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Easy as Child's Play? Co-designing a Network-Based Metric for Children's Access to Play Space

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Abstract. Accessible outdoor spaces for unsupervised play are important for children's health. However, parents impose constraints based on their perception of safety, which can have a significant impact on which play spaces are actually accessible to children. Such constraints are not taken into account by widely adopted accessibility indicators that use generic radial buffers or travel distances. We introduce a child's play accessibility metric, which measures the ease with which children can reach outdoor play spaces without supervision. We developed this metric through an iterative co-design process with experts on the built environment and children's health, leveraging open data. Our metric considers traffic, natural barriers to children, and a range of playable spaces. It can be used by planners and policymakers to enable large-scale assessments of play space accessibility, identify associated equity issues, and benchmark progress toward healthier environments for all ages.

Keywords: Accessibility, Play space, Children, Co-design, OpenStreetMap

1 Introduction

Outdoor play space is essential for children's physical activity, social interaction, and exposure to vegetation, all of which contribute to their mental and physical health (Perez-Del-Pulgar et al., 2021; McCurdy et al., 2010; Sundevall and Jansson, 2020). Unsupervised outdoor play benefits children's self-esteem, motor skills, independence, risk management, physical activity, and social health in particular (Brussoni et al., 2015). According to research, children express the desire to play unsupervised (Veitch et al., 2007) in environments with challenging equipment or natural features that match their physique, and where peers are present to play with (Finney and Atkinson, 2020; Qiu and Zhu, 2021; Sundevall and Jansson, 2020; Veitch et al., 2007).

However, rates of unsupervised outdoor play have decreased over generations, and parental perceptions of safety have shifted dramatically (Gaster, 1991; Clements, 2004), resulting in a reduction of risky play and physical activity (Brussoni et al., 2015). Evidence suggests that changing parental perceptions of safety influence how accessible outdoor play is for children. That is, parents limit their children's unsupervised play (Truong et al., 2023), because they are concerned about traffic safety (Carver et al., 2008; Truong et al., 2022; Amiour et al., 2022), incidents involving strangers (so-called

stranger danger, such as abductions) (Carver et al., 2008; Qiu and Zhu, 2021; Truong et al., 2022; Veitch et al., 2006), and play-related injuries (Finney and Atkinson, 2020). For instance, parents in Texas, USA, allow their children to play unsupervised only in a few places close by the house (Qiu and Zhu, 2021), whereas parents in Japan do not allow unsupervised play in natural spaces other than parks, despite knowing the importance of exposure to nature (Truong et al., 2022). Such restricting behaviors can have a significant impact on the outdoor play spaces that children can actually access.

Widely used indicators for measuring access to outdoor play spaces do not take into account parental restrictions or children's preferences for accessing places for play. Accessibility is typically measured using radial buffers around or travel distances from dwelling units (Zhang et al., 2011; Wang et al., 2021; Labib et al., 2020; Mears et al., 2020; van Dillen et al., 2012; Zhang et al., 2021). Children's accessibility studies use generic network-distance buffer zones or ignore the impact of parental restrictions, such as not allowing children to cross any street independently (Perez-Del-Pulgar et al., 2021; No et al., 2022).

To address this gap, we propose a *child's play* accessibility metric, which measures the ease with which children can reach public outdoor play space without supervision. We refine an existing network-distance buffer zone metric to account for the aforementioned restrictions and preferences. We focus on children of primary school age (i.e., approximately 6 to 12 years old) and explore the elements that should make up such a refined metric, as well as its potential and limitations. To that end, we organized two co-design sessions: the first with built environment experts on play space in Utrecht, The Netherlands, and the second with a diverse group of professionals on children's health and the built environment from eight European countries. In these sessions, we iteratively investigated what factors limit or promote children's play, and how they relate to spatial data, such as maps and street-level imagery. By actively involving experts in the process of designing our metric, we not only receive immediate feedback on our work, but we also ensure that we translate their input and ideas meaningfully into our final child's play accessibility metric.

