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Participatory Design of Urban Green Spaces to Improve Residents' Health

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Abstract: Urban green space (UGS) has important impacts on human health, but an integrated participatory approach to UGS design for improved residents' health has been lacking to date. The aim of our study was to develop and evaluate such a novel approach to address this gap. The approach was developed following guiding principles from the literature and tested with groups of children and elderly as participants in two neighborhoods of Maastricht (The Netherlands) with a low score in economic and health indicators. The novel aspects of the approach are the inclusion of both positive and negative health effects, the combination of resident self-assessment and model-based assessment of the health effects of UGS designs, and the use of maps to visualize UGS designs and health effects. The participant-generated UGS designs resulted in a considerable (up to fourfold) self-assessed increase in the use of the UGSs for meeting, stress reduction, and leisure-based physical activity as compared to the current situation. The model-assessed positive and negative health effects of the participant-generated UGS designs were limited: heat stress slightly decreased (by 0.1 °C), active transport slightly increased (by 30 m per day), and the perceived unsafety slightly increased (8%). The effects on unattractive views, air pollution, tick bite risk, and traffic unsafety were negligible. The major strength of this approach is that it combines active participation of residents in UGS (re)design with assessment of the health effects of these UGS designs. While in other participatory approaches to UGS design, it often remains unclear whether the resulting designs represent an improvement in terms of health, our combination of computer model-based assessment and a participatory process produced clear outcomes regarding the health benefits and use of UGS designs. A major recommendation for improvement is to involve decision makers already in the initial steps of the approach.

Keywords: spatial model; urban green space; human health; ecosystem services; ecosystem disservices; participatory design; GIS; quantitative assessment

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1. Introduction

The role of urban green space (UGS) in urban sustainability is widely acknowledged and studied within the broader fields of urban ecosystem services, green infrastructure, and, more recently, nature-based solutions [1–3]. In the last decade, the important role of UGS in the provision of ecosystem services for human health has been stressed in particular. The WHO regional office for Europe, for example, presented the various benefits and burdens of urban green space [4] and the effects of UGS-based interventions [5]. In the same decade, review studies have shown that strong positive relationships exist between the amount of UGS and people's health [6–16]. Practical UGS design principles for city planners to implement the result of such studies and reap the health benefits are also

available [17–20]. At the same time, it has become more common to involve citizens in the design of UGSs. This last development has the potential to 'seal the deal' by combining general UGS design principles with location-specific knowledge and the preferences of residents, and, in this way, to come up with an effective and broadly accepted UGS design for neighborhoods or cities. Another recent development is to combine a participatory approach with mapping, with which, in this context, we mean acquiring spatially explicit data, storing spatial designs, or presenting assessment results on a map. Mapping is not only useful for identifying place-specific use and valuation of public spaces, but also for spatially explicit problem identification, prioritization, and communication [21,22]. In an integrated participatory approach, maps can give participants a comprehensive overview of areas that can be redesigned or that may be affected and enable them to visually identify (spatial) opportunities and trade-offs.

Reviews and overviews of studies on participatory approaches to planning of UGS show that these studies often focus on specific aspects, for example, on the types of street design features, the types of UGS benefits assessed, or the different ways in which actors are involved [21,23–25]. An analysis of studies published in the last decade indicates that integrated approaches are not yet available (Supplementary File S1). Inclusion of multiple health benefits and the use of mapping are fairly common, but other elements of an integrated approach are often lacking. Firstly, and most importantly, this concerns the omission of health-related burdens. Secondly, impact assessments and redesign of UGS are often not included, let alone their combination: assessments of the health-related benefits and burdens of new UGS designs produced in a participatory process.

Concerning assessment of health-related impacts in a participatory approach to UGS design, it can be argued that a combination of resident (participant) self-assessments and expert- or model-based assessments would be preferable. On the one hand, UGS–health assessments based on expert judgment, measurements, and/or computer models can quantify effects that are not directly observable by residents. On the other hand, a participatory process can include subjective factors and a more accurate representation of resident exposure to UGS effects. After all, residents are the local experts of how they themselves use the UGSs of their residential surroundings, as well as on a number of health-related effects of that UGS. Examples of such effects are effects on mental health, the amount of physical activity, and social encounters with other residents, but sometimes also more biophysical effects such as heat stress. Finally, a participatory approach may lead to more involvement and perhaps even empowerment of residents and other stakeholders [26–28].

Regarding quantification of health effects of UGSs that are not directly observable by residents, several computer models exist to aid in city-scale spatial decision making. Such computer models would also benefit from being embedded in a participatory approach, as this may yield more reliable or more detailed input data. Regarding the output of the model, it could lead to better understanding of and more agreement on model results by residents and other stakeholders, which may lead to more acceptance of spatial redesign decisions. There is a vast body of literature available that describes participatory modeling approaches [29–31]. However, such approaches do not exist for the UGS–health theme, and in general, very few publications have focused on geospatial participatory modeling [32].

In sum, an integrated participatory approach to UGS design to improve residents' health is currently lacking. Key elements to be integrated are attention to health-related burdens in addition to benefits, and a focus on assessments of the health-related impacts of UGS designs using a combination of resident self-assessments and spatial modeling in addition to the use of mapping. To address this gap, the aim of our study was to develop and evaluate such an integrated, novel approach to support participatory design of UGSs to improve residents' health. The research questions following from this aim are twofold, the first more descriptive: "what are the results when implementing this approach in practice?", and the second more evaluative: "what are strengths and weaknesses of the approach?".

In the next section, we describe the development of the approach and testing in two neighborhoods in the city of Maastricht (The Netherlands), and the role of a computer

model [33] in this approach. We also explain our evaluation framework and its application to the developed approach. In the subsequent section, we report on the results of both the implemented approach and its evaluation. In the final section, we discuss the major strengths and weaknesses of the approach, provide recommendations for possible improvements and needs for further research. We end with a conclusion on the key contribution of the approach.

2. Methods

In this section, we describe the development of a novel approach to participatory design of UGSs for beneficial health effects, followed by a description of how this approach was implemented and tested.

2.1. Developing a Novel Approach for Participatory Design of Urban Green Spaces

This section describes the development of the novel approach in two phases: formulation of 'guiding principles' and translation of these principles into process steps for participatory design. The guiding principles relate to the need to assess a wide spectrum of effects (principle 1), as well as the need to assess both positive and negative health effects of urban green spaces (principle 2) and mainly stem from the stressed importance of being able to identify synergies and tradeoffs [34,35]. Guiding principles related to stimulating participants to feel personally connected to the effects (principle 3) and making impacts tangible (principle 5) were chosen because they make identification of challenges by participants less abstract, and they may advance information transfer, social learning, and idea exchange [32,36]. Guiding principles related to dividing roles in estimating health effects (principle 4) and making full use of the capabilities of the participants (principle 7) were chosen as participants may possess reliable information on expected effects and useful insights on design that are actually implementable [37–39]. The principle 'allow participants to adapt their design' (principle 6) was included because participants can in this way contribute to checking for unwanted side effects of a plan, but also because taking their possible concerns about initial results into account at an early stage may increase the likelihood that local needs and priorities are successfully met [32,40]. Finally, the principle to involve decision makers throughout the process (principle 8) was chosen because, in this case, participants can more fully understand the broader problem that decision makers would like to address [32,38].

2.1.1. Guiding Principles to Develop the Approach

1. Assess a wide spectrum of health effects of urban green spaces

It often is the broad range of health effects of UGSs that make their overall effect on health significant. Regarding mental health, systematic reviews have found strong evidence for positive relationships between the amount of UGS and perceived (self-assessed) mental health effects [14]. Stress reduction is often mentioned as a health-related benefit of UGSs. A green living environment also invites people to meet, which is important for increasing social cohesion and thus for reducing loneliness [41]. The precise mechanisms are still unclear and whether, for example, meeting can be increased with more green space. Concerning the effect of urban green space on physical activity, reviews also report positive associations, both for actual and self-reported physical activity [9,10]. Other health benefits of UGSs are stress reduction through a view of urban greenery [42]. Certain types and compositions of UGS also encourage people to travel by bicycle or on foot more often or for longer distances to destinations such as workplaces and shops, or for recreation ('active transport') [43]. This leads to, among other things, less obesity and less cardiovascular disease [44]. Examples of UGS benefits to which city residents are more passively exposed to are heat stress decreases and air pollution decreases [17,45,46]. Cooling by vegetation in cities with heat island effects leads to less heat stress and fewer deaths, especially among the elderly and during heat waves [47]. Finally, air pollution decreases through vegetation lead to fewer cardiovascular and respiratory diseases, among other effects [48,49].

