological

management. These insights directly informed our recommendations for building robust maintenance networks and establishing clear channels of communication among stakeholders. Expert Interviews provided valuable operational insights, particularly regarding specific technological implementations. For instance, the integration of soil moisture sensors and automated irrigation systems emerged as viable solutions to address maintenance challenges, while weather stations connected to educational displays created opportunities for data-driven learning. These technological solutions were carefully balanced with stakeholder capabilities and local regulations, ensuring sustainable implementation.

The framework’s success in Szombathely reveals both opportunities and challenges for future NbS implementations aligned with the government’s strategy for the coming years. While the SD tools effectively facilitated stakeholder engagement and innovative solution development, several challenges merit attention in future applications. These include the need for continuous stakeholder motivation, technical expertise development, and sustainable funding mechanisms. The framework’s adaptability to different educational contexts requires careful consideration of local cultural, environmental, and regulatory factors.

Looking ahead, future research should focus on longitudinal studies of NbS implementations using this SD-enhanced framework, particularly examining the long-term effectiveness of technological solutions and stakeholder engagement strategies. Additionally, developing standardized metrics for evaluating the success of SD tool applications in NbS projects would provide valuable benchmarks for future implementations. The Szombathely case demonstrates that integrating SD tools in NbS projects can create more resilient, sustainable, and community-centered urban green spaces, while providing a replicable model for similar interventions in educational settings worldwide.

CRedit authorship contribution statement

Francisca Tapia: Writing – original draft, Visualization, Resources, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Andras Reith:** Writing – review & editing, Validation, Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