Our participants stated that traffic infrastructure, large greenspaces, and waterways prevent children from reaching play spaces on their own, whereas various types of formal and informal spaces can serve as play spaces. Our child's play metric takes these barriers into account, as well as a broader range of play areas such as playgrounds, schoolyards, and small parks. We describe the codesign sessions that led to the development of our metric, implement it using open spatial data, compare it to widely used indicators for measuring access to play space, and discuss its practical value for play-space design and policymaking. The paper concludes with a call to action and research directions for the future.

2 Method

Through an iterative co-design process (Sanders and Stappers, 2008), we collect factors that promote or limit children's outdoor play, how these relate to the urban environment, and how we can incorporate these in our child's play accessibility metric. Fig. 1

visualizes this process: we recruit participants for two co-design sessions and prepare a spatial dataset, reflecting spaces that potentially limit play space accessibility, such as traffic infrastructure. During the co-design process, we iterate on these spatial data and explore their potential and limitations, before composing our final child's play accessibility metric.

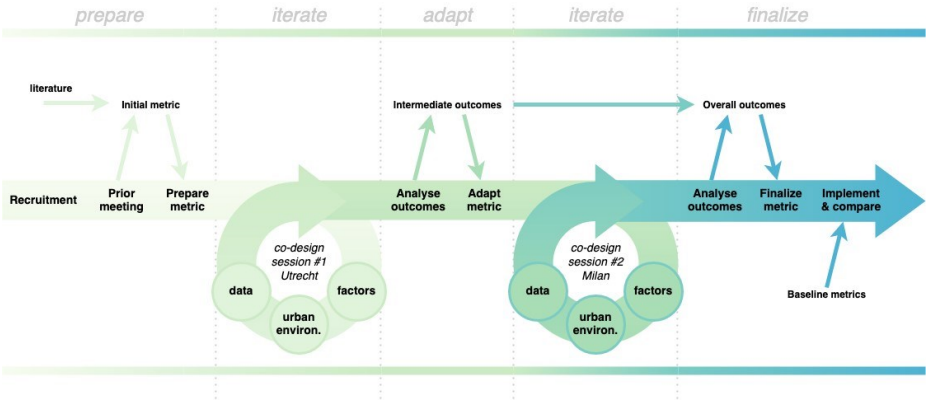

Fig. 1 Iterative co-design process: preparation and co-design session 1, adaptation and co-design session 2, and finalisation of our child's play accessibility metric.

2.1 Recruiting expert participants

We recruit expert participants via the stakeholder network of the Horizon 2020 *Equal-Life* project[1] (van Kamp et al., 2022), combining convenience and snowball sampling (Gill, 2020). The first session takes place in Utrecht, The Netherlands, with a small sample (n=4) of local professionals on play space in the built environment[2]. The second session takes place in Milan, Italy, with a larger sample (n=16) of experts, both researchers and practitioners, working on children's health and the built environment in eight European countries[3].

We ask participants for their informed consent to participate and in return for participating, we offer them the spatial data shown during the session for own use.

[1] https://www.equal-life.eu/en

[2] Working on urban planning, policy-making, and play space assessment for Utrecht.

[3] Four participants from Italy, four from Slovenia, three from The Netherlands, while Slovakia, Ireland, Estonia, Finland, and Belgium each had one participant. Six participants work on the built environment (e.g., urban planning and policy-making, architecture, or geo-information), and ten on children's health (i.e., mental, physical and social health).

2.2 Materials, spatial data, and case study areas

As materials in the co-design process, we use two types of spatial data: maps from OpenStreetMap[4] and street-level imagery from Google Street View[5]. As case study cities, we use Utrecht (The Netherlands) for session 1, and Milan (Italy) and Ljubljana (Slovenia) for session 2. These are medium to large cities in Western, Southern, and Central Europe, respectively.