In addition to representing the actual overall health effects more truthfully, there may be other advantages of a more comprehensive assessment. Local decision makers will often focus on a limited number of specific health effects that are most relevant to them, for example, based on city-specific problems or national legislation. If all or most of these effects are included in the assessment, they will consider the approach as more relevant. A similar reasoning could hold for participants of the approach such as residents.

2. Assess both positive and negative health effects of urban green spaces

UGSs can also have negative effects on human health. Vegetation in the vicinity of emissions can trap the polluted air, which can lead to more cardiovascular diseases [17]. Trees and shrubs can in some places block the view of crossing cyclists and pedestrians and thus cause traffic accidents [50]. Certain compositions of UGSs can be a suitable habitat for ticks, which are a major disease vector [51], leading to more cases of Lyme disease [52]. Finally, fear of crime in parks with less visibility, surveillance, or other features that are considered unsafe [53] can lead to other negative psychological effects. Such health-related burdens should be taken into account as well, in order to make a more balanced assessment of the (net) health effects of UGS.

3. Stimulate participants to feel personally connected to the effects of urban green space

If the participants of the approach feel personally connected to the problems and their possible solutions, they may try to understand the issues better, possibly leading to more accurate input. Moreover, their engagement in the process may increase, as well as the likelihood that they will be present at all sessions [32]. To achieve this, it is important to delimit the problem and the solutions to a scale that is still comprehensible for the participants.

4. Health effects best estimated by expert methods must be estimated by experts, and health effects best estimated by self-assessment must be estimated by participants

Some health benefits of UGSs can be achieved without conscious contact with or being within a UGS. Examples are the benefits of attractive views and active transport (mediated, respectively, through a more stress-reducing view and attenuation or drowning out of traffic noise). Examples of UGS benefits to which city residents are even more passively exposed to are heat stress decreases and air pollution decreases. A large park can cool the air up to hundreds of meters away in the city through evaporation of water [54,55]. Air at some distance to a UGS can be sheltered from air pollution, for example, along footpaths adjacent to busy roads [17]. These types of health benefits are difficult for residents to assess, and could be better assessed with expert methods, such as measurements, standardized analyses, computer models, or expert consultation.

Conversely, the extent to which health improves through stress-reducing meetings and physical activity in green space largely depends on whether residents are actually 'engaged' in that green space [8]. Appreciation of UGSs by residents and the resulting intensity of use then plays a major role in the magnitude of the health effect. These effects are harder to estimate through expert methods due to variation in personal preferences and a lack of readily available data, at least concerning appreciation and use of new UGS designs. In contrast, current or future use of a UGS design to achieve these health effects will be something that residents themselves can estimate relatively accurately.

5. Make impacts of user designs tangible for the participants

When UGSs designed by participants and users are assessed with expert methods, impacts may by default be expressed in a less intuitive metric (for example, $\mu g/m^3$ of an air pollutant) or on a spatial scale that is less relevant to the resident (for example, city-wide scale). It is therefore important to ensure that these impacts are presented to the participants so that they get a feeling for the magnitude of the impact.

6. Allow participants to adapt their design

After the participants are informed about the impact of their design, they should be given the possibility to adapt it. Adaptation may aim at, for example, reducing an undesirable health-related burden or increasing an additional health-related benefit that was not taken into account when creating the initial UGS design. This possibility may not only lead to co-design of better UGS solutions, but may also increase the acceptance of the final UGS design, for example, because the participants now have a better idea of why a certain compromise was necessary.

7. Make full use of the capabilities of the participants

Participants such as residents can not only contribute by sufficiently reliably assessing certain health effects for both the current situation and the proposed redesigned situation (principle 4), but they are also able to design desired UGS compositions that form such alternative scenarios. These two different contributions should be efficiently combined whilst guiding the participants through the steps of the participatory process.

8. Involve decision makers throughout the process

Direct involvement of decision makers (representatives of the local government responsible for urban planning) will likely be the most effective way to communicate the results of the process. In addition, decision makers may learn about the applied approach and the degree to which this approach improved the relation of the participant (e.g., resident, local entrepreneur) with the local government. Also, learning firsthand about resident-estimated use and the health effects of public spaces may be a relevant result for the decision maker. Such insights may make the decision maker more involved in the process and its follow-up as well.

2.1.2. Suggested Process Steps of the Approach

When placed in a logical order, the guiding principles take shape as the steps of a participatory process, as shown in Table 1. Guiding principles 1 and 2 about a comprehensive set of health effects were addressed in preparatory Step 1 of the approach. Stimulating personal connectedness of participants (principle 3) was addressed in Step 2 by a neighborhood walk, and in Step 3 by specifying the design session. In Step 3, more specifically, areas of interest were marked, making it easier for participants to connect places that they had visited with places on the map. The neighborhood walk also served to make participants more acquainted with the area to be assessed, and possibly trigger initial ideas of redesign. The participants were informed of these goals of the walk beforehand. Guiding principles 4 to 8 are (amongst other principles) addressed in Steps 4 to 8, respectively.

Table 1. Process steps for participatory UGS design.

Step	Name	Instruction for Facilitator of the Approach	Relates to Guiding Principle
1	Choose a set of health effects to assess and decide how to assess each health effect	Choose a wide enough spectrum of health effects. Determine which health effects are best assessed by the participants and which are best assessed by an available expert method.	1, 2 (and 8)
2	Orienting neighborhood walk	Organize a walk through the area of interest and visit all UGSs of significance.	3 (8)
3	First design session	Construct maps by drawing lines around the border of the areas of interest. Indicate—within the areas of interest—where participants can or cannot change the current situation on the map.	3 (8)
4	Pre-processing participant urban green space designs for expert assessment	Process the maps such that they are ready for expert assessment of the health benefits selected during Step 1. Consider generalizing or extrapolating designs to make the effects more clear to participants at Step 6.	4 (8)

Table 1. *Cont.*

Step	Name	Instruction for Facilitator of the Approach	Relates to Guiding Principle
5	Expert assessment for both the current UGS and UGS design situation	Perform expert assessment of the initial (participatory) UGS designs. Process the results of the expert assessment such that the difference between the current UGS situation and initial design UGS situation is clearly visible for participants; for example, only display hotspots.	5 (8)
6	Feedback meeting with participants	Present the digitized initial UGS designs and explain the health effects. Finally, give the participants the opportunity to make adjustments to their UGS design after being informed about the expert-based health benefits and burdens ('adjusted UGS design').	5, 6 (8)
7	Determine participant self-assessed score on a selection of health effects	Conduct surveys, interviews, or other methods to determine UGS usage scores for both the current UGS situation and the adjusted UGS design that includes possible adjustments made by the participants.	7, 4 (8)
-	Possibility for iteration of steps 4 to 7	Optional re-assessment of the adjusted UGS designs by expert and participants by repeating Steps 4 to 7.	6 (8)
8	Report results to local decision makers	Assessment of the final UGS designs by experts. Process the results of the expert assessment such that the difference between the current situation and the adjusted design is understandable for local decision makers. Facilitate an interactive session with the local government.	8

During the expert assessment of Step 5, the assessment method would be more suitable if the effect of spatial factors other than UGS (such as location and composition of buildings and infrastructure) can be estimated as well. This is because residents may add elements in their design which are not UGS, but which they do consider important for their well-being or for their motivation to participate. Similarly, experts may consider non-UGS adaptations to be necessary to realize participant UGS designs. If in Step 5 there are no threshold values available to distinguish what is and what is not a health-relevant benefit or burden, then 'health impact hotspots' within the areas of interest can be selected: areas with the lowest benefit and highest burden values for each of the health-related benefits and burdens assessed by the expert method.