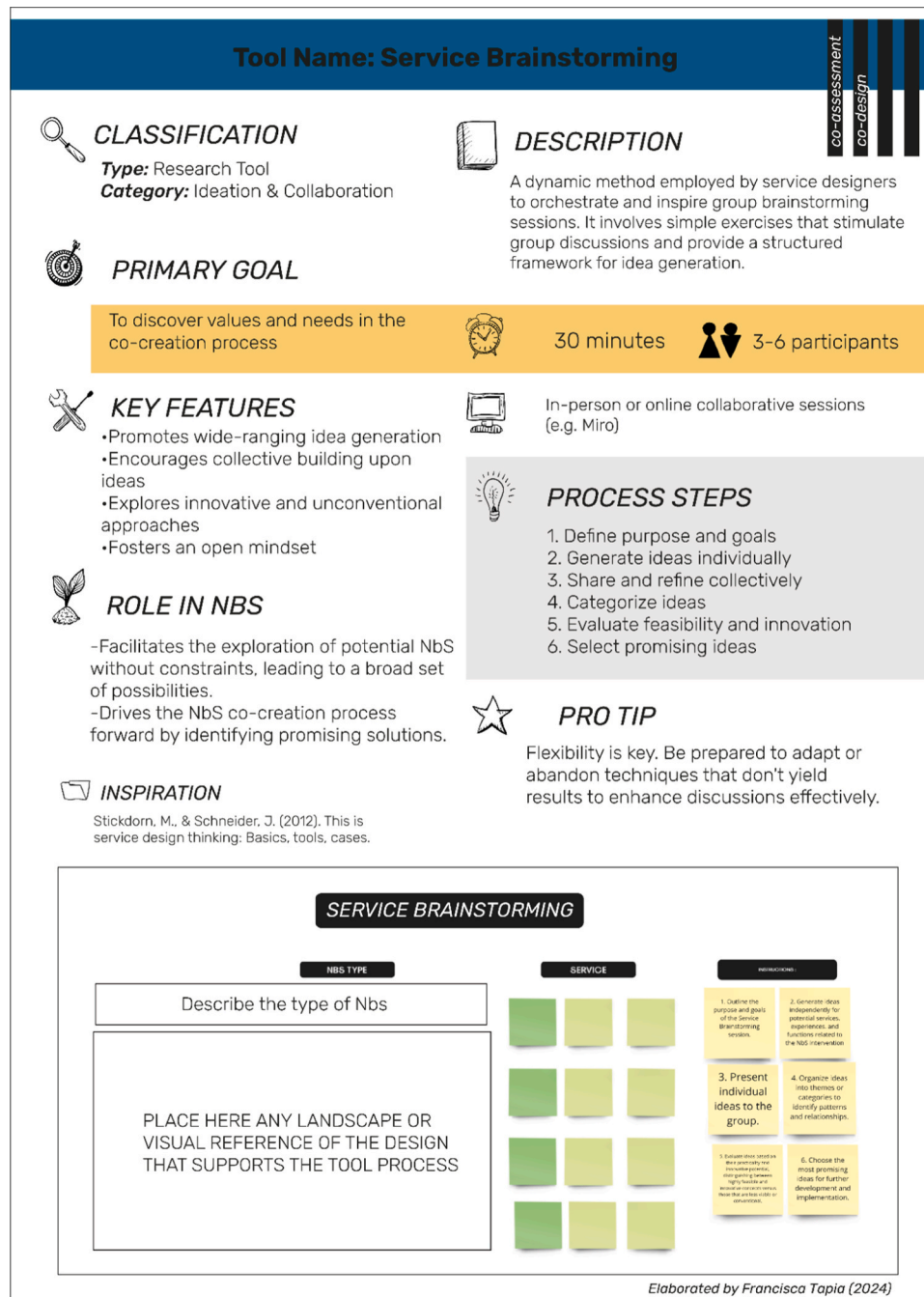
Acknowledgement

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Appendix A

Service design guidelines

Service design tool 1: Service brainstorming.



Service design tool 2: Personas

co-assessment

co-design

co-monitoring

Tool Name: Personas



CLASSIFICATION

Type: Research Tool
Category: Stakeholder Analysis



PRIMARY GOAL

To create a deep understanding of diverse stakeholder groups and their needs in the context



KEY FEATURES

- Research-based character profiles
- Representation of diverse stakeholder groups
- Emphasis on needs, motivations, and behaviors
- Facilitates empathetic design decisions



ROLE IN NBS

Ensure NbS solutions are grounded in a deep understanding of diverse stakeholder groups, aligning interventions with varied community interests and needs.



INSPIRATION

• Stickdon, M., & Schneider, J. (2012). This is service design thinking: Basics, tools, cases.
• Cooper, A. (1998). The Innkeepers Are Running the Asylum.
• Goodwin, K. (2009). Designing for the Digital Age: How to Create Human-centered Products and Services.



DESCRIPTION

Fictional profiles representing key stakeholder groups. They transform abstract demographics into empathetic, user-centered representations, guiding design choices to meet specific user needs.



30 -40 minutes



3-6 participants



In-person or online collaborative sessions (e.g. Miro)



PROCESS STEPS

1. Define purpose and goals
2. Generate ideas individually
3. Share and refine collectively
4. Categorize ideas
5. Evaluate feasibility and innovation
6. Select promising ideas



PRO TIP

Regularly revisit and update personas as the project evolves to ensure continued relevance and accuracy in representing stakeholder groups.

Create as many personas as needed.

PERSONA

Basic Info

Relationship

Age :
Gender :
Family status :
Wealth-Income:

How this persona interact with the NbS? How often?

Occupation, Role

Mode of transportation

Social activities

How the NbS is connected to the role ?

Interests and activities connected and involved to the city.

INSTRUCTIONS :

1. Basic Description (age, gender, family status, income)
2. How this persona interact with the NbS? How often?
3. Professional background, title and role (e.g. decision maker, buyer, user)
4. Mode of transportation, routines
5. Social activities and hobbies. Are these connected to the NbS?

Follow the instructions for each step and adhere to the color-coding system.

Elaborated by Francisca Tapia (2024)

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Service design tool 3: Motivation matrix.