For session 1, we focus on three adjacent districts in Utrecht, that participants are working on at the time of the session, varying in neighborhood typology and socio-economic status. As materials, we use a base map and an initial spatial dataset of features that potentially limit children's access to play space, based on the literature and a prior introductory meeting with the participants: traffic infrastructure (i.e., tram and train railways; main roads ranging from tertiary to motorways; and roads with a maximum speed of 50km/h or higher) (Amiour et al., 2022; Carver et al., 2008; Truong et al., 2022) and natural environments (i.e., parks, other greenspaces, and water) (Truong et al., 2022).

For session 2, we focus on central areas in Milan and Ljubljana, characterised by a variety of potential barriers and potential places for play. For these areas, we collect both base maps and street level imagery to serve as materials for the session, and we adapt our spatial data based on preliminary outcomes of session 1.

2.3 Co-design process

We run two in-person co-design sessions, both structured in three rounds: (1) What factors promote or limit children's access to play space? (2) How can these be recognised in the urban environment? (3) How do the spatial data we present reflect these factors, and what should be added or omitted? We record audio and collect written and drawn annotations.

We implement our metric in the three case study cities using open data and open-source software (i.e., OpenStreetMap and Python). Repositories containing the implementation of our metric and associated data are publicly available to allow for reproducibility[6]. We evaluate its implications in terms of how many children have access to play space, in comparison with baseline metrics by overlaying their respective outcomes with high-granularity population data (i.e., per 100 meter grid cell) (Centraal

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4 OpenStreetMap is an open-source geographical data platform increasingly used in research (Jokar Arsanjani et al., 2015). We collect land cover, place of interest, and street network data from OpenStreetMap using the Overpass API and the Osmnx Python package (Boeing, 2017). The OpenStreetMap road network is highly complete in cities world-wide, including many informal road connections (Barrington-Leigh and Millard-Ball, 2017; Labib et al., 2020).

5 Google Street View is commonly used imagery data in research, including studies on health, greenery, and environmental perception (Biljecki and Ito, 2021).

6 The workflow underlying this paper is fully reproducible and can be found at https://github.com/rflteeuwen/ChildsPlayAccessibility (https://doi.org/10.4121/2e16ff97-dabb-421f-803d-d05fd3204959). The associated datasets are available at https://doi.org/10.4121/0ec69d2a-d966-4dcd-a415-f05d756636d6.

Bureau voor de Statistiek, 2021). As baselines, we use metrics that account only for formal playgrounds and ignore potential barriers to children in the city.

3 Co-design outcomes and their implications

Figure 2 and Figure 3 show impressions impressions of the physical set-up and materials presented during the co-design sessions in Utrecht (October 2022) and Milan (November 2022), respectively.

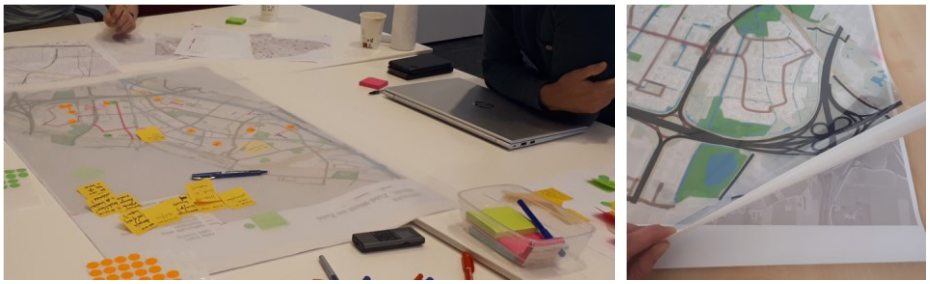

Fig. 2 Impression of co-design session 1 with local experts in Utrecht: physical set-up; and base map materials with spatial data on transparent overlay sheet

3.1 Outcomes of session 1 and implications for session 2

Based on the outcomes of session 1, we identified four themes relevant to our child's play metric: (1) There is limited public space suitable for child's play (e.g., sidewalks, playgrounds, and informal play spaces); (2) The interplay between physical and social factors is important (e.g., neighborhood culture and social cohesion, peers to play with); (3) Greenspaces can promote or limit child's play depending on their type and size; and (4) Traffic is the main barrier to unsupervised play.