Note that between Step 7 (participant self-assessed health score) and Step 8 (report results to local decision makers), there is the option to iterate Steps 4 to 7 and thus reassess the neighborhood designs after correction. This iteration would place a stronger emphasis on guiding principle 6 (possibility for participants to adapt their design).

2.2. Testing the Developed Approach in Two Neighborhoods of Maastricht

This section describes the neighborhood selection process, the implementation of the developed approach in the selected neighborhoods and the development of a framework to evaluate the approach.

2.2.1. Selecting Neighborhoods, Focus Areas, and Participants

Certain groups appear to benefit more from nearby green spaces than others. This applies to children, young people, and the elderly [56]. Reasons for this include that these population groups are more vulnerable, and that they spend on average more time in their immediate living environment. Also, people with a low socio-economic status appear to benefit more from nearby green spaces. They are more likely to have an unhealthy lifestyle, which means that more health benefits can be achieved in this group [4]. We selected

two of the most vulnerable neighborhoods in Maastricht. The selection was made on the basis of socio-economic status, the health of the residents, and the amount of green space in the neighborhood (Box 1). For 27 neighborhoods within the built-up area of Maastricht, the values of the various indicators were summed (Supplementary File S2). Two neighborhoods (Figure 1) were chosen that score low in both socio-economic status and health. Pottenberg as well as Wittevrouwenveld are within the worst scoring 20% of neighborhoods within the city of Maastricht for indicators such as income per resident, risk of anxiety disorder, self-assessed health, loneliness, and overweight. They were also chosen as they vary considerably in the amount of green space; Pottenberg has relatively much more green space, and Wittevrouwenveld has relatively little green space. Moreover, one neighborhood is located in Maastricht-East (Pottenberg) and one in Maastricht-West (Wittevrouwenveld).

Box 1. Indicators used to select neighborhoods in Maastricht. High values of the socio-economic status and health indicators increase the chance of neighborhood selection. Data sources: 1 = CBS [57], 2 = GGD Zuid Limburg [58] (Health Monitor Adults and Elderly 2016, data 19+).

1. **Socio-economic status**
   - % Households below the social minimum [1]
   - % Households with a social assistance benefit (allowance) [1]
   - % Households that have difficulty getting by (making ends meet, self-assessed) [2]
   - Average income per resident (value inverted for scoring) [1]
2. **Health**
   - % At risk of an anxiety disorder [2]
   - % Good perceived health (self-assessed, value inverted for scoring) [2]
   - % Socially excluded [2]
   - % Lonely [2]
   - % Overweight [2]



Figure 1. Overview maps of Wittevrouwenveld (**left**) and Pottenberg (**right**) neighborhoods, showing the neighborhood boundary, buffer zone (of 500 m) around the neighborhood, locations where the participants meet, and the focus areas. Aerial photo: Beeldmateriaal Nederland [59].

After selecting the neighborhoods, we focused on the target groups of children and the elderly within these neighborhoods. We investigated which primary schools, children's activities, clubs, and organized activities for the elderly exist in these neighborhoods. In each neighborhood, at least one children's group and a group of adults were selected and found willing to participate in the study (Table 2). Seven focus areas were then determined for each selected neighborhood. These are somewhat larger public areas that could be 'greened' or where adaptation of the existing green space was possible.

Table 2. Participant information.

Neighborhood of Most Participants *	Group	Number of Participants	Average Age (Year)
Pottenberg	Elementary school	9	11
Pottenberg	Scouts	10	7
Pottenberg	Seniors social meeting group	12	80
Wittevrouwenveld	Elementary school	6	11
Wittevrouwenveld	Seniors social meeting group	5	55

* In some cases, participants lived around these neighborhoods.

2.2.2. Implementation of the Developed Approach in Two Neighborhoods of Maastricht

Step 1: choose a set of health effects to assess and decide how to assess each health effect

For testing the approach, we report on a selection of seven health-related benefits and four health-related burdens and their related ecosystem service (Table 3). We assumed that the following of these health determinants are best estimated by computer modeling: the benefits of 'air pollution decreases' and 'active transport', as well as the burdens of 'air pollution increases' and 'tick bite increases'. Furthermore, we assumed that specifically for *new* UGS designs, the benefits of 'decreased heat stress' and 'decreased unattractive views', as well as the burdens of 'increased perceived (social) unsafety' and 'traffic accident increases' are also difficult to assess by residents and are best estimated via computer modeling. With a computer model [33], we planned to make a quantitative estimate of the current state of benefits and burdens as well as the change therein based on the initial UGS designs (Step 5). Conversely, we assumed that residents best estimate the following health effects of both current and new UGS design: the benefits of 'meeting opportunities', 'leisure-based physical activity', and 'stress reduction opportunities'.

Table 3. Overview of health-related benefits and burdens of urban green space and how they were assessed.

Urban Green Space Benefit	Indicator	Type of Assessment
Meeting opportunity increases	Area visiting frequency score 1–5 (never–daily) for use as meeting place	Resident self-assessment
Stress reduction opportunity increases	Area visiting frequency score 1–5 (never–daily) for use to relax	Resident self-assessment
Leisure-based physical activity increases	Area visiting frequency score 1–5 (never–daily) for use to sport, play or go for a stroll	Resident self-assessment
Unattractive view decreases	Unattractive views score (decrease)	Computer modeled
Heat stress decreases	Temperature (decrease)	Computer modeled
Air pollution decreases	Air pollutant concentration (decrease)	Computer modeled
Active transport increases	Walking distance (increase)	Computer modeled
Urban Green Space Burden		
Air pollution increases	Air pollutant concentration (increase)	Computer modeled
Perceived unsafety increases	Perceived social unsafety score (increase)	Computer modeled
Tick bite increases	Tick bite chance (increase)	Computer modeled
Traffic accident increases	Pedestrian invisibility (increase)	Computer modeled

Step 2: orienting neighborhood walks

In February and March 2019, we held a meeting of approximately two hours within each group individually. During this meeting, the purpose and general setup of the research were first explained. Furthermore, all participants were informed that no individual (per person) data would be recorded. Moreover, they (or, in the case of children's groups, their teachers/guides) were informed that they could leave the session whenever they pleased and were asked if they agreed to participate in the sessions. This introduction was followed by a walk of approximately 45 min through the neighborhood. Upon return to the meeting location, the participants were asked to contribute to new green space designs.

Step 3: first design session

Neighborhood maps were constructed that included a buffer zone of 500 m around the neighborhood borders. This was executed because this is the distance at which green space and other factors can still have an effect on the health benefits and burdens within a neighborhood and because the elderly and children who live on the outskirts of the neighborhood also use these places. The areas managed by the municipality where there were no buildings, water, or trees were left blank (white) on the maps, as places for possible extra UGS. These are often lawns or roads, but could also be, for example, a parking lot, football field, or playground. The UGS managed by the municipality was indicated with a green (transparent) marking, because this can possibly be 'removed' in the participants' design. Participants could (re)design the UGS by indicating on the map of the neighborhood with various materials (markers and post-its) how green spaces could be changed so that they would be used more and better for meetings, sports, play, and stress reduction. The participants' design focused on the seven preselected areas in each neighborhood, sometimes supplemented with areas that the participants themselves indicated as benefitting from a UGS redesign.

Step 4: pre-processing participant urban green space designs for expert assessment

The drawings and notes on the map, made by the participants during the design sessions, were digitally incorporated into a GIS map using the software ArcGIS 10.8.1 (Esri). Drawn or indicated trees, shrubs, herbs, flowers, grass, and paths were created as polygon features and categorized as such. In addition, drawn or indicated non-green features were also digitized: hills, bridges, and groups of natural objects (tree trunks, stepping stones). These initial designs were then spatially extrapolated within the neighborhood area and its buffer zone. This means that where areas similar to the focus areas occurred, the same design elements were added or removed.