Tool Name: Motivation Matrix

co-design

CLASSIFICATION

Type: System Map

Category: Stakeholder Analysis

PRIMARY GOAL

Identify benefits, values, and functional relationships among stakeholders in NbS projects, providing a structural foundation for cooperation and negotiation

45 -60 minutes

3-6 participants

KEY FEATURES

- Visualizes stakeholder interactions
- Categorizes values by importance and time frame
- Facilitates strategic decision-making
- Promotes shared understanding of roles and responsibilities

ROLE IN NBS

- Facilitates the exploration of potential NbS without constraints, leading to a broad set of possibilities.
- Drives the NbS co-creation process forward by identifying promising solutions.

In-person or online collaborative sessions (e.g. Miro)

PROCESS STEPS

1. Identify values important for NbS delivery
2. Categorize values by importance (very important, important, somewhat important)
3. Further categorize values based on time frame (long-term, medium-term, short-term)
4. Visualize connections between stakeholders and potential services
5. Analyze patterns and alignments among identified personas.

PRO TIP

Use the Motivation Matrix as a foundation for subsequent tools like Actor Network Mapping to further enhance understanding of stakeholder dynamics throughout the NbS project lifecycle.

INSPIRATION

- Morelli, N., & Tollestrup, C. (2007). New representation techniques for designing in a systemic perspective. In Design Inquiries, Nordes 07 Conference
- Manzini, Collina et al. 2004

MOTIVATION MATRIX

- Utilize personas from previous tool.
- Include relevant services
- Replicate template as needed.

PERSONA		VALUE		PARTICIPATION		
		GAIN	LOSS	TASKS	DIRECTION	FREQUENCY
PERSONA 1						
PERSONA 2						

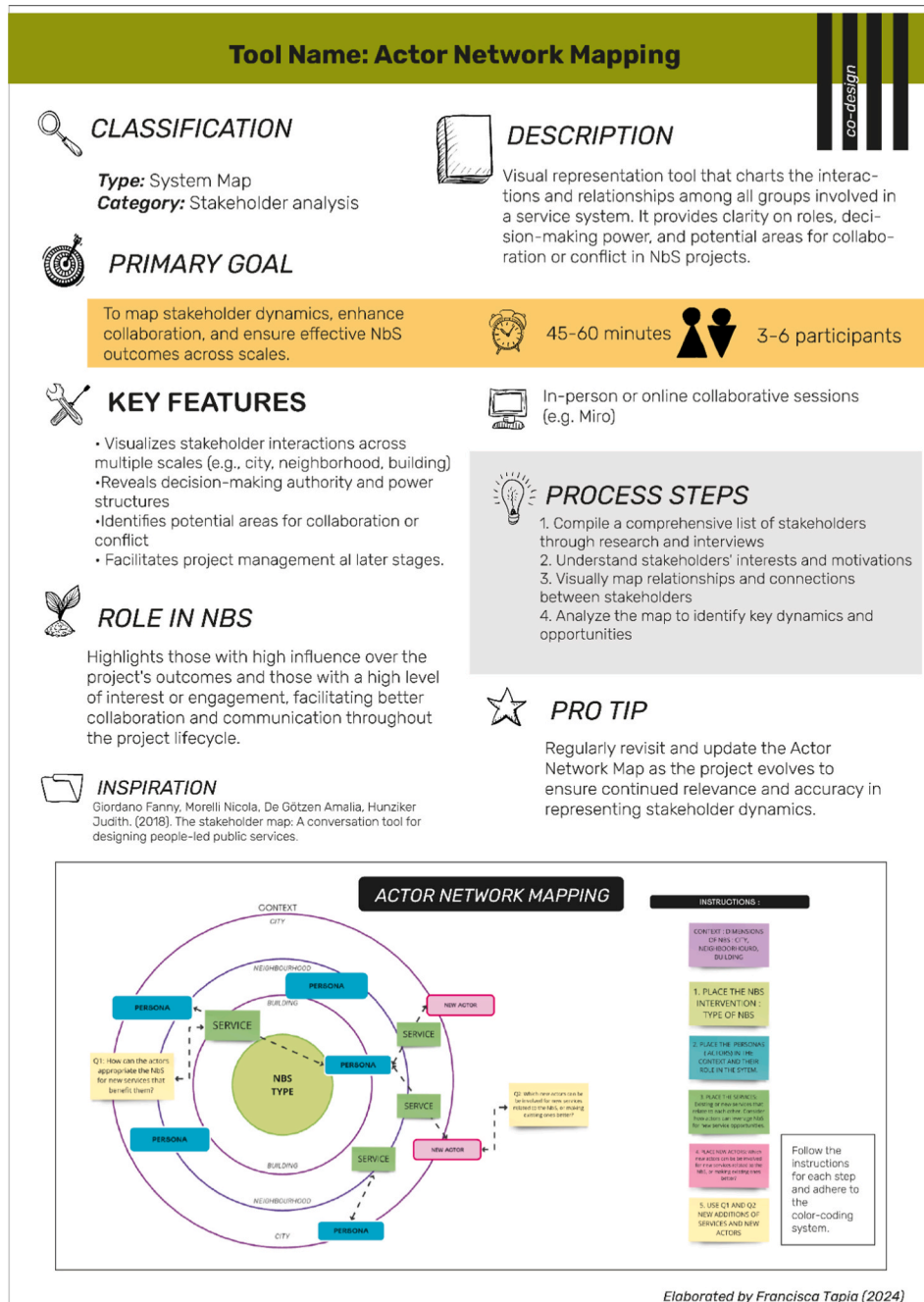
INSTRUCTIONS:

1. SELECT: select 3-5 values that are most important to the service.
2. ACTOR: describe the actor. Use the provided BBCode system.
3. GAIN/LOSS: does the interaction help to meet goals/needs?
4. TASK: what issues can this service bring?
5. DIRECTION: what kind of action does the actor have in the service?
6. FREQUENCY: how often does the actor have in the service?
7. FREQUENCY: what is the frequency of the service provided to the actor?

Follow the instructions for each step and adhere to the color-coding system.

Elaborated by Francisca Tapia (2024)

Service design tool 4: Actor-network mapping.



Service design tool 5: Expert interview.

Tool Name: Expert Interviews

co-design

co-implementation

co-monitoring

CLASSIFICATION

Type: In-depth qualitative research tool
Category: Ideation & Collaboration

PRIMARY GOAL

To gain comprehensive understanding of stakeholder support, implementation challenges, and best practices.

KEY FEATURES

- In-depth exploration of specific topics
- Access to specialized knowledge and experience
- Identification of trends, challenges, and opportunities
- Validation or refinement of existing ideas

ROLE IN NBS

- Provide crucial insights into stakeholder support, community needs, and potential obstacles to NbS adoption.
- They inform the design process, anticipate challenges, and ensure alignment with best practices in urban green infrastructure.

INSPIRATION

Stickdonn, M., & Schneider, J. (2012). This is service design thinking: Basics, tools, cases.

DESCRIPTION

Structured conversations with professionals possessing specialized knowledge in a particular field. This tool provides invaluable insights into complex issues, best practices, and potential challenges in NbS implementation.

45-60 minutes

2-3 participants

PROCESS STEPS

1. Identify and recruit relevant experts
2. Develop a tailored interview guide
3. Conduct interviews in the expert's environment when possible
4. Record and transcribe interviews for thorough analysis
5. Synthesize findings to inform NbS design and implementation

PRO TIP

Combine expert insights with on-the-ground community feedback to create holistic, effective NbS designs that balance expert knowledge with local needs and preferences.

EXPERT INTERVIEW

Professionals background of the interviewee

How are you using the data in operation and maintenance tasks?

What are the maintenance tasks that are dependent on specific (environmental) conditions?

In which way can involvement of other actor/partners benefit the maintenance tasks?

What are the maintenance tasks that require expertise, but do not have an actor/partner responsible for it yet? Who do you need for that?

