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Article

Methodological Framework for Fostering the Implementation of Climate-Responsive Public Spaces and Streetscapes to Support Multifunctional Design

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Abstract: The ongoing effect of climate change heating up urban areas is forcing cities to exploit the adaptation potential of their public open spaces. Streets and squares are important urban open spaces that can contribute to climate change adaptation through the targeted application of individual measures. In order to ensure the effective and appropriate application of climate-relevant measures for the public good, the city of Vienna relies on the development of a guideline that focuses on measures from the field of urban green and blue infrastructure (UGBI) (and a few technical measures (TM)) in the urban open space. In the future, this guideline will make it easier for city employees to select appropriate measures. In the context of an applied research project, existing and possible measures in Vienna were collected, examined, and assessed for their climate, ecological, and social sustainability based on the concept of ecosystem services (ES). The challenge here is to capture this broad topic of sustainability and climate change and to draw on a broad spectrum of knowledge from science and research, as well as directly from practice. The result is a methodological framework that can be used by other cities as a basis for the development of individual guidelines to foster climate-relevant measures and a critical analysis of the use of co-creation in the development of the framework.

Keywords: urban green and blue infrastructure; climate change adaptation; urban planning; public/urban open space; climate-fit public spaces

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1. Introduction

Today's European cities face major and diverse challenges in the field of climate change. Climate changes, such as an increase in average temperatures, have been shown to lead to urban heat and precipitation-related extreme events such as heavy rain and dry periods [1,2]. The steady increase in soil sealing at the expense of green and open spaces [3] is also directly linked to the urban heat island effect (UHI-effect), which is common in urban areas, and leads to further increases in temperatures and heat stress within cities [4]. Climate conditions have a direct impact on the quality of life and the health of urban residents, the economy, and infrastructure [5,6]. The COVID-19 pandemic has also had an effect on the urgency of climate adaptation for cities. The pandemic led to an increase in social inequality, subsequently exacerbating the effects of climate change [2].

Adaptation services are needed in order to counteract these climate impacts in urban areas. In this context, we refer to the concept of ecosystem services. The concept is based on the principle that only a healthy ecosystem can lead to a sustainable city because ecosystems provide important services such as regulating, cultural, provisioning, and supporting services [7,8]. The adaptation services needed in cities are developed in terms of ecosystem services. They can be provided through the use of specific climate-relevant measures in urban and landscape planning. In particular, urban green and blue infrastructure design elements [9,10] make an important contribution at climate, ecological, social, and economic levels in cities through the provision of a variety of ecosystem services [3,11–13].

1.1. Public Space as a Mean for Climate Adaptation Measures in Vienna

Public spaces, especially streets and squares, have a high degree of multifunctionality. They play an active role in functional, ecological, social, and economic terms [14], especially in the provision of ES. In Vienna, up to 90% of public space in densely built-up areas consists of street surfaces [14]. Furthermore, these open spaces are almost exclusively in the hands of the public due to their classification as public property [15]. For these reasons, streets and squares are central fields of action for the implementation of climate adaptation measures in the urban environment. Additionally, their accessibility and usability for all city residents have a positive impact on their importance as climate adaptation tools. Urban streets and squares designed with special design elements can mitigate or counteract the effects of climate change and thereby increase the quality of life for inhabitants in different fields. For example, a street tree provides shade and cools the air through evapotranspiration. People feel a lower perceived temperature under the tree when it is hot [16].

For several years, the city of Vienna has been actively working toward the goal of adapting the urban public space to climate change while at the same time improving the quality of stay in these open spaces. Numerous streets and squares have already been either permanently changed, e.g., through the installation of permanent shade and water design elements, the use of light-coloured surfaces, and planting trees [17], or temporary climate-relevant measures have been implemented for this purpose, e.g., through temporary water and seating [18].

This is the context against which this article has been written. Within the framework of the applied research project "Sustainable climate-fit urban squares and streets for the city of Vienna" [19], commissioned by the city of Vienna, climate-relevant measures have been collected, such as different rainwater management elements or pavements with different uses, primarily measures that are already in use in Vienna. In addition, existing climate-fit streets, good-practice examples in the city of Vienna were analysed and climate-relevant measures in use were identified. This was followed by a multi-criteria assessment of the collected measures by experts from research and practice in order to check them with regard to their ecosystem services. The whole process was accompanied and supported by research in the literature, workshops, and expert interviews. The project has resulted in a guideline for the Viennese city administration, containing descriptions and the results of the assessment of different adaptation measures for public open space. It is intended to guide the employees in their choice of the right design elements for the respective open space or square and to support them in justifying the use of climate-relevant measures. In this article, design elements are understood to mean adaptation measures or climate-relevant measures in the area of UGBI and technical measures for public open spaces (see Section 3.2). This paper describes, based on the experience of this Viennese research project, the process of defining appropriate adaptation measures on streets and squares and quantifying them through multi-criteria assessment. We highlight two measures of the guideline as an example for describing the entire process of developing it: the vegetation element "tree" and the water element "water feature".

1.2. Co-Creation in Support of Acceptance of the Implementation of Climate-Relevant Measures in the Urban Open Space

Co-creation was used to foster collaboration between the various participants in the project. Currently, knowledge exchange and co-creation play an important role in the collaboration between science/research, and practice [20]. The aim is to close the gap between science and practice [21]. Experiences from the field of participation research are transferable to this expert participation [22,23]. It is also important here that participants are informed about the entire project. Furthermore, it is crucial that the opinions and decisions of the participants be independent, free, and uninfluenced by the "power holders" [22] mentioned by Sherry R. Arnstein; the research project this article refers to is the city of Vienna itself and the project team.

According to Thomas C. Beierle [24], if, for example, participants from practice are involved in the process, the decisions made are of better quality, trust in science is strengthened, and the practicality of results is evaluated in advance by implementation. A prerequisite for the use of this method is the practical relevance of the questions [21]. The topic of sustainability and climate adaptation in urban areas is a multidimensional issue that requires complex interaction between different stakeholders from different fields and disciplines and different planning and execution levels [25,26]. For a co-creation process to succeed, complex organisation, together with well-defined rules and power relations for all participants, is essential right from the start [27,28]. It should also be borne in mind that co-creation is always associated with increased effort in terms of time and resources [29]. Co-creation also stands and falls with the communication mode and instrument, the communication strategies. As in classical participation research, a high quantity and quality of communication leads to a just and more democratic outcome [30]. Conventional modes of communication are supported by newer models, such as workshops and online tools, as a place for the exchange of knowledge and information. These have a positive impact on the overall process [31]. Co-creation supports acceptance of the results of the relevant project [26]. It has been shown that stakeholders from science and practice (see Sections 2.1 and 2.4) who are actively involved throughout the project contribute to acceptance of the implementation of the project results.

This paper describes the transdisciplinary process of developing a guideline for sustainable, climate-fit urban streets and squares. The aim of the paper is to (1) identify specific climate-relevant measures for urban streets and squares (both existing and possible) that will support climate adaptation of public open spaces in the future, (2) present a guideline to support the implementation of adaptation measures, and (3) present the added value of the transdisciplinary contributions in the entire project process and specifically in the assessment process of the adaptation services of climate-relevant measures, using the co-creation method to improve the quality of urban streets and squares.