Step 5: expert assessments of both the current urban green space and the urban green space design situation

The 'extrapolated initial neighborhood designs' (from here on called 'initial neighborhood designs') were used as input for the spatial computer model EcoMATCH. The approach followed to model the health benefits and burdens of UGSs with this computer model is documented in Oosterbroek et al. [33]. For the model application in this study, two model modules were developed in addition to the modules already described in that study: 'Active transport' and 'Traffic unsafety' modules. In line with Oosterbroek et al. [33], Supplementary File S3 presents both these modules in detail, including all parameter values and sources used. By applying this approach, the influence of the neighborhood designs on the health-related exposures as listed in Table 3 was quantitatively assessed. First, the model was run for the eight health-related benefits and burdens that were deemed best estimated by the method of computer modeling for the current UGS situation in both neighborhoods. Based on these model results, health impact hotspots were defined as areas with the 10% lowest beneficial and highest burden values for each of the eight health-related benefits and burdens. This concerns 10% of the two selected neighborhoods together. It is therefore possible that health impact hotspots related to certain benefits or burdens are only located in one of the two neighborhoods. Subsequently, the model was

run for the initial neighborhood design situation. Per health impact hotspot, changes in benefits and burdens as compared to the current UGS situation were calculated. Based on these outcomes, we created a map that displayed these hotspots, their health-related benefits and burdens, and the change in these benefits and burdens based on the initial neighborhood designs. These maps were displayed in 3D and printed to use during the feedback meeting with participants.

Step 6: feedback meeting with participants to communicate health-related benefits and burdens and adjust the design

A second meeting was held for each group of participants in June and July of 2019. During this meeting, we first presented the digitized initial neighborhood designs. Subsequently, we explained the computer-modeled health determinant values at the neighborhood level. During this meeting, the participants were given the opportunity to make adjustments to their designs after having seen the design and hearing about the modeled health benefits and burdens. In the feedback meetings, only the health impact hotspots with the largest change in health benefit or burden caused by the green design were discussed. With the elderly, for example, we discussed the hottest areas in degrees Celsius and the areas with the most cooling by UGSs in degrees Celsius. For the children, given their age (no older than 12), we translated the changes into (qualitative) infographics. These pictures showed beneficial (green) or detrimental (red) effects of their initial neighborhood designs. Participants were subsequently given the opportunity to adjust their design by drawing and commenting in the group. The resulting 'final neighborhood designs' were once more fed into the model to quantify health determinant values.

Step 7: determine participant change in urban green space use after redesign

During the feedback meeting (Step 6) a survey was conducted to determine the extent to which the focus areas were used by the participants. The participants were asked to estimate how often they would visit a certain area for meeting, relaxation, and physical activity. This was asked for the current situation as well as for the (adjusted) new design situation. The elderly were asked about the frequency of going to the area to meet people or together with others, to relax or enjoy being outside, or to get some physical activity (sport, play, go for a stroll), respectively. For children, these types of use were not distinguished, and they were asked only about their frequency of 'playing and meeting other children'. The participants could choose between 0 = no use, 1 = little use (a few times a year), 2 = medium use (a few times a month), and 3 = frequent use (a few times a day or week). Where opinions differed, the group's mean score was calculated. We refer to this method as '(resident) self-assessment'. Participants were included in the score if they lived (or used to live) in the vicinity of the focus area or regularly visited the area. (For an overview of the degree of current and intended use of the focus areas, see Supplementary File S9).

Step 8: discuss the method and results with local decision makers: the spatial planners of the municipality

After Steps 1 and 2, the selected health determinant values, neighborhoods, and participant groups were discussed with an employee of the spatial planning department of Maastricht municipality. After Step 3, the initial designs of children and elderly were also discussed with this spatial planner. Finally, after Step 7, the final neighborhood designs by the participants, the model–based assessment of the current and designed situation, and the resident self-assessment were presented to two employees of the spatial planning department of Maastricht municipality. This was achieved in the form of a dialogue, so that questions could be answered and lessons could be learnt.

2.2.3. Development and Application of An Evaluation Framework

Considering that our novel approach to participatory UGS design resembles most closely what is known as 'participatory mapping' in the literature, this body of literature was searched to identify relevant criteria for our framework to evaluate the implemented

approach. The keywords used in the literature search reflected different participatory mapping approaches, participatory mapping criteria, and participatory mapping lessons learned (Supplementary File S4). The identified criteria, categorized under 'Data quality for participants', 'Data quality by participants', 'User friendliness', 'Feasibility', 'Usefulness for decision makers', and 'Usefulness for participants' (also Supplementary File S4), were then applied to evaluate the performance of our novel approach.

3. Results

In this section, we present the results of implementing and evaluating the developed approach. Section 3.1 answers research question 1: "what are the results when implementing this approach in practice?". Section 3.2 answers research question 2: "what are strengths and weaknesses of the approach?".

3.1. Implementation of the Developed Approach in Two Neighborhoods of Maastricht

The results for seven process steps (2–8) of the approach are described in the following sections. Step 1 concerns the choice of a set of health determinants and is described in Section 2.2.

Steps 2 and 3: orienting neighborhood walk and first design session

The neighborhood walks and the design sessions showed that elderly people are generally quite satisfied with the amount and type of green space in their neighborhood. They expressed a need for more flowers, for example, on roundabouts at the entrance to the neighborhood. The elderly explained that their neighborhood is seen as a 'disadvantaged neighborhood' and that beautiful flowers in characteristic places give the neighborhood a better appearance. The elderly would also like to see more benches in the existing green spaces (especially in larger green areas, further from homes), so that they could take a rest during walks, enjoy the view, and possibly have a chat.

The children especially indicated the need for more play facilities in the green spaces, such as climbing trees, stepping stones, a zip line, hills, and football fields. The children also indicated the for need a sheltered place, out of sight of adults, to get together and chat or play. More benches (for a picnic), flowers, water, and walking paths were also often mentioned by the children. For more information about what the children and the elderly had included in their initial designs, see Supplementary File S5.

Steps 4 and 5: expert assessment of current and redesigned urban green space situation

The digitized initial green designs per group and per focus area can be found in Supplementary File S6. During the final feedback meeting of Step 6, participants made a few changes and/or additions to their UGS designs (see Supplementary File S7), which we processed into a single, final UGS design. The health-related impacts that we report on in this section concern the effects of the (adjusted) final UGS design. We extrapolated the UGS design input of the participants for all focus areas together to similar areas within the neighborhood (for Wittevrouwenveld, see Figure 2; for Pottenberg, see Supplementary File S8).

All health impact hotspots with regard to heat stress and air pollution and most hotspots with regard to unattractive views were located in the Wittevrouwenveld neighborhood (i.e., the neighborhood with the least amount of green space). However, this neighborhood is not expected to have sites with a suitable habitat for ticks. Pottenberg, on the other hand, does have such an area. The hotspot areas are shown in Figure 3, and Tables 5 and 6 compare the estimated effects of the current UGS situation with the effects of the final UGS design situation.

In Wittevrouwenveld, the current UGSs in the hottest places may provide some heat stress reductions (1.7 °C warmer than the rural area instead of 2 °C), which were made even larger by the final UGS design (1.6 °C warmer than the rural area). Increases or decreases in air pollution due to the current UGS situation were not changed by the final UGS design. Also, the benefit of decreasing unattractive views hardly changed due to the final UGS design, because the additional UGS is not in the field of view at the hotspots

of the associated health problem. With regard to active transport, there are already some 'functional UGSs' on routes, especially those routes from residential areas to shops and recreation areas. The 'play parks' and 'flower meadows' of the final UGS design make these routes more attractive, which provides slightly more predicted active transport for residents in the hotspot 'Inactive transport'. However, increases in walking due to UGSs are low, especially due to the large, less walkable distance to shops. In the current UGS situation, the overall perceived unsafety level is almost exclusively due to factors that have nothing to do with UGS, as these locations are out of sight of built-up areas and of busy roads, for example. The final UGS design does not change this much. The increased risk of traffic accidents is substantial due to current UGS (hedges and tall shrubs), but this burden does not increase with the final UGS design.