For the second co-design session, we collected base maps and street-level imagery of a variety of places, including: playgrounds, small and large parks, squares, streets and crossroads, and bridges. We modified our spatial data to highlight large parks and greenspaces, as well as water bodies, as barriers, while pedestrian bridges were considered permissible crossings. Second, we incorporated playgrounds, schoolyards, and small parks as attractive places for play. Third, in the context of accessibility modeling, we chose to ignore sidewalks as play spaces because we see them as an extension of the home environment rather than a destination for play. We also chose to ignore nuanced play space qualities (e.g., challenging equipment, materials), because participants stated that identifying these requires fieldwork, which we note as an interesting direction for future work.

Fig. 3 Impression of co-design session 2 with European experts in Milan: physical setup at each of the six tables; and base map materials with spatial data on transparent overlay sheet.

3.2 Overall outcomes: four themes

From the spoken, written and drawn contributions in both co-design sessions by built environment (*BE*) and children's health (*CH*) experts, we identified three themes on how the urban environment limits or promotes access to play space by unsupervised children, and a fourth general theme on unsupervised play.

The joy and fear of getting there: Having a space to play nearby is key for access, yet the *distance threshold* varies with the attractiveness of the play space, season, and neighborhood (*"they can easily navigate through this play neighborhood, then a distance of 400 m is much less of an issue ... then, in a neighborhood where that is not possible at all, then maybe 200 meters is already way too far" (BE, The Netherlands*)). *Traffic* remains the main barrier to children's independent mobility, for example busy roads with fast-driving vehicles, and bus and tram routes (*"this one is the most limiting because it's the crossing between two really important streets"* (CH, Slovenia); *"there's the tramway that passes through, so also this is a, another barrier"* (BE, Italy)). Participants in The Netherlands mention bicycle through-routes too. *Nature* may form physical or perceived barriers as well, for example large parks and greenspaces, and waterways (*"we often see parks as barriers now"* (BE, The Netherlands); *"like 'you stay on this side of the water'"* (BE, The Netherlands)). While barriers and associated parental safety concerns may restrict choice of destinations or cause detours, pedestrian bridges and tunnels, or formal crossings may allow children to cross them. Lastly, well-designed routes to play spaces can be playable too (*"the play starts then, and I think that's very important, as opposed to the barriers"* (BE, Ireland)).

A perfect place for play: The spectrum of playable spaces ranges widely, including the aforementioned routes, grounds specifically equipped for play (i.e., playgrounds), and open spaces (i.e., informal play spaces), all of which may, however, still be boring for play if not designed well. Attractive *playgrounds* have challenging, varied equipment matching different ages and abilities (*"risk-free playgrounds, they don't exist"* (CH, The Netherlands)). Participants prefer natural materials and find both sunlight and

shade important. *Informal play spaces* include squares and other open spaces where children can be active (*"they use it as a skate park"* (BE, Slovenia); *"they're running around"* (CH, Belgium)), spaces with interesting statues or landmarks (*"improving the playfulness of the area a lot"* (BE, Slovenia)), spacious sidewalks (*"many children they don't even get to a play area at all"* (BE, The Netherlands)), and greenspaces. Greenspaces, specifically, have potential, depending on their character, size, and vegetation type: While large parks form a barrier, visited only under supervision, their *outskirts* may be playable without supervision (*"only on those fields where you can see them"* (BE, Utrecht); And *small parks*, well-integrated in the urban fabric, with an open layout and playful vegetation, are destinations for play (*"kids love trees"* (BE, Ireland)). Yet, not all small greenspaces may be represented in data (*"places where I feel the presence of the nature ... it's difficult to map"* (BE, Italy)). Lastly, a special type of informal play spaces are those part of children's routines, such as *schoolyards* (*"they often also go to this school"* (CH, Slovenia) or churches *"in Italy, because they go to church"* (BE, Italy).