The resulting main research questions of this paper are:

1. What would a guideline promoting the implementation of climate-relevant urban public spaces and streetscapes look like?
2. What is the added value of a transdisciplinary (co-creation) process in the development of a methodological framework for the implementation of climate-relevant urban public spaces and streetscapes?

2. Materials and Methods

2.1. Description of the Project Process

As already mentioned, this article is based on the results of an applied research project that took place in the city of Vienna between 2020 and 2022 [19]. The project focused on the identification of the current state of knowledge in the municipal departments of the city of Vienna (Architecture and Urban Design, Environmental Protection, Road Management and Construction, Parks and Gardens) concerning the development and implementation of sustainable climate-fit urban squares and streets, as well as on the improvement of sustainable knowledge building and the sharing of information.

The current complexity of the challenge of climate change requires a transdisciplinary approach [25]. The development process of the project included a comprehensive transdisciplinary collaboration of research and practice, as well as administration. The co-creation method [27,31] was applied throughout the project. At different levels of the process, a link between science and practice was actively created in order to achieve the involvement of relevant stakeholders and practitioners already in the development process (Figure 1). In an urban context, adaptation measures on a climate, ecological, and social level are needed to counteract climate impacts such as heat, heavy precipitation, and drought [7]. These can be fulfilled in public green and open spaces through UGBI [9,10]. In the context of this project, research was examined to identify which specific design elements on squares and in streets can take on this task. Figure 1 shows the most important steps in the process: the identification of climate-relevant measures and their most important services; the assessment of these measures and their services, characterised by a broad assessment process and several workshops.

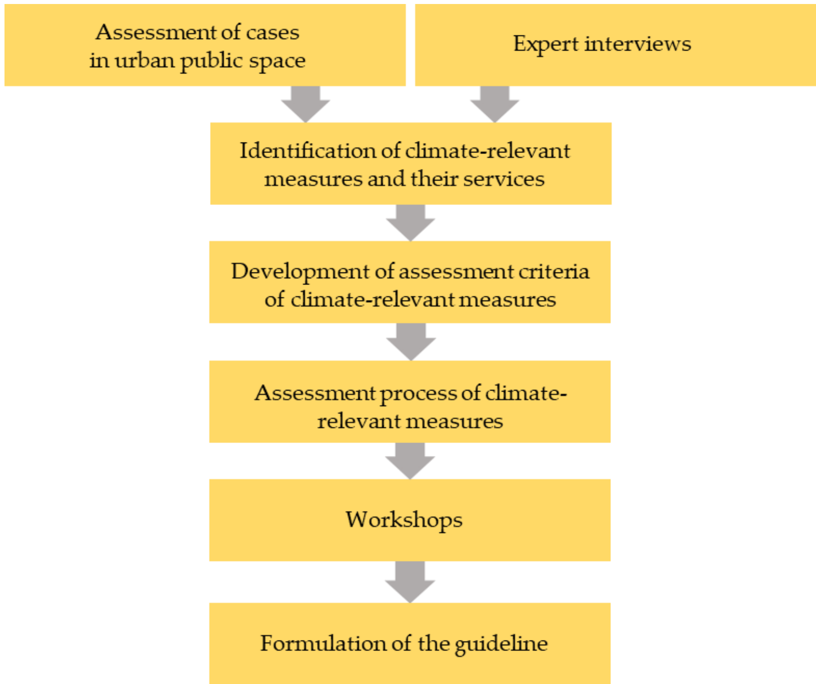


Figure 1. Methods used in the project process in collaboration with stakeholders from science and practice.

The final output of the project is a guideline for the development of climate-friendly urban public green and open spaces as a set of climate-relevant measures for urban streets and squares. The guidelines, in the form of a catalogue of design elements, will, in the future, support the balancing of different goals and demands on space so that adaptation to climate change can take place in a socially and ecologically acceptable way [19].

2.2. *Identification of Climate-Relevant Measures and Their Services*

In constant collaboration between the research team and experts from the city of Vienna departments, the process of identifying climate-relevant measures started with a comprehensive review of the literature on climate change adaptation in urban public spaces. For this purpose, research already conducted in previous projects [32,33] was used to obtain an overview of European, global, and national goals and strategies. Analysis of relevant city policies and surveys followed on a municipal level. Spatial strategy and development concepts in the city of Vienna, such as the "Urban Development Plan Vienna 2025" (STEP 2025) [34], the thematic concept "Public Space" [35], the thematic concept "Green and Open Space" [34], the "Urban Heat Islands—Strategy Plan Vienna" [36], and the "Smart City Vienna Framework Strategy" [37], were examined for their contribution to climate change adaptation.

Furthermore, Viennese case studies of streets and squares as "practice examples" and their existing climate-relevant measures were analysed and then discussed and evaluated together with the responsible departments of the city of Vienna. Based on this, possible design elements were derived that could make Vienna's streets and squares more climate-fit at present or more adaptable to climate change in the future. In voting events in the form of workshops, expert interviews, and working meetings, the numerous design elements collected were examined, standardised and adapted. Finally, 24 climate-relevant measures were identified, divided into five groups. These groups are explained in more detail in Section 3.1. In addition to the practical experience of a project partner, interviews were held with experts on their previous experience with climate-relevant measures in urban areas with departments of the city of Vienna [19]. Due to COVID-19 requirements, information was exchanged online. This had a positive effect on the intensity of the exchange. The interview results supported the assessment of the selected design elements with regard to their suitability as climate-relevant measures.

2.3. Development of Assessment Criteria for the Services Provided by Climate-Relevant Measures

Criteria are needed to assess the performance of the design elements. Based on knowledge from the assessment processes in the previous project "Green and Open Space Factor (GFF)" [38,39] and information from relevant city policies and surveys [36,40], an assessment scheme for quantifying specific services was derived and further developed for the design elements, always in direct dialogue with experts from the Viennese municipal departments and a planning office. The basis of the assessment categories is the classification of the ES according to the TEEB, which is based on four services [7,8]. The assessment criteria are explained in more detail in Section 3.1.

A multi-criteria approach is needed in order to be able to assess the climate-relevant measures in terms of their ES despite their complexity. Multi-criteria assessment enables the combination of the quantitative and qualitative results of the process [41]. The services to be assessed were constantly reviewed and discussed in a transdisciplinary process. Provisioning, cultural, regulating, and supporting services with climate, ecological, and social benefits were assessed. The legal and technical frameworks were also included in the multi-criteria assessment [19,38].

2.4. Experts' Multi-Criterial Assessment Process for Climate-Relevant Measures

The 24 climate-relevant design elements identified were evaluated by a group of 23 people consisting of 12 experts from the municipal departments and urban planning directorate of the city of Vienna, 2 practitioners from planning offices, and 9 European experts in the fields of urban ecology and planning. The assessment process took place online in the autumn of 2021. Each participant was sent assessment documents by e-mail, including: (1) a short description of the assessment process, the design elements to be evaluated, and the assessment criteria; and (2) an assessment table to be filled in. It was intended that the short description should lead to a common knowledge base in advance. In order to further increase the transparency of the quantitative assessment results, a confidence score for each individual measure was also collected on the assessment form itself [42]. The participants were asked to indicate numerically (1 = "I don't know much about it" to 3 = "I am an expert in this field") how familiar they were with the particular climate-relevant measure. There was also the possibility of qualitative additions in the form of textual explanations in the Excel table. On the assessment form itself, the participants were asked to rate the climate-relevant measures on a five-point scale with regard to their impact on climate comfort and their ecological and social effects. The legal and technical framework was to be rated as "suitable" or "not suitable".