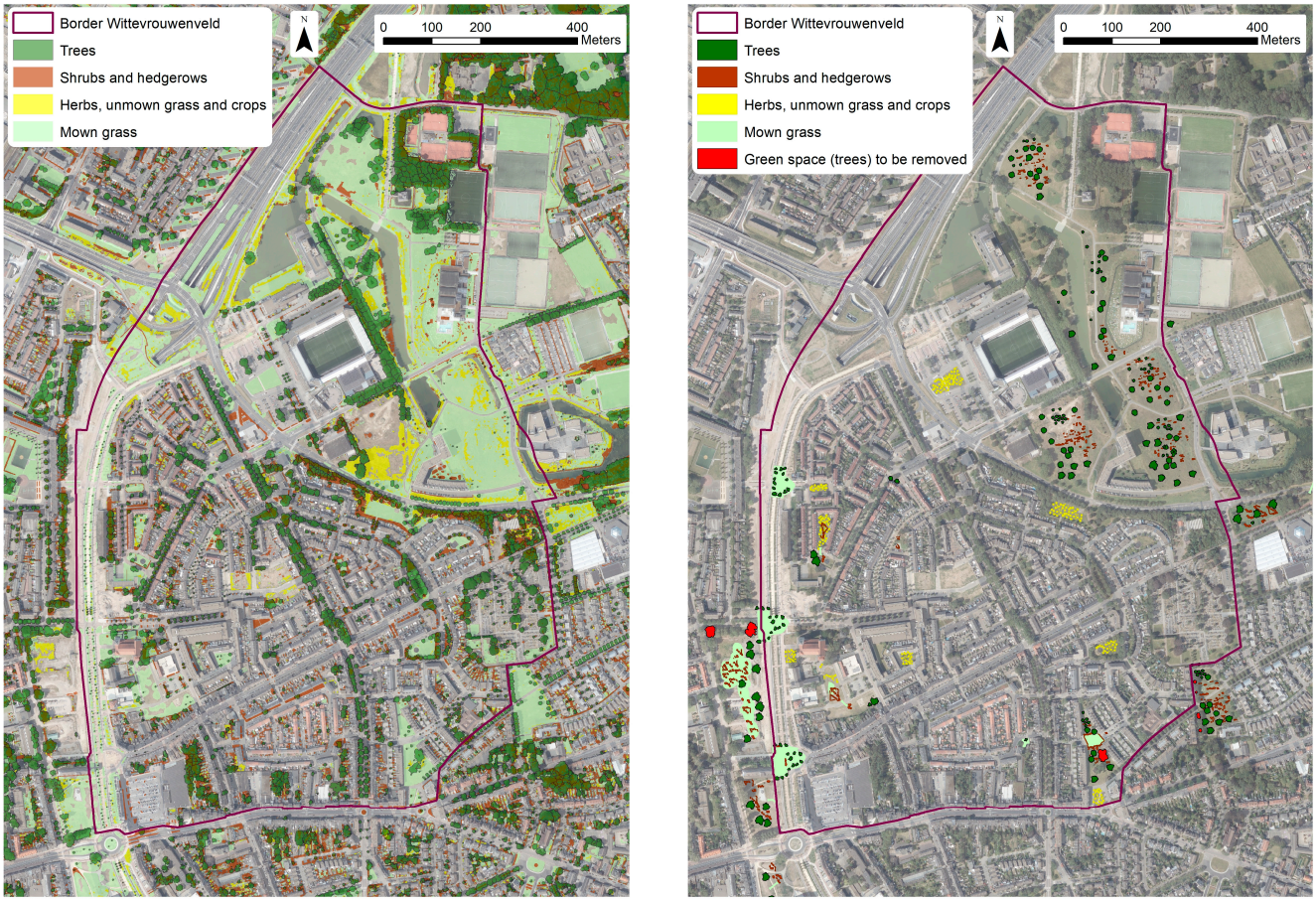


Figure 2. Current situation (**left**) and changes proposed in the final UGS design (**right**) for the 'Wittevrouwenveld' neighborhood.

For Pottenberg as a whole, it is estimated that the inhabitants already walk a bit more than in Wittevrouwenveld, which can be explained by the greener neighborhood. Specifically, for the 'Inactive transport' hotspot, however, the amount of extra walking due to UGSs is low, mainly because the west side of Pottenberg is almost a kilometer away from the nearest larger shopping center, so the model assumes that a car will often be taken from there. In contrast to Wittevrouwenveld, the current UGS in Pottenberg (due to a somewhat larger wooded park) is considered to be responsible for perceived (socially) unsafe places to a substantial extent. The final UGS design is expected to exacerbate this effect locally. Tick bite risk is not expected to increase in the final UGS design. Finally, there is only one location in Pottenberg where it is predicted that an object (a bush near a roundabout) will substantially reduce traffic safety, and the final UGS design does not create more of such places.

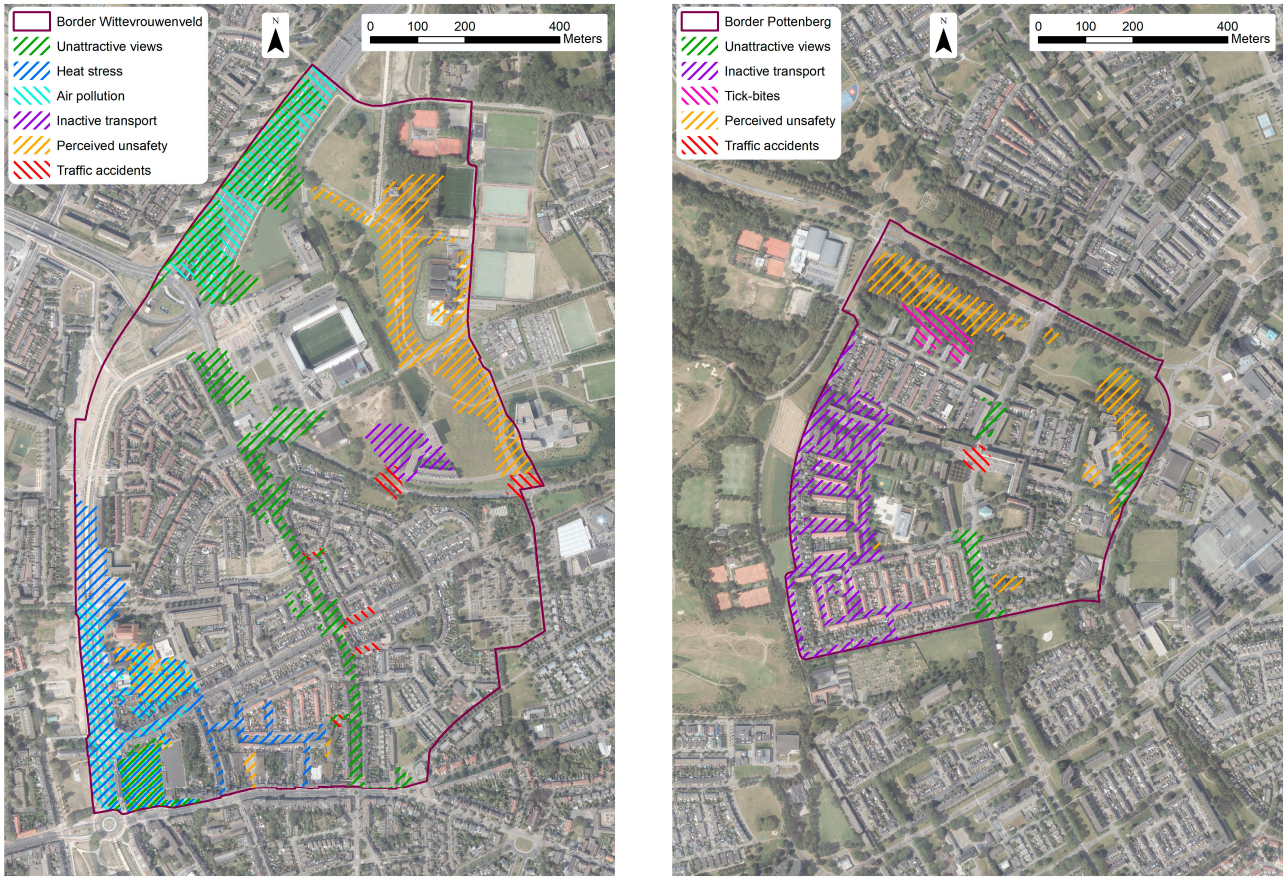


Figure 3. Wittevrouwenveld (**left**) and Pottenberg (**right**) neighborhoods with health impact hotspot locations.