- Keeping the green healthy (restoration/maintenance, cutting/trimming, leaving the riparian)
- Specific maintenance of technical elements
- Others

- Others

(Especially in the long term), are there maintenance tasks that can be outsourced from experts to locals?

Where do you need help?

In your opinion, what kind of maintenance tasks can benefit from automation?

INSTRUCTIONS:

1. Request permission to record the interview for 100% on 2 purposes.
2. Briefly explain the interview's purpose and expected duration.
3. Start with general questions to establish rapport.
4. Listen actively and ask follow-up questions for clarification.
5. Take notes on key points and non-verbal cues.
6. Reconfirm the expert's time and tick to the agreed duration.
7. Conclude by thanking the expert and explaining next steps.

Elaborated by Francisca Topia (2024)

Appendix B

Expertise interview template

EXPERT INTERVIEW

City:

Date, time:

Interviewers:

Professional background of the interviewee:

Municipality employee (specify):

NGO employee (specify):

Other:

How are you using the data in operation and maintenance tasks?

For example: using sensor data for forecasting, irrigation purposes

What are the maintenance tasks that are dependent on specific (environmental) conditions?

For example: normally, watering happens with the rain, but if there is extreme drought and several days without rain what should be done

In which way can involvement of other actors/partners benefit the maintenance tasks?

The category of actors that can be more precisely specified for your NbS network:

Academy (university)

Governmental body (local municipalities)

NGO

Private company (shops nearby...)

Civil, local people

What are the maintenance tasks that require expertise, but do not have an actor/partner responsible for it yet? Who do you need for this?

Green and blue maintenance actions:

General housekeeping (cleaning of the area, simple tasks)

Keeping the green healthy (watering/nutrition; cutting/pruning; treating the injuries)

Special maintenance of technical elements

Others

Social actions:

Engagement of the people (organize events, improve the area)

Environmental education (training, workshops)

Others

(Especially in the long term), are there maintenance tasks that can be outsourced from experts to locals?

What level of involvement do landscape design professionals currently have in the project planning and implementation?

What are the steps to overcome the challenges in the maintenance tasks? Where do you need help?

Highlight the results from the Motivation Matrix tool

In your opinion, what kind of maintenance tasks can benefit from automation?

Appendix C

Service design tools analysis

SD Tool Name	Tool Type	Description	Steps	Co-Creation Main Goal	Role in NbS	Goal in NbS	Co-Creation Stages applicability	Relevance	Source
Brainstorming (Service Brainstorming)	<i>Research Tool</i>	Group ideation techniques to organize and inspire brainstorming sessions.	Individual ideation, sharing ideas, clustering, analyzing, prioritizing	Discover values, needs	Stimulates diverse ideation, helps identify a wide range of potential NbS solutions	Needs selection, clustering, analyzing, prioritizing	Co-assessment, Co-design	High	<i>(Stickdorn & Schneider, 2012)</i>
Personas	<i>Personas</i>	Develops fictional profiles based on real data to understand target groups and their needs.	Define attributes, needs, challenges, behaviors, motivations	Engage stakeholders	Empathizes with target groups and bridges gaps between stakeholder expectations and NbS design	Profiles based on shared behaviors and needs	Co-assessment, Co-design	High	<i>(Stickdorn & Schneider, 2012; Cooper, 1998; Long, 2009; Goodwin, 2009)</i>
Motivation Matrix or Canvas	<i>System Maps</i>	Visualizes relationships and values between various actors, essential for stakeholder alignment and coordination.	Identify values, classify importance, categorize by timeframe	Design action plans, achieve long-term goals	Establishes a common understanding among actors for sustainable co-creation	Identification of mutual goals and structural roles	Co-assessment, Co-design	High	<i>(Morelli & Tollestrup, 2007)</i>
Stakeholder Map (Actor Network Mapping)	<i>System Maps</i>	Visual or physical depiction of stakeholders and	Compile stakeholder list, define interests,	Engage stakeholders	Clarifies roles, influences, and connections in NbS projects	Maps out key roles, relational dynamics, power structures	Co-assessment, Co-design, Co-implementation	High	<i>(Giordano et al., 2018)</i>