The aim of the multi-criteria assessment process was to integrate the different professional perspectives of the various disciplines and actors involved in the planning of streets and squares, as well as experts from the field of research, in order to specify, evaluate, and check the knowledge already available to the project team on the identified elements from literature and practice and to close any gaps in knowledge and exclude problems of understanding.

2.5. Workshops

The results of the assessment process were evaluated; the quantitative results were presented graphically and the qualitative results clustered. Subsequently, the results of the assessment of the design elements were processed, presented, and discussed in a workshop attended by experts from the Viennese municipal departments. Any significant differences from the results expected by the project team, as well as discrepancies in the assessment between the experts from the field and the scientists, were pointed out and debated. The entire workshop process took place online due to COVID-19.

Finally, a guideline with relevant results on the analysed and assessed climate-relevant measures was drafted for the city of Vienna.

3. Results

A central result of the article is a methodological framework for the development of guidelines with proven design elements that can be used in urban streets and squares. It is shown in detail how adaptation measures were selected and assessed. Moreover, the article presents the importance of co-creation for this development process of adaptation measures. The guidelines are also explained in more detail in this chapter.

3.1. A Methodological Framework for a Guideline for the Implementation of Climate-Relevant Urban Public Spaces and Streetscapes

This methodological framework (Figure 2, see Supplement material) represents the development of guidelines for the implementation of climate-relevant measures in the planning of urban public spaces and streetscapes and shows the close connection between ecosystem services and their functions with sustainable streetscapes and squares. The different elements of the methodological framework (Figure 2) are described in the following.

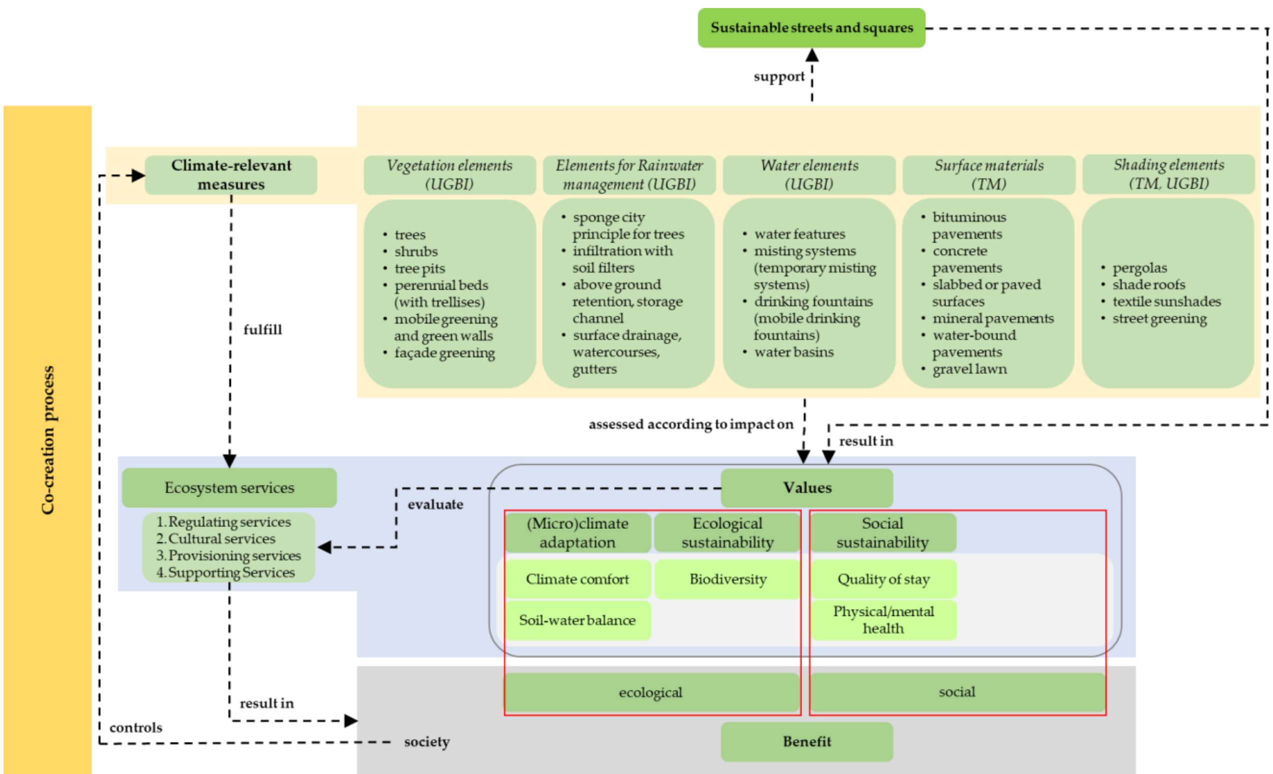


Figure 2. Methodological framework.

Climate-Relevant Measures and Their Services

Before examining the design elements for their significance as climate-relevant measures, the focus was on identifying and collecting design elements that are currently being used or discussed in Vienna. The basis was a list containing streets and squares in Vienna where climate-relevant measures were implemented in the past 5 years, drawn up by the Viennese programme "InKA" (Infrastructural Adaptation to Climate Change). This list was extended to cover what are known as "Cool Streets" (streets where temporary design elements have been implemented) and "Cool Streets Plus" (streets where permanent adaptation measures have been implemented) and what are known as "Cool Spots" (urban public open spaces, designed with cooling measures) (see Supplement material). On-site surveys of the collected streets and squares were then carried out. For each street/place, an inventory was made, supplemented by photographic documentation of the climate-relevant measures to be found. As the research project progressed, "Cool Streets" were excluded due to their temporary design. In close cooperation between the project team and the city of Vienna and the respective districts, the results of the surveys were discussed and the design elements clustered in a deductive and inductive process. The outcome was a pool of relevant Viennese case studies that covered many different climate-relevant measures.

In the next step, 24 different design elements were divided into five groups that can actively contribute to improving climate adaptation, based on intensive literature research and the examination of these Viennese case studies. The adaptation measures provide regulating and cultural ES and thereby bring an ecological and/or social benefit for society. The groups include UGBI design elements and technical adaptation measures. Table 1 shows the groups and their specific climate-relevant measures. The design elements support the sustainability of public streetscapes and squares.

Table 1. Climate-relevant measures.

Climate-Relevant Measure Group	Climate-Relevant Measure
Vegetation elements (UGBI)	Trees Shrubs Tree pits Perennial beds (with trellises) Mobile greening and green walls Façade greening
Elements for Rainwater management (UGBI)	Sponge city principle for trees, infiltration with soil filters Above-ground retention, storage channel Surface drainage, watercourses, and gutters
Water elements (UGBI)	Water features Misting systems (temporary misting systems) Drinking fountains (mobile drinking fountains) Water basins
Surface materials (TM)	Bituminous pavements Concrete pavements Slabbed or paved surfaces Mineral pavements Water-bound pavements Gravel lawn
Shading elements (TM, UGBI)	Pergolas Shade roofs Textile sunshades Street greening

The categorisation of individual adaptation measures into groups is based on the ES approach. The groups "Vegetation elements" as well as "Elements for Rainwater" and "Water elements" contain only design elements of the UGBI. It is commonly acknowledged that vegetation and water, as part of the UGBI, provide a variety of ES services [13]. In the field of climate adaptation, this concerns mainly the regulating services, such as shading, evapotranspiration, and evaporation [43], and cultural services. Vegetation and water have a positive effect on the physical and mental health of humans and support urban biodiversity [8,13,44]. TM such as "Surface materials" also provide regulatory and cultural services. The permeability and color of the surface materials used provide positive or negative services. These attributes have a direct influence on heat generation, the temperature perception of users, usability, and biodiversity [45,46]. Shading elements can be designed as UGBI, e.g., street greening, and therefore fulfil the typical ES services of UGBI. If they are constructed as TM, the regulating and cultural services predominate here as well. They have a regulating effect through their shading function and provide cultural services through the lower PET of people staying under a shading element [19].