Steps 6 and 7: feedback meeting with participants and determining change in use of the urban green space by the participants

Step 6 concerned the feedback meeting with participants to communicate the health-related benefits and burdens that resulted from the model assessment. After this, participants were given the opportunity to adjust the UGS design. Regarding UGS design additions, participants added some flower areas, hedgerows, and trees. Regarding UGS removal from their original UGS design, some trees were removed after participants had seen the assessment results to reduce the perceived unsafety burden, for example, trees close to each other. An overview of all specific adjustments made by participants during the feedback meetings can be found in Supplementary File S7. After that, the group of participants was asked if they all agreed on the adjusted designs, which they all did.

For the elderly, and certainly for the children, making a distinction between the use of a public area for meeting, relaxing, or sport and play was particularly difficult. We therefore did not make this distinction with the children. This observation was also reflected in the scores of these different self-assessed uses by the elderly, which showed an equal increase in the ordinal scale (see Supplementary File S9). For an overview of the survey results of focus area use and intended use per neighborhood, see Table 4 (and see Supplementary File S7 for more detail). In Pottenberg, the elderly mainly use the parks to go for a stroll and relax, and hardly to meet. For the final UGS design, the participants expected that their use would increase. For the children, the current use is less than for the elderly, but for the final UGS design, a significant increase in use was expected. In Wittevrouwenveld, the elderly also mainly use the UGS to go for a stroll and relax, and hardly to meet. Here too, the expected use increased for the final UGS design. Also, the children expected to use the UGS more after the redesign.

Table 4. Self-assessed use by participants of the focus areas for meeting and play. Both the current use and use after the redesign are shown.

Group	Current Use	Self-Assessed Expected Use after Design	Summary of Designed Elements
Elderly (n = 17)	A few times per month	A few times per week	Flowers, solitary trees, street trees, extra dog-walking areas, benches added. Bushes on roundabouts pruned for traffic safety.
Children (n = 28)	A few times per year	A few times per month to a few times per week	Climbing trees and play trees, paths, flowers, shielding shrubs, play bushes, hills, flowers, fallen trees, stepping stones added. A few trees removed (because of soccer fields, social safety, tick habitat)

Tables 5 and 6 provide an overview of the health-related benefits and burdens as assessed for the final UGS designs in both neighborhoods. The benefits of meeting opportunities, stress reduction opportunities, and leisure-based physical activity are taken together here as well. Overall, the usage scores in Wittevrouwenveld are slightly higher than in Pottenberg, both for the current situation and the designs. As indicated earlier, a considerable increase in use for meeting, stress reduction, or leisure-based physical activity was expected by residents in their final UGS designs, but the additional health benefits and especially the additional health burdens of these designs included in this study appear limited.

Table 5. Health benefits and burdens of green spaces for the final UGS design of Wittevrouwenveld.

Benefits of UGS (Intended *)	Indicator Value of Current Green Space [2]	Indicator Value after Design [2]
Meeting, stress reduction, and physical activity	Used a few times per month [1]	Used a few times per week [1]
Benefits of green space (additional *)		
Unattractive views decrease	87%	88%
Heat stress decreases	14% (or 0.3 °C) [3]	19% (or 0.4 °C) [3]
Air pollution decreases	0%	0%
Active transport increases	2% (10 m) [4]	4% (30 m) [4]
Burdens of green space (additional *)		
Air pollution increases	0%	0%
Perceived unsafety increases	3%	7%
Tick bites increase	-	-
Traffic unsafety increases	22%	22%

* Benefits as intended by the participants. Additional benefits and burdens may not have been intended. [1] The score is an average of the different groups and focus areas. [2] '-' = no value: the neighborhood did not contain any hotspot areas for benefits or burdens of green space. [3] % reduction as compared to total heat island effect. [4] extra meters walked per day.

Table 6. Health benefits and burdens of green space for the final UGS design of Pottenberg.

Benefits of UGS (Intended *)	Indicator Value of Current Green Space [2]	Indicator Value after Design [2]
Meeting, stress reduction, and physical activity	Used a few times per month [1]	Used a few times per month to a few times per week [1]
Benefits of green space (additional *)		
Unattractive views decrease	94%	96%
Heat stress decreases	-	-
Air pollution decreases	-	-
Active transport increases	3% (20 m) [4]	7% (50 m) [4]

Table 6. *Cont.*

Benefits of UGS (Intended *)	Indicator Value of Current Green Space [2]	Indicator Value after Design [2]
Burdens of green space (additional *)		
Air pollution increases	-	-
Perceived unsafety increases	30%	38%
Tick bites increase	100% [5]	100% (no extra areas) [5]
Traffic unsafety increases	78%	78%

* Benefits as intended by the participants. Additional benefits and burdens may not have been intended. [1] The score is an average of the different groups and focus areas. [2] '-' = no value: neighborhood did not contain any hotspot areas for the benefit or burden of green space. [4] extra meters walked per day. [5] tick bite risk values can be fully attributed to UGS presence. The participatory design did not lead to additional areas with predicted risk.

Step 8: discussing the results with local decision makers

When the results (i.e., the health determinant values of the current situation and the final UGS designs) were presented to two spatial planners of Maastricht municipality, they indicated that the representation of these results was largely self-explanatory. It was clear to them what health determinants the different indicators represented and why they were marked at specific areas of the neighborhood maps. They asked about the assessment of the 'active transport' benefit and what explained the small difference per neighborhood. Furthermore, they made two remarks related to the usefulness of the results for decision support. Firstly, they were especially (but not solely) interested in areas where municipal spatial interventions recently had taken place, were ongoing, or were planned. Secondly, they commented that some of the identified health impact hotspots overlapped with areas where there was no practical possibility for spatial redesign.

3.2. Evaluation: Strengths and Weaknesses of the Developed Approach

Table 7 presents the strengths and weaknesses (per category of evaluation criteria) identified when implementing the developed approach. The following sections elaborate on several of these strengths and weaknesses.

Table 7. Strengths and weaknesses of the developed approach per category of evaluation criteria.

Criteria Category	Strengths	Weaknesses
Data quality for participants	■ Large-size aerial imagery background map was recognized as representing the actual living environment	-
Data quality by participants	■ Possibility of either drawing or making notes prevented problems with misrepresenting areas or point locations. ■ Computer-generated (uniform), bird's-eye-view versions of the participatory designs made an accurate assessment of self-assessed use more reliable	■ Group pressure for younger children to choose what their peers choose.
User friendliness	■ The facilitated flexibility for residents to choose either drawing or making notes to co-design UGSs allowed for more participation. ■ The bird's-eye-view maps visualized the UGSs in a way recognizable by the residents, making the possible changes to UGSs clearly visible as well as giving insight into their effects. ■ Flexibility in including design ideas beyond UGSs made the concrete wishes of residents explicit where it was harder for them to translate them into pure UGS design ideas. ■ Assessment of health determinant values after a session with participants implied no unnecessary waiting times for participants.	■ Participant sessions were not explicitly planned at moments when high motivation and concentration could be expected.