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SD Tool Name	Tool Type	Description	Steps	Co-Creation Main Goal	Role in NbS	Goal in NbS	Co-Creation Stages applicability	Relevance	Source
Value Proposition Canvas	<i>System Maps</i>	their relationships, focusing on formal and informal networks. Identifies and aligns NbS components with stakeholder needs, focusing on tangible and intangible values.	analyze relationships Define customer profiles, visualize value, refine based on feedback	Discover challenges, goals, actors	Tailors NbS propositions to stakeholder needs and validates them through iterative feedback	Maps value propositions, pains, and gains by stakeholder group	Co-assessment, Co-design	Medium	[45]
Customer Journey Maps	<i>System Maps</i>	Captures and visualizes a user's experience over time, including emotional journey and pain points.	Identify touchpoints, structure stages, visualize touchpoints and channels, map emotions	Design action plans, achieve long-term goals	Analyzes stakeholder interactions with NbS at each touchpoint, facilitating improved user experiences	Defines stages of interaction, highlights barriers and emotional flows	Co-design, Co-implementation	Medium	(Stickdorn & Schneider, 2012; [45])
Expert Interviews	<i>Research Tool</i>	Facilitates deep insights through structured interviews in the user's environment, uncovering behavior and attitudes.	Select participants, prepare questions, conduct interviews, document insights	Discover needs and values	Provides context-specific insights, enables direct feedback for co-creation processes	Obtains behavioral insights, operational information, and NBS-specific challenges	Co-assessment, Co-design, Co-implementation, Co-monitoring	High	(Stickdorn & Schneider, 2012)
Storyboard	<i>Research Tool</i>	Visualizes user interaction sequences and scenarios to clarify service use, often in comic-strip format.	Define scenario, create visual narrative, present to stakeholders for feedback	Improve creativity, discover needs, validate solutions	Simulates real or hypothetical service interactions, fostering empathy and highlighting potential areas of improvement	Outlines service scenarios, reveals touchpoints and outcomes	Co-assessment, Co-design, Co-implementation, Co-Monitoring	Medium	(Stickdorn & Schneider, 2012)
Service Blueprint	<i>System Maps</i>	Provides a detailed specification of each aspect of a service, including customer contact points and behind-the-scenes processes, creating a shared visual schematic for users, providers, and other relevant parties.	Collaborative creation to ensure shared understanding, periodic revisions for alignment with operational changes, and regular updates to refine activities and adapt to changes.	Engage Stakeholders, Test and Validate	Visualizes process flow from visible user actions to hidden backstage processes, helping align front-stage and back-stage elements.	Facilitates co-creation by enhancing process transparency, coordination, and communication among diverse actors.	Co-assessment, Co-design Co-implementation, Co-evaluation	High	(Stickdorn & Schneider, 2012)
Ecosystem Map	<i>System Maps</i>	Captures major roles influencing the user, organization, and environment; represents all entities and their value exchanges to identify gaps and synergies.	Identify sectors, define actors (people, organizations, platforms, etc.), determine relationships or value exchanges.	Design Action Plans, Achieve Long-Term Sustainability	Maps complex interactions between human and non-human actors in NbS (e. g., stakeholders, the environment), highlighting gaps and synergies.	Enhances understanding of interconnections within NbS systems, improving alignment and fostering collaborative solutions.	Co-assessment, Co-design	Medium	[45]
Business Model Canvas	<i>System Maps</i>	Outlines nine essential components of a business model, aiding in understanding business impact,	Identify Value Propositions, Customer Segments, Channels, Relationships, Key Activities,	Design Action Plans, Achieve Long-Term Sustainability	Enables co-creation participants to understand the infrastructure, target customers, and financial	Assists in defining and refining the operational model for sustainable NbS, facilitating collective	Co-assessment, Co-design	Medium	[45]

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(continued)