Assessment categories were needed in order to be able to carry out an assessment of the climate-relevant measures. Based on the ES, values were defined that bring a benefit to society on an ecological and social level. As already mentioned, the evaluation process and criteria are based on a project that has already been carried out and completed, in which this evaluation method has been tested [38,39]. Moreover, the choice of assessment categories and criteria was coordinated with the local conditions on site in Vienna and validated together with the city of Vienna. Table 2 shows the five assessment categories and their classifications. The selected assessment categories enable the evaluation of the ecosystem services provided by the climate-relevant measures.

Table 2. Assessment criteria of the climate-relevant measures.

(Micro) Climate Adaptation		Ecological Sustainability	Social Sustainability	
Climate comfort	Soil-water balance	Biodiversity	Quality of stay	Physical/mental health

Due to the assessment of the selected design elements according to their impact on their values, it is possible to classify the implementation of the measures. The results of the evaluation support the selection of measures according to the desired climate-relevant effects at the location.

3.2. Guideline for the Implementation of Climate-Relevant Measures

One result of the project is a set of climate-relevant measures in the form of an internal guideline for the Viennese city administration. In the future, this will support the employees of the city of Vienna in their planning decisions and will be constantly expanded and updated by the city of Vienna. The cross-section of the street, the microclimate conditions, the location or orientation of the street or square, as well as the height of the surrounding buildings, require the use of different climate-relevant measures. The guideline includes fact sheets for 24 adaptation measures, which, in addition to a detailed description of the individual design elements, contain the most important requirements for the respective measures and their functions, their benefits, as well as possible conflicts of interest and challenges of the proven measures and the assessment result.

3.2.1. Results of Climate-Relevant Measures and Their Ecosystem Services

The results of the literature review, the analysis of relevant city policies and surveys, the assessment of the cases in urban public space, and the expert interviews on the individual design element groups and their services are discussed below.

Vegetation Elements and Their Contribution to Climate Adaptation

Vegetation elements in urban green and open spaces are an effective and efficient measure to reduce heat due to their shading and evapotranspiration [47,48]. How high the evapotranspiration capacity of the vegetation is at the respective location depends not only on the plant species itself but also on the prevalent meteorological and microclimate conditions (especially temperature and wind), the water supply to the plants and their soils, and the sum of the leaf surfaces [49]. The influence of location was shown in the results of measurements of the cooling performance of plantings in open spaces in a green strip compared with plantings next to paved, narrow open spaces. The cooling capacity at the planted site is 20% higher than at the narrow, paved site [19]. Cooling capacity through planting also depends essentially on the location, orientation, and dimensioning of the street space or square as well as the interaction with the shading of the neighbouring buildings.

A narrow street cross-section with high adjacent buildings can lead to a weakening of nocturnal cooling due to the higher sky-view factor, despite the shadow effect of the buildings and vegetation [48,50]. Orientation and width, as well as the prevailing site conditions of the streets and squares, determine which vegetation measures are successful at which locations for shading and cooling. In the case of complex street cross-sections and squares, it is recommended to consult landscape planners and architects as well as use microclimatic simulations. Furthermore, vegetation in open spaces on the street and in squares, also by greening, increases the quality of stay and supports rainwater management as well as biodiversity.

Elements for Rainwater Management and Their Contribution to Climate Adaptation

In the area of rainwater management, we took a look at the sponge city principle for tree measures, infiltration with soil filters, above-ground retention and storage channels, as well as surface drainage, watercourses, and gutters. The challenge in the urban environment is the high degree of sealing in public spaces. As a result, streets and squares are flooded, e.g., during heavy rain events [51]. There are attempts to prevent this by directing rainwater into the sewage system. The aim is to reduce surface rainwater runoff in cities (or at least to delay it so as not to overload the sewage system and rivers) [52]. There are attempts to prevent this by directing rainwater into the sewage system. The aim is to reduce surface rainwater runoff in cities (or at least to delay it so as not to overload the sewage system and rivers) [52] and to provide water for vegetation during periods of increasing heat and drought. A positive example from the city of Vienna is the so-called "Vienna dual system" of the "sponge city principle for trees". Here, rainwater is fed directly into the root zone on site and stored temporarily while at the same time making it available to plants. A special feature of the dual system is that, in the case of high road salt loads in winter, the surface water is fed into the combined sewer. Infiltration via soil filters is also well suited for urban public green and open spaces.

Water Elements and Their Contribution to Climate Adaptation

The main purpose of water elements in urban public open spaces is to improve quality of stay in hot weather by reducing heat stress or people's perception of it through the water itself [53]. They are used by citizens for playing, having a sensory experience, cooling down, or drinking [54]. Measures that were identified as climate-relevant are: water features, misting systems (permanent and temporary misting systems), drinking fountains (stationary and mobile drinking fountains), and water basins. Depending on their design, water elements are permanent or temporary, fixed or mobile. In Vienna, for example, stationary drinking fountains are supplemented with mobile systems in the summer to supply the Viennese and tourists with drinking water. Their climate-relevant effect is limited to improving the quality of stay. There is no influence on the microclimate because of the small volume of water [49]. Classical water basins and fountains are often located as classical design elements with low cooling via the evaporation effect in the absence of planting. Water features can be used for playing and cooling down. In the summer months of recent years, Vienna in particular has focused, especially in densely built-up urban areas, on the adiabatic cooling effect of open spaces through misting systems that are fixed, mobile, or temporary. These are fed by drinking water. The local cooling effect is maximised when they are installed next to trees (up to max. 10 °C) [19].

Surface Materials and Their Contribution to Climate Adaptation

The group of surface materials does not belong to the UGBI, but it is a technical measure that has an essential influence on climate adaptation. Factors such as function, service life, usage properties, and costs, but also ecological sustainability, are decisive for the choice of surface material [19]. Not only the production itself but also long-distance transport can have a negative impact on the energy balance [55]. Local and regional materials should be used in preference. In this article, bituminous pavements, concrete pavements, slabbed or paved surfaces, mineral pavements, water-bound pavements, and gravel lawns were evaluated. Pavements, as they are often used in Vienna, had already been assessed and developed according to ecological criteria before this project (Project "Nachhaltigkeitsbewertung von Wegebelägen", "Richtlinie für Bodenbeläge im Freiraum—Planung" [40]). The result shows that bituminous pavements and bituminous concrete pavements have a poor environmental balance. Poured asphalt pavements have twice the carbon footprint of concrete pavements laid in sand. The choice of surface materials and their properties has a great influence on heat load and rainwater management. Properties such as heat storage capacity and albedo strongly influence heat development in streets and on squares [56,57]. The higher the heat storage capacity and the darker the surface, the more heat is stored when exposed to sunlight and released at night [50]. The highest possible water permeability of the surface materials used, measured by the runoff coefficient, supports the availability of water to plants.