Table 7. *Cont.*

Criteria Category	Strengths	Weaknesses
Feasibility	■ Materials (paper maps, drawing material) needed for the participatory sessions are low-cost. ■ Design by participants did not require much instruction and guidance. ■ Adjusting designs by participants was more straightforward as health burdens (and benefits) were displayed on the map	■ Expert(s) need(s) to be available to assess health-related effects between participatory sessions.
Usefulness for decision (maker) support	■ Resulting maps with designs as well as maps with health determinant values were easy to interpret for spatial planners. ■ Health hotspots for multiple health determinants and both benefits and burdens were considered relevant by the spatial planners.	■ Design sessions were not based on feasible redesign options as provided by the local planner. ■ Relevant preference of decision makers regarding results was only identified during the final step
Usefulness for participants (residents)	■ The elderly realized that public spaces in their neighborhood could be improved to achieve more meetings, stress reductions, and physical activity benefits. ■ Awareness of how spatial design affects human health beyond meetings, stress reductions, and physical activity for both the elderly and children.	■ Health determinant values could not be fed back directly to participants

3.2.1. Strengths of the Developed Approach

Regarding the quality of the data made available to the participants, a strength was that the participants recognized the neighborhood maps (based on large-size aerial imagery) as representing their actual living environment. This was noticeable, for example, because the children and elderly immediately reported on and pointed to reference locations where they had been or that they more frequently visited.

The quality of the data delivered by participants was positively affected by allowing the participants to use different methods to represent their input. Using notes for point locations and drawing for areas prevented problems with interpretation of the participants' inputs. Both the children and elderly combined these two methods. Multiple people working on the same design used different ways to mark areas (e.g., different styles of drawing). Computer-generated, bird's-eye-view versions of the participants' designs resulted in a uniform representation and clearer overview of the joint end-result for all participants. This enabled them to make a more accurate assessment of possible changes in UGS use if their design were implemented.

Regarding user friendliness, the flexibility to use either drawing or making notes in the participants' UGS design appeared to stimulate a broad participation. The elderly that participated mainly preferred to work with notes, whilst for the children, the preference for drawing or making notes varied between individuals. The more uniform computer-generated maps not only made the proposed changes to the UGS and their effects more clear, but also made it easier for the participants to adjust their designs in the subsequent session. Another strength regarding user friendliness was the flexibility in including landscape elements other than UGSs, as it was sometimes harder for the participants to translate their ideas into what the UGS would then look like. For example, children drew natural objects for certain tag-based games or a maze made out of vegetation, but found it hard to translate these ideas into trees and shrubs (or hedgerows) themselves. Health determinant values of designs were estimated after the first design session and feedback was kept for the next session, which meant that participants did not need to wait for this during a session.

Regarding feasibility, the participants did not require much instruction and guidance during the design sessions. Due to the aerial imagery background on the neighborhood map (with some labels for distinct places), residents knew which place on the map was where, and the white areas on the map were also self-explanatory as areas where UGS (re)design was possible. During the second session, adjusting the designs by participants was assisted by displaying the health burdens caused by the initial participatory design

on the map (through infographics, color shades, and numbers). It was therefore easier for them to locate where the UGS needed to be adjusted to prevent or reduce these burdens.

Regarding the usefulness for decision makers, both the maps with the participants' final UGS design and the maps with health determinant values were found to be easily interpretable by spatial planners. In addition, they considered the map with hotspots of multiple (beneficial and detrimental) health-related effects useful as a product on its own.

Finally, regarding usefulness for participants (residents), the elderly indicated initially that they knew that neighborhood design affects benefits such as meetings, stress reductions, and physical activity, but at the same time that they believed that their neighborhood did not need improvement in this regard. However, after the sessions, they stated that they realized how the addition or removal of landscape elements could improve their well-being through effects on meetings, stress reduction, and physical activity. Additionally, both the elderly and children did not know much about other health determinant values of urban spatial design, nor how health issues such as heat stress and air pollution could be affected by green space. They indicated during the feedback session (Step 6) that using their own designs to explain these effects gave them new insights in this matter.

We also identified some strengths that are probably more related to the implementation context (the specific neighborhoods and participant groups) than to the developed approach itself. Regarding feasibility, all contacted schools and clubs responded that we were welcome to organize the sessions if we came to their location. Also, regarding feasibility, it was possible for all participants to join the neighborhood walks and they were also willing to do that and seemed to appreciate the walk. Regarding the usefulness for decision makers, several of the participants' design elements were low budget (flowers, small play objects, benches), increasing the feasibility of these ideas.

3.2.2. Weaknesses of the Developed Approach

Implementing the developed approach with children and elderly also revealed some weaknesses. Regarding the quality of the data delivered by participants, we observed group pressure on younger children to choose what their peers chose during the session with resident self-assessment (Step 7). Some children apparently did not want to be the only person indicating that they (expect to) visit a place frequently or not at all.

Regarding user-friendliness, but also related to the quality of the data delivered by participants, it appeared that sessions were not always planned at moments of high motivation and concentration. For children, where sessions took place during school hours, it mostly seemed a welcome change from regular class activities. The design sessions also aligned well with some of the school's educational objectives. During sessions organized outside school hours, the children also participated for longer periods without losing concentration when they were well rested (e.g., the scout group in the morning). One session with children, however, took place after school and it was clear that these children found it difficult to maintain their concentration while drawing on the maps after a day at school. For most elderly groups, the design sessions appeared not to be their preferred activity. They, for example, often returned to chit-chatting when the (30 min) design session was not yet finished.

The usefulness for decision makers was diminished because the participants' designs were not restricted to feasible redesign options. The types of UGS considered feasible by the spatial planners (e.g., flowers on roundabouts) were only identified during the final step (Step 8). Another relevant preference of the spatial planners that was only identified during the final step concerned the model output. They would have appreciated an indication of the 'degree to which UGS redesign is possible' on the maps displaying the health impact hotspots. Taking this into account before Step 8 may increase the chance of implementation of designs.

Regarding usefulness for participants, a minor weakness was that the health determinant values of their designs could not be fed back immediately to them as they first needed to be assessed using the computer model. In the experience of the participants, this

may have resulted in a less direct connection between their own designs and the health determinant values of these designs.

4. Discussion

This section discusses the major strengths and weaknesses of the developed approach and presents recommendations for improvement and further research.

4.1. Major Strengths and Weaknesses

The major result-related strength of the developed approach to support participatory design of UGSs is that it allows for conclusions about whether the final designs actually represent an improvement compared to the current situation in terms of health. In both neighborhoods, the results show that the designs presented by the elderly and children can be expected to lead to an increase in use of the green spaces for meeting, stress reduction, and physical activity. With regard to the model-assessed health benefits, a small increase in active transport (walking), with approximately 20–30 extra meters walked per day, and a small heat stress decrease of around 0.1 °C was estimated. According to the model, little change in the other health benefits can be expected. With regard to health burdens, a small increase in the feeling of social unsafety in the neighborhood of Pottenberg was predicted due to the extra UGS introduced in the participants' UGS design. One of the reasons why increases in burdens were absent or small was the feedback meeting (Step 6), where participants could and did correct such unintended detrimental effects.

Through testing the developed approach for participatory design of UGSs, we have also learnt about its strengths and weaknesses in relation to literature-based process evaluation criteria. The core strength of this method is the use of visual material, specifically large-size aerial imagery background maps and computer-generated (uniform) bird's-eye-view versions of the participatory designs with visualized health determinant values. These products improve aspects regarding the quality of data to be used by participants, the quality of data delivered by participants, user-friendliness, and feasibility. Regarding the usefulness for decision support, the resulting maps with participatory designs and health determinant values were easy to interpret for spatial planners, and expressing the results as impacts on 'health hotspots' was considered relevant by spatial planners. Finally, regarding the usefulness for the participants, the strengths are an increase in knowledge and awareness of residents of how green spaces in their neighborhood could be improved to achieve positive health effects and of the mechanisms behind generation of health benefits and burdens in green spaces.

A major weakness identified after applying the approach to the neighborhoods in Maastricht was that participant sessions were not purposefully planned at moments when motivation and concentration could be expected to be high. Moreover, the fact that the relevant, more specific preferences of decision makers regarding the results of the approach were now only identified during the final step could be considered a weakness as well. Before initiating our developed approach, we verified with decision makers that they would consider an assessment of multiple health effects as well as the mixed-method approach for this both useful and relevant to their policy ambitions. However, participatory designs were now more purely based on the preferences of participants, and not limited to feasible urban green space redesign options, locations, and priority health effects as demarcated by the local planner. Although we feel that this freedom in design made the approach clearer to the resident participants, this likely impacted the extent of implementation of design ideas in policy and practice after we communicated our results. In short, we suggest that the balance between freedom of resident design and local planner priorities is moved more towards the latter in our approach.