SD Tool Name	Tool Type	Description	Steps	Co-Creation Main Goal	Role in NbS	Goal in NbS	Co-Creation Stages applicability	Relevance	Source
Scenario Planning	<i>System Maps</i>	user experience, and the value proposition in a service. Uses hypothetical narratives to explore specific service aspects under various scenarios, providing insights into potential problems and solutions.	Resources, Partners, Costs, and Revenues. Define context, actors, and events for each scenario; identify key interactions, pain points, and opportunities; use group settings for collaborative knowledge exchange.	Design Action Plans, Achieve Long-Term Sustainability	model necessary for NbS. Helps visualize system evolution over time, analyzing actor interactions and system dynamics, crucial for NbS adaptability.	ownership and commitment. Allows teams to predict potential challenges and collaboratively design adaptive solutions, ensuring NbS resilience.	Co-Assessment, Co-design, Co-evaluation	High	(Stickdorn & Schneider, 2012)
Service Prototype	<i>System Maps</i>	Simulates parts of a service to evaluate design feasibility, fostering collaboration and idea refinement through mock-up experiences.	Create mock-ups (physical, digital, or experiential), test in real-world environments, gather feedback, iterate and refine design.	Implement, Monitor, Test and Validate	Enables stakeholders to test and validate NbS design by simulating final interactions, assessing challenges, and refining implementation.	Allows for the pre-implementation testing of NbS to ensure all user and operational needs are met, reducing risks.	Co-implementation, Co-evaluation	High	(Stickdorn & Schneider, 2012; [45])
Transition Journey	<i>System Maps</i>	Connects various user journey points, analyzing triggers that facilitate user role evolution and engagement.	Reflect on one user type at a time, link their journeys, focus on transition points (triggers and barriers), and ideate design opportunities for engagement.	Implement, Monitor, Test and Validate	Enhances user engagement by guiding them through evolving roles within NbS, fostering sustained involvement.	Promotes long-term user engagement by supporting role progression in NbS, ensuring solution sustainability.	Co-implementation, Co-evaluation	Medium	(Stickdorn & Schneider, 2012)
User Scenarios	<i>System Maps</i>	Narratives depicting typical user interactions with a service, focusing on specific needs, motivations, and goals to highlight service value and impact.	Define persona's goals, context, and environment; create a scenario narrative; add visuals for clarity.	Monitor and Evaluate	Helps identify practical needs and user interactions within NbS, clarifying requirements for design and functionality.	Offers valuable insights into user experience, supporting tailored NbS solutions that meet diverse user needs.	Co-assessment, Co-design, Co-evaluation	Medium	Service Design Toolbox, (Interaction Design Foundation, 2016)
AI Opportunity Landscape	<i>System Maps</i>	Framework for mapping a wide range of AI opportunities within a service, identifying potential AI applications (automation, assistance, augmentation) based on service needs.	Outline service context and roles, identify challenges, prioritize opportunities, and explore solutions through AI functionality categories (automation, assistance, augmentation).	Improve Creativity, Discover Needs, Test and Validate	Supports NbS by ideating AI-driven enhancements that address complex environmental and operational challenges.	Enables ideation of AI applications to optimize NbS implementation, enhance value, and improve sustainability.	Co-assessment, Co-design, Co-implementation	Medium	Service Design Toolbox and Oblo Studio AI Tools Documentation https://servicedesigntools.org/tools
AI Functionalities Cards	<i>System Maps</i>	A set of cards listing various AI capabilities, used to inspire ideation and guide creative processes by showing feasible AI applications for services.	Review AI capabilities, brainstorm potential applications within the service context, and combine functionalities to explore synergies.	Inspire Creativity, Test and Validate	Facilitates exploration of AI functionalities that can enhance various aspects of NbS, fostering innovation.	Aids in the ideation phase by expanding the range of possible AI interventions within NbS, encouraging inventive solutions.	Co-Design, Co-Evaluation	Medium	Service Design Toolbox and Oblo Studio AI Tools Documentation https://servicedesigntools.org/tools

Data availability

Data will be made available on request.

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