Shading Elements and Their Contribution to Climate Adaptation

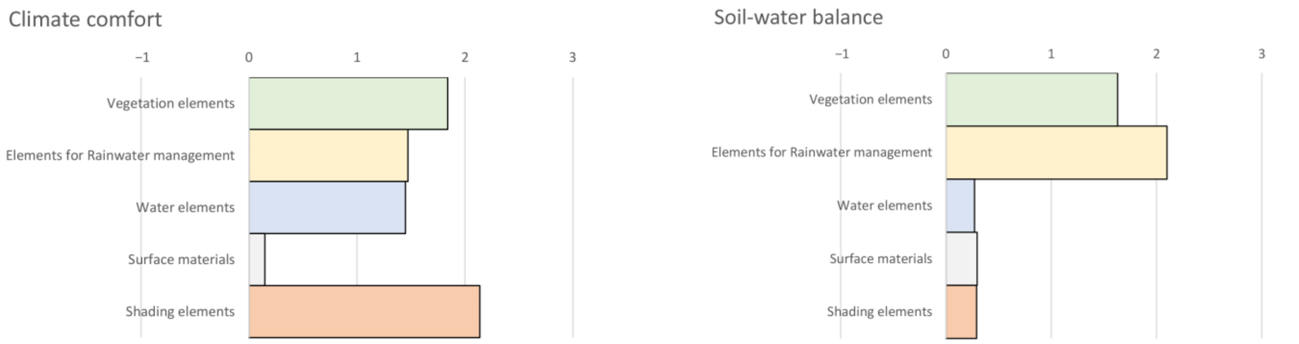
Urban squares and open street spaces can only be used in the summer months if there is sufficient shade. Where tree planting is not possible, shading elements, such as pergolas or shade roofs (ideally planted to increase their effect), street greenings, or textile sunshades, can help. A brief look at Vienna shows that there are currently no standard shading elements, as this topic has only become relevant in recent years. In particular, the shading of open spaces in streets using shading elements often raises legal and technical questions due to the large surface area, e.g., regarding wind load [19].

3.2.2. Results of the Assessment Process of Climate-Relevant Measures—The View of Experts from Science and Practice

As already described in Section 2, after the definition of climate-relevant measures and their assessment criteria, they were assessed by 23 experts according to the defined criteria. In the following section, the results of the multi-criteria assessment process by practitioners and researchers, classified according to the assessment categories, are discussed in more detail, and individual significant results are presented.

(Micro) Climate Adaptation

As shown in Figure 3a, shading elements are considered to have a significant effect on climate comfort, especially by the research group. For both groups of evaluators, vegetation elements and rainwater management elements have a strong positive influence on microclimate. Besides vegetation elements such as trees, tree pits, and shrubs, the sponge city principle and infiltration with soil filters have a positive effect on climate comfort and soil–water balance (Figure 3a,b). In general, surface materials, with the exception of gravel lawns, are considered to have a low micro-climatic effect, and researchers rate surface materials as tending towards deterioration.



(**a**) (**b**)

Figure 3. Assessment of (micro) climate adaptation (**a**) Climate comfort; (**b**) Soil water balance.

Ecological Sustainability

Biodiversity is generally supported by vegetation elements and green elements (Figure 4). The use of trees is seen as having a particularly positive effect on biodiversity. The evaluators rated surface materials such as bituminous, concrete, and mineral pavements as having a deteriorating effect. The exception is gravel lawn, which is seen as supporting biodiversity due to its permeability.

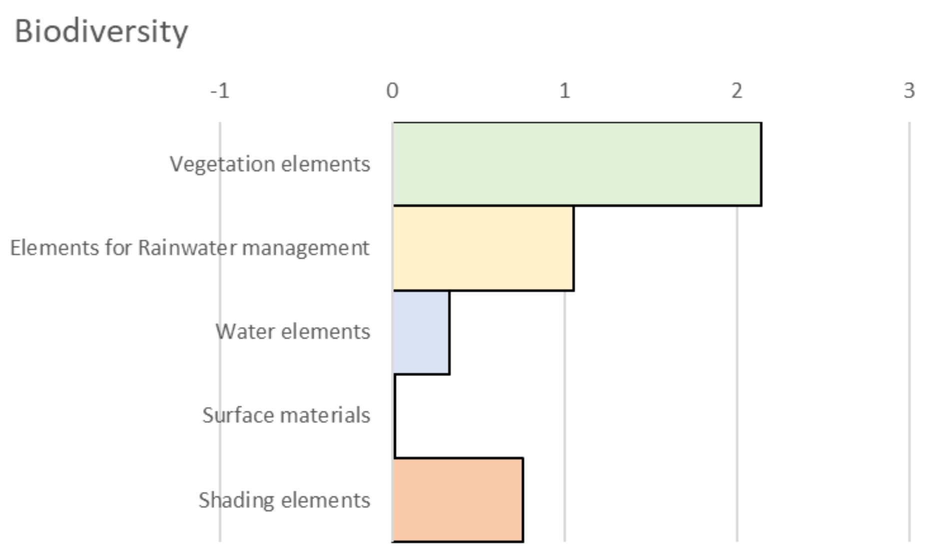


Figure 4. Assessment of ecological sustainability biodiversity.

Social Sustainability

The quality of stay as well as the effect on the physical and mental health of users are positively influenced by vegetation elements, water elements, and shading elements (Figure 5a,b). According to the evaluators, the use of bituminous and concrete pavements has a negative impact on the quality of stay. According to the researchers, elements for rainwater management have a higher positive influence on quality of stay than the practitioners see.