4.2. Recommendations for Improvement

The developed participatory approach can be applied to all cases in which the impacts of UGSs on health is of interest, provided resources for model or expert assessment are

available. However, we recommend applying the approach only at spatial scales no larger than a neighborhood. Otherwise, the number or size of the focus areas to extrapolate the results to the desired scale would be too large. As mentioned, the major identified weaknesses of the proposed approach are the lower levels of involvement of some participant groups and the insufficient involvement of spatial planners in terms of their possibilities and preferences. The approach could be improved by addressing these weaknesses as follows. When organizing sessions, the daily schedule of the participant group should be considered (e.g., sessions for children during school or on weekends, rather than after school). Sessions could also be more aligned or integrated with the preferred activities of the participant group (e.g., accommodate for chit-chatting during design sessions with elderly visitors in a community center). The involvement of decision makers (e.g., spatial planners) could be improved during the first steps of the approach, e.g., by asking the local decision makers which health issues related to UGS design have priority. In the following steps, these priority problems may then be focused upon. The local decision makers could also be asked about feasible redesign options, for example, with regard to preferred UGS types, favored locations for UGSs, or areas available for UGS redesign. Finally, the decision makers could be asked in these first steps what type of results from the participatory approach they would consider most valuable. Taking the perspective of the local decision makers into account in the further steps of the approach will increase the chance that the outputs and insights are adopted in policy or practice. Communicating this perspective to the participants may make them more involved in the approach as well, as there is a larger chance that their designs will be implemented. In a new final step of the approach, decision makers could communicate their remarks on the feasibility and usefulness of the proposed designs directly to the participating residents. Based on our experiences with spatial planners in this study, we think that they could be incentivized to join during these additional steps of the participatory approach by explaining to them that their involvement in these steps will allow them to receive various inputs such as assessment results specifically for themes and locations in their professional interest.

The neighborhoods where the proposed approach was tested, as well as the type and number of participants, will have affected the outcomes of the approach in terms of UGS designs, health benefits and burdens, and the expected increase in use of UGSs after redesign. The factors determining the effect of type of participant may, amongst others, be age, sex, income level, and ethnic background. In this study, we only involved the elderly and children. It is recommended to include other age groups (youth and younger adults) in the design process as well. In this way, a UGS design can be obtained that better represents the age distribution of the neighborhood and that can meet the needs of all the residents of the neighborhood. Another factor that may influence the outcomes and in particular UGS use is the distance at which participants live from the area of interest. In the Wittevrouwenveld neighborhood, for example, it turned out that some of the older participants who are active in groups in this neighborhood do not live in the neighborhood concerned. Although they knew the neighborhood well, for example, because they had lived there, an improved version of the approach should take the type of residents better into account.

The health benefits and burdens from urban green spaces assessed in this study do not cover all mechanisms that link urban green space and health. Specifically, when including residents in assessments, information can be gathered about more indirect (often behavior-dependent) benefits of UGSs, such as exposure to sunlight and thus vitamin D production when in parks or protection against UV radiation under trees (through their shadows). Similarly, the indirect burdens of UGSs may become more tangible to assess when including participants, such as when playing in parks encourages soil ingestion (pica), or when a UGS occurs in the form of natural exercise or play objects that cause injuries. Especially with regard to current urban spatial design, the perceptions, observations, and experiences of (resident) participants could play an important role in assessment of the impact of current UGSs on these health benefits and burdens.

The final recommendation concerns the suggestion to adopt a dual approach that combines estimations from experts and residents to assess the values of a selection of the same health determinants. This is mainly because models are better at predictions of effects of new street designs to which residents have not been exposed in real life, whilst residents are the local experts that, for example, know which places they use the most or where they are exposed to the most within the current street design. Although most health determinants are probably best assessed with a dual approach, health determinants that we assessed in this study that seem especially suitable for this are unattractive views, heat stress, and active transport. Regarding the former two health determinants, this is because they can be directly observed and perceived by residents if they are physically present at the locations concerned. Regarding the latter health determinant, residents will likely have memories of why they chose certain routes and how long these routes were. Biases and constraints when purely modeling such health determinants are, for example, a model's lack of micro data on certain streetscape elements, and especially its lack of data on the use and valuing of such streetscape elements, and how use and valuing differ between different types of residents. Examples are the presence and different valuing of street litter or neglected street furniture, different considerations of what plants are considered 'weeds' (related to assessing unattractive views), or differences in the use of sun-protection measures per type of resident (related to assessing heat stress).

4.3. Recommendations for Further Research

Apart from effects of the participatory UGS designs on the participant-assessed benefits of meeting, stress reduction, and physical activity, the only substantial model-assessed effect of the UGS designs is on the benefit of 'heat stress decreases'. The low impact of the designs on the benefits of 'air pollution decreases' and 'unattractive view decreases' was to be expected, because the design process was primarily aimed at increasing the three participant-assessed benefits and was limited to the focus areas. In addition, the influence of green at a greater distance is lower for these benefits. For example, the 'unattractive view decreases' benefit is often limited for pedestrians outside a park because buildings block the view of the park. However, it will be interesting for further research to find out if these minimal effects on other benefits and burdens is a general pattern when applying the approach to other neighborhoods as well. In such a study, the health benefits that participants are requested to focus on in their (re)design, the location of the area to be redesigned in relation to health hotspot locations, and the population density of the neighborhood can be varied.

The developed approach did not consider outcome-related criteria that can be linked to implementation of designs or the generation or reinforcement of participatory governance. It will be interesting for further research to evaluate to what extent the results of this approach influenced spatial planning decisions. It will also be interesting for further research to evaluate to what extent the participatory process stimulated participants to form a network or community to improve UGSs to improve health or to strengthen such an existing network or community. Finally, it will be interesting for further research to evaluate to what extent the developed approach and similar approaches increased trust in institutions and reduced conflict beyond the participatory process [60]. Evaluating such effects of the approach would require monitoring further developments after the participatory process has ended, and a long-term evaluation effort would be needed.

5. Conclusions

This study aimed to develop and evaluate a novel approach to support the participatory design of UGSs to improve residents' health, as such an approach has been lacking thus far. The approach was developed following guiding principles from the literature, including addressing a comprehensive selection of health benefits and burdens, combining inputs of residents and experts in a complementary way, making impacts tangible for residents, and involving local decision makers. The proposed approach has proven to be

effective in supporting a participatory urban green space design process, whilst meeting most of the guiding principles identified in the literature. However, in particular, the implementation of the guiding principle of 'involving local decision makers' could still be improved. The use of a computer model as part of the novel approach can be considered successful as well. The model aided in visualizing UGS designs as well as their health benefits and burdens in a recognizable way for the participants. The model and the participatory sessions complemented each other and, in this way, a more complete assessment of health determinants was obtained. While in other participatory approaches to UGS design, it often remains unclear whether participation actually improves green spaces, our combination of a computer model with a participatory process produced clear outcomes as far as health benefits and the use of UGSs are concerned. A major recommendation for improvement is to involve decision makers in the first steps of the approach. Applied in this manner, the approach can be expected to effectively support decision makers in the (re)design of urban green spaces in such a way that both residents' health and ownership are promoted.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13010088/s1, File S1: participatory studies for planning of urban green spaces [23,26,28,61–72]; File S2: scores per neighborhood [57,58]; File S3: overview of the geoprocessing method per module [33,73–79]; File S4: participatory mapping evaluation criteria: search, inclusion method and results [23,26,28,32,60,68,80–83]; File S5: first meeting, input children and elderly; File S6: first meeting, digitized initial green designs; File S7: feedback meeting, input children and elderly; File S8: current and designed green situation for neighborhood Pottenberg; File S9: degree of use per neighborhood and per participant group.

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