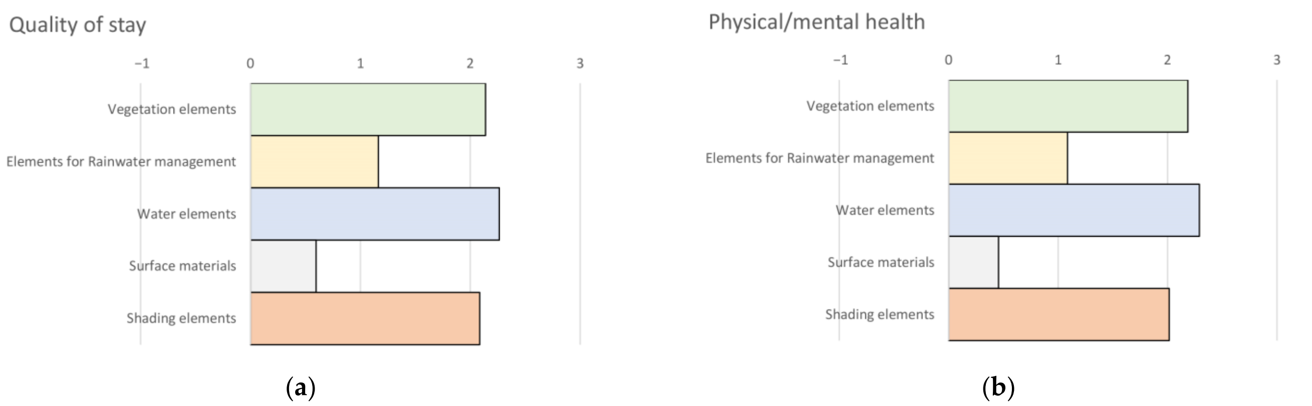
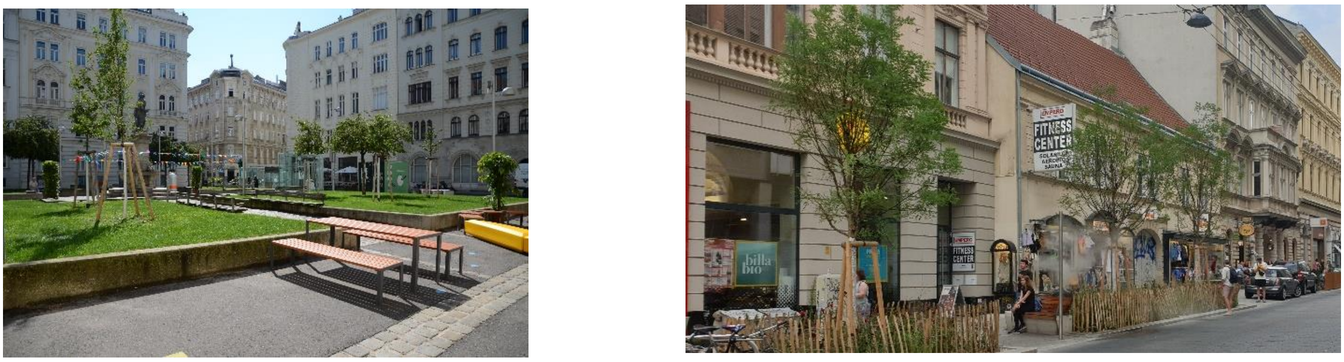


Figure 5. Assessment of social sustainability (**a**) Quality of stay; (**b**) Physical/mental health.

Tree as Adaptation Element

In the following, trees as a vegetation element and their climate-relevant effects will be described in more detail (Figure 6a,b).



(**a**) (**b**)

Figure 6. Tree (**a**) Schlesingerplatz (Josefstadt, Wien); (**b**) Neubaugasse (Neubau, Vienna).

The tree is, as both science and practice confirm, a design element that provides adaptation services on a microclimatic, ecological, and social level, as already described (see Section "Vegetation elements and their contribution to climate change adaptation"). The impact depends on the size, quality, type, and location of the planting. The fact that trees make an important contribution to biodiversity and serve as habitat, depending on the type of tree, has been demonstrated [58,59]. From a microclimate perspective, trees play an important role due to their cooling capacity through evapotranspiration and shading. Surface temperature can be reduced by up to 12–20 °C through the shading effect [60,61] and air temperature by up to 2.6 °C through evapotranspiration [62]. The combination of tree planting with the sponge city principle optimises the effect of both adaptation measures at all levels.

From a social point of view, the presence of trees increases the quality of the open space along the street or in the square. They serve as a design and natural element. On the one hand, as already mentioned, trees are one of the most effective measures for heat reduction, and alternatively, they contribute to perceived noise reduction [13]. Trees absorb high-frequency noise very well. At the same time, people perceive noise less strongly if the noise source is not visually apparent due to greenery. The denser the association, the more effective the noise reduction [63,64]. The high filtering capacity of air pollutants and the dust-binding capacity of urban trees have a positive effect on humans and animals (Table 3).

Table 3. Climate-relevant services of the trees.

(Micro) Climate Adaptation		**Ecological Sustainability**	**Social Sustainability**	
Climate comfort	Soil-water balance	Biodiversity	Quality of stay	Physical/ mental health
Cooling capacity and shading Filtering of air pollutants Dust binding		Given habitat [58]	Cooling capacity and shading Perceived noise reduction [11,13] Filtering of air pollutants Dust binding	

Depending on whether deciduous or evergreen trees are used, the effect of these on the surroundings also changes. The advantage of deciduous trees is a reduction of the shading effect and the presence of light in the open space and neighbouring buildings in the winter months. The cooling capacity of trees (and vegetation in general) in very narrow street cross-sections must also be critically considered (see Section "Vegetation elements and their contribution to climate-change adaptation"). If trees are planted too densely, a reduction in long-wave radiation can lead to a weakening of night-time cooling [50,59]. Alternatively, ground-level vegetation, façade greening, or free-standing planting frames can be used to replace or supplement rows of trees, even if there is no space for them. Like all adaptation measures in the guideline, the tree, used in combination with other elements, makes the greatest contribution to a sustainable urban street space or square. Designed tree pits, water-permeable surface materials, a combination with rainwater management elements, or placement next to misting systems or water features, support the life and health of the urban tree, and at the same time, increase the joint ES effect.

Water Feature as Water Element

The design element of the water feature will now be described in more detail (Figure 7a,b).

(**a**) (**b**)

Figure 7. Water feature (**a**) Johann-Nepomuk-Berger-Platz (Ottakring, Vienna); (**b**) Wallensteinplatz (Brigittenau, Vienna).

The adaptation measure water feature is rated positively, especially in the social sustainability category. Water features are mainly used by children and young people as a way to play and cool down. Designs with integrated floor jets increase the play value and also offer a high entertainment and performance value for watching adults through changing water images. On the one hand, barrier-free design enables the use of the feature with aids such as wheelchairs, and on the other hand, the area of the feature can be used for other purposes outside operating hours. In general, this measure also has a positive effect on people's psyche due to the presence of water [65]. From a climate point of view, water features cool the nearby environment through water droplets and evaporative cooling. The cooling effect of the water feature has a direct impact on the ground in the streets and squares. When constructing water features, a number of points need to be mentioned. Excessively long drainage sections provide an additional play experience, but must be strictly controlled in terms of hygiene. Additionally, daily flushing and inspections must be carried out to minimise hygiene risks. The wind situation on site also plays an important role: any wind shear must be considered even in the planning, and the heights of the fountains must be adjusted. In order to ensure the safety of the feature's users, the surfaces of the water feature must have good grip. In terms of biodiversity, water features play a subordinate role. In some cases, they serve as watering places for animals such as dogs, birds, or insects [19]. A combination of this design element with other climate-relevant measures, such as the sponge city principle for trees, also makes sense. The use of water features can result in high water consumption. The water that runs off can be used to irrigate trees. Another positive aspect is that the water features mostly use water synchronously with irrigation demand (during summer heat periods). If water from the water features is fed into the sponge city, there is also an effect on the soil–water balance (Table 4).

Table 4. Climate-relevant services of the water features.

(Micro) Climate Adaptation		Ecological Sustainability	Social Sustainability	
Climate comfort	Soil-water balance	Biodiversity	Quality of stay	Physical/ mental health
Cooling capacity (direct ground) Cooling capacity (environment through water droplets and evaporative cooling) Dust binding		Watering place for animals (e.g., birds, dogs)	Cooling capacity Dust binding Design element Play area	

The original project management expectation that the climate-relevant element group vegetation, in particular the tree, is to be classified as the most favourable adaptation measure with a clearly positive influence on all assessment categories and the greatest potential, was confirmed by the assessment participants from research and practice (Figure 8a). In general, the presence of green has a positive impact on the assessment of the design elements. If it is supposed that adaptation measures such as water basins are planted, the rating in all categories is much better than if there is no planting. In this case, the evaluators noted, the effect of the design element on climate comfort and soil–water balance decreased. On an ecological level, too, water elements supplemented by greenery perform best.

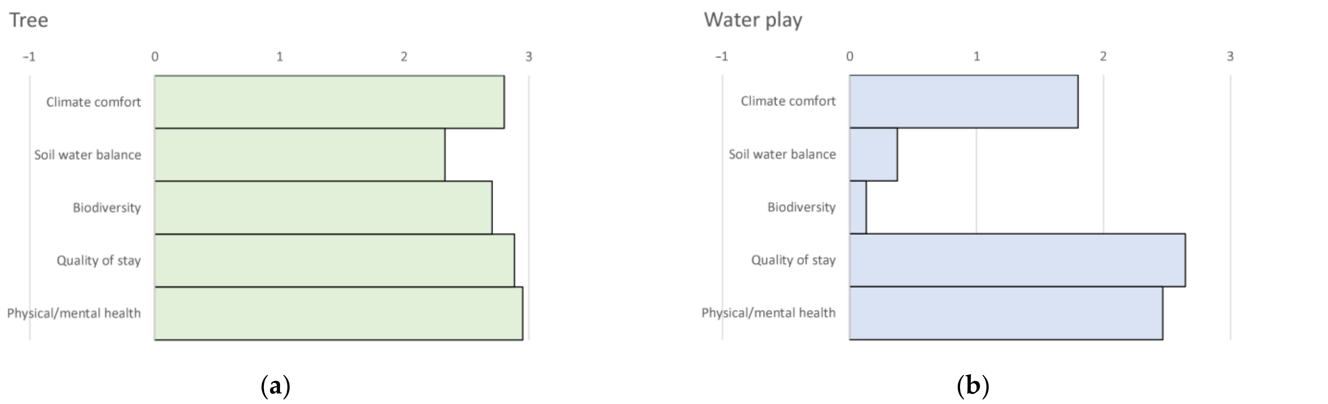
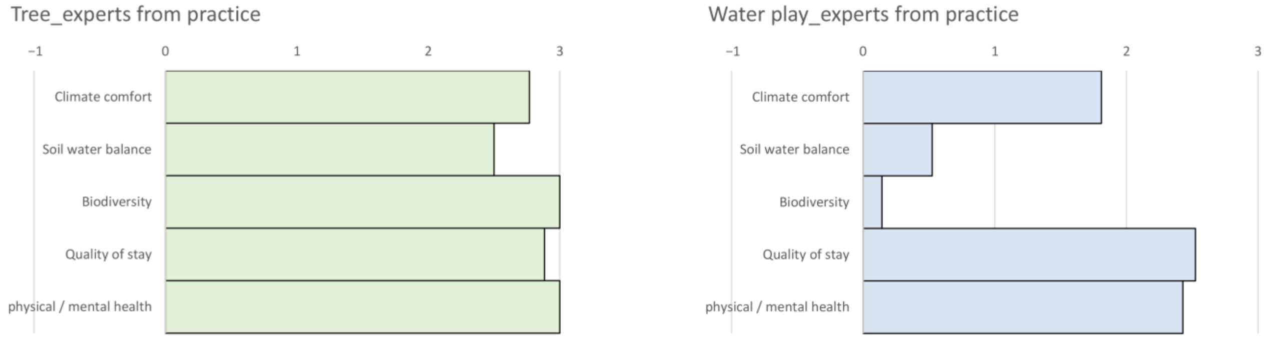


Figure 8. Experts from practice and academic research: combined assessment of (**a**) tree; (**b**) water play.

In social terms, the combination of "blue and green" (water and planting) has the highest impact. Figure 8 shows that the tree (urban green infrastructure) (a) and water play (urban blue infrastructure) (b) are rated highly in the categories "Quality of stay" and "Physical/mental health". According to the evaluators, the shading elements seen as positive for social sustainability are also enhanced by greenery.

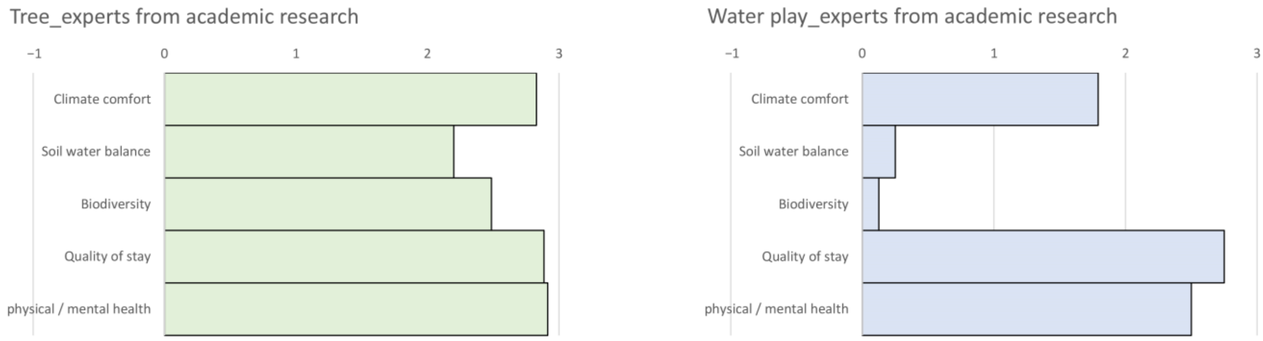
The impact of surface materials such as bituminous and concrete pavements is consistently rated as low by the experts in research and practice and, in some cases, as negative. Exceptions are gravel lawns and slabbed or paved surfaces. Due to their permeability and the possibility of small habitats, e.g., in joints, these are considered to have a certain degree of performance. According to the evaluators, the accessibility of these surface materials should be considered.

It was analysed to see if there were significant differences between the researchers' results and the practitioners' evaluations. In general, the results are consistent. Figures 9a and 10a compare the results of the assessment of the tree element by academic research and experts from practice. It can be seen that both groups have a consistently positive view of the tree's services. There are small differences in the biodiversity assessment category. The biodiversity of trees was rated lower by researchers than by practitioners. The second example is the water element's water play (Figures 9b and 10b). For this element, the rating differs in the area of soil–water balance, which is rated more positively by practitioners, and in the area of quality of stay. The quality of stay is rated more positively by the researchers.



(**a**) (**b**)

Figure 9. Experts from practice: assessment of (**a**) tree; (**b**) water play.



(**a**) (**b**)

Figure 10. Experts from academic research: assessment of (**a**) tree; (**b**) water play.

General information on the individual climate-relevant element groups: In detail, the shading elements were considered to have a more positive effect on climate comfort by the researchers than by the practitioners. This was justified, among other things, by the fact that shading is essential for the prevailing microclimate. Experts from the city of Vienna rated it as even more crucial than the experts from academic research. Practitioners rated the microclimate performance of the vegetation elements and elements for rainwater management higher. In particular, according to them, the combination of different elemental measures, such as tree and sponge city, would be preferable. With regard to social sustainability, differences emerged in the area of surface materials. Surface measures were clearly attributed a more positive effect by the practice side than by the research. This was justified by the possibilities of using the areas as playgrounds and sports fields and their given accessibility.

4. Discussion

In this section, the added value as well as limitations and challenges of the methodological framework and the transdisciplinary approach are presented and discussed.

4.1. Addded Value, Limitations, and Challenge of the Methodological Framework

The added value of the developed methodological framework relates to quality assurance. The methodological framework supports the appropriate use of climate-relevant measures for the specific site.

In the methodological framework, the selection of design elements was not based on generally existing elements. The selection was made inductively. Specific adaptation measures already implemented in the project area, the city of Vienna, or planned measures suitable for this location in the future were selected. The advantage of this is that employees of the city of Vienna and participants working in Vienna who were involved in the framework itself but also in the multi-criteria assessment contributed to a certain amount of basic knowledge and experience of the individual design elements to the process. This knowledge base, which was already available at the beginning of the project, had a positive effect on the entire process of the project. If one has already gained experience with specific climate-relevant measures and can actively bring that experience into the process, this supports the participants' identification with the project. It is also assumed that people from practice who were actively involved in the entire process of the methodological framework identify with the project itself, as well as with the design elements. Participants from the city of Vienna (administration) can therefore play an essential role in the implementation and application of the guidelines in Vienna [66]. The developed guideline can support Vienna city employees in decision-making and argumentation for the choice of certain (green) climate-relevant measures with planners and other institutions in practice, with the aim of creating better-planned sustainable streets and places, independent of political calculations. However, the inductive approach to the selection of adaptation measures also holds challenges. Specifically, the adaptation of the methodological framework to other cities (see Section 5).

The assessment is a challenging part of the framework. The challenge lies on the one hand in the different background knowledge of the assessors and on the other hand in the difficulty of the comprehensive assess ability of the ES [41]. In order to deal with the first challenge, clarity, transparency, and comprehensibility are important factors in the preparation of the assessment document. The scope of the assessment and therefore the time required must be adapted to the time and background knowledge of the person doing the assessment. As is already known, ES is a complex topic that is difficult to assess. To counteract this, the criteria to be assessed and specific adaptation measures are concentrated on the Vienna project area, and a multicriteria assessment is used.

Another challenge concerns the design elements to be assessed. Vegetation elements in general are subject to constant change. Depending on the tree species, age, size, or quality, and their arrangement/association, their impact (intensity) also changes. For example, newly planted trees have little effect on climate comfort at this point in time, but a positive effect can be expected in the future. Adaptation measures also influence each other. For instance, if a tree is planted in combination with the sponge city principle, the positive effect on rainwater management is stronger than if the tree is planted on a narrow green strip along a busy road.

In summary, it must always be kept in mind that a climate-relevant measure never works alone but is always in context with its environment and other measures. This must be included in the assessment process as much as possible. The opportunity for qualitative assessment of the adaptation measures and the assessment criteria also supports this.

The aim is to obtain a good overview of the impact of the individual design elements, despite the incompleteness of the assessment criteria and inconsistencies with the modifications of the adaptation measures.

4.2. Added Value, Limitations, and Challenges of the Transdisciplinary Process

The paper deals with the question of the added value of involving people from academic science and practice, as well as from different disciplines, throughout the entire development process and right from the start. Furthermore, the limitations and challenges of the application of co-creation are discussed.

Even in the selection of assessment criteria and potential climate-relevant measures, a broad knowledge base was created through the networking and collection of knowledge from diverse participants. All participants contribute their specific knowledge and individual experiences. The quality of the developed multi-criteria assessment was directly influenced by the early involvement of different stakeholders and the coordination with and review by the various disciplines. In this way, any inconsistencies and contradictions could be discussed and eliminated in advance.

It has been shown that, especially in a transdisciplinary process, the definition of the framework is important. A common "language" has to be found [29]. As in the project this article is about, the participants came from different fields and disciplines and contributed different perspectives on the topics due to their practice or research orientation; a common knowledge base is the basis for collaboration. During the assessment process, the validity of the results was further supported by a low score and the use of the confidence score [29]. If there is international collaboration or if the assessment process is international, it must also be taken into account that topics such as legal requirements are country-specific, and therefore, on the one hand, it must be defined in advance to which country/location the work refers, and on the other hand, this knowledge cannot be questioned by people who are not familiar with the location.

An important limiting factor in co-creation processes is time. The time budget of the project team, but also of the researchers and practitioners involved in this project, set the framework for the research. It must be planned well in advance how much time can actually be made available by the people involved. In the project described in this article, the time factor mainly affected the assessment process. When creating the assessment scheme, a lot of attention was focused on ensuring that the assessment itself did not take more than 1.5 h for the evaluators, as previous experience from other projects has shown that the more time required, the lower the return rate of completed assessment forms. An increased time allotment would have a positive effect on the level of detail of the measures. The involvement of more researchers and practitioners would also have been an advantage. Language has been a further limiting factor in this research. As the project was based in Vienna, German was the main language used. The assessment process was also organised in German, limiting the participants to German-speaking researchers and practitioners. Translation of the project documents would support more detailed research.

Despite limiting factors, the application of co-creation led to increased identification of participants with the project, thereby contributing to more active implementation of the results in the specific case of this project: climate-relevant measures [66].

5. Conclusions

Due to their large surface area and multi-functionality, especially in densely built-up urban areas, street spaces and squares are increasingly coming into focus as places for climate-relevant measures and as a possible open space for living sustainability.

The methodological framework that has been developed can be applied in order to finally be able to select the right climate-relevant measures for a specific location. As has already been mentioned, the current framework has been designed for the city of Vienna. Its outcome is the described guideline, with the results being continuously discussed and tested with employees of the city of Vienna in terms of opportunities for its implementation. The guideline brings together knowledge on the adaptation performance of different design elements and the technical and legal framework conditions for implementation from diverse departments of the city of Vienna and European experts. It is a contribution to knowledge brokerage within the city of Vienna. In the short term, the guideline is used as a guide to the selection of design elements for urban open spaces and to support city employees in justifying the creation of climate-fit streets and squares. The implementation of climate change adaptation in streets and squares will thus be accelerated and facilitated. In the long term, it will serve as a basis for the development of a further steering tool, securing the quality of climate adaptation for the public good. However, this requires adaptations of the guideline depending on the structural-spatial, social, and climatic conditions of the site of use. Only the careful application of individual, optimised local measures in the guidelines can lead to sustainable streets and squares of adequate quality. Integration or combination with other city of Vienna strategies is preferable. In order to be able to use the catalogue of climate-relevant measures as a basis for further tools, the adaptation measures themselves as well as the assessment and framework conditions of the measures must be continuously updated and, where necessary, supplemented. Details on the implementation of the adaptation measures in practice, such as the selection of tree species and sizes, have not been dealt with in detail in the guideline and are subject to the advice of experts in the appropriate departments.

The methodological framework itself can be used, after site-specific adaptations (structural-/spatial, social, climatic, etc.), to support the development of guidelines for other cities.

After translating and transfering the Vienna methodological framework with the developed design elements and assessment criteria into the respective national language, it is recommended to check, in the form of a co-creation process with experts of the appropriate city, whether and to what extent the criteria and adaptation measures applied in Vienna are compatible. Especially with respect to legal and technical framework conditions, there are major country-specific differences that would have to be revised in advance by users.

Cities benefit from know-how already gathered from administration, practice, and research in recent years in the city of Vienna and international networks, and can build on this knowledge. The adapted methodological framework can then be used as a basis for discussion on the application of UGBI in the open space of streets and squares.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su15043775/s1, Figure S1: Methodological framework, Table S1: Viennese case studies of streets and squares.

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