Social interactions in physical space: Public space is shared by everybody, and thereby social interactions play a key part. Foremost, children love to play with others (*"children go to those places where other children, probably they meet also other children"* (BE, The Netherlands)), and parents feel more comfortable letting them. A neighborhood *"play culture"* (BE, The Netherlands) and visible traces of outdoor play, e.g., chalk on sidewalks or play equipment, reinforce play further. Parental perceptions of safety benefit from the confidence their children are seen by others. Social cohesion and control, natural surveillance, other young families, and knowing your neighbors contribute to this (*"then it's probably easier to let their children free a little earlier"* (BE, The Netherlands)). Occasionally, however, interactions have adverse effects, either with peers (*"because 'it's my place, you're not allowed to come here'"* (BE, The Netherlands), or other groups of people *"also drinking at night or like also hanging out there during the day can be also limiting for kids"* (BE, Italy); *"this conflict with dogs, dog owners, can be quite serious"* (BE Slovenia)).

Un-, semi-, or supervised play? Some notes. Participants stress *"it is also very good for children if they play outside with other children and not just under supervision of their parents"* (BE, The Netherlands). Yet, possibilities for unsupervised play depend on their age (with thresholds mentioned varying widely from 5-7 and 11-12 years old), experience (*"because children don't play outside often, they are 'poor in experience'"* (BE, The Netherlands)), and the cultural context (*"in Finnish society ... get really independent really early"* (CH, Finland)). Participants also mention semi-supervised play: supervisors doing their own activities close-by (*"then they can play around while you are watching and grabbing a coffee"* (CH, Belgium)). Lastly, participants feel in some places, supervision is simply inevitable, such as near water (*"still, when I see a child climbing or doing stuff around these fences [on the river banks] ... for me, it's completely unacceptable* (BE, Slovenia)).

4 Child's play accessibility metric

Based on co-design outcomes regarding barriers, attractive play spaces, and distances, we built our final child's play accessibility metric, using OpenStreetMap data and Python code.

Traffic and natural barriers to unsupervised children were *"well-represented"* by our spatial data layers (BE, Italy), *"the basis is there"* (BE, The Netherlands), while participants did mention some barriers are missing, and noted pedestrian bridges or tunnels and formal crossings can help children cross them safely. We refined our spatial data set such that it does not include barriers that can be crossed via pedestrian infrastructure on *bridges or tunnels*. Furthermore, we maintained *large parks and greenspaces* (> 5 hectares, in line with participants' examples) as barriers, but not their *outskirts*, i.e., within 40 meters of its boundaries (*"40 meters is a very important distance for natural surveillance"* (BE, Ireland)).

As *play spaces*, we incorporated three categories: *playgrounds*, *schoolyards* (including playgrounds located on school premises), and *small parks* (≤ 5 hectares), that are *not* explicitly tagged in OpenStreetMap as private. However, we should note that all of these may still be boring for play, schoolyards may be closed outside of school hours, and not all greenspaces perceived by people are tagged as such in our data. Incorporating these qualities, as well as other *informal playable spaces*, such as squares and routes, requires further research.

We incorporated a *distance threshold* by using street-network buffer zones around play spaces. We used a 300 meter distance (i.e., a 5-minute walk (Waddell and Ulfarsson, 2003)), in line with UNICEF guidelines on children's independent mobility (UNICEF, 2018; Perez-Del-Pulgar et al., 2021), and the 200-400 meter range mentioned by a built environment participant.

Out metric identifies the areas from where children can reach a play space within a 300 meter walk via the street network without crossing barriers. Fig. 4 shows our metric applied on a part of Utrecht West (Fig. 4A), and the case study areas in Milan (Fig. 4B) and Ljubljana (Fig. 4C).

5 Implications and recommendations

5.1 Interpretation of results and their implications

Factors affecting children's unsupervised play mentioned by our participants are largely consistent with the literature, for example: limiting (perception of) traffic (safety) (Carver et al., 2008; Truong et al., 2022; Veitch et al., 2006, 2007; Lambert et al., 2019; Powell-Wiley et al., 2013); need for diverse spaces, both formal and informal, suiting ages, genders, and abilities (Perez-Del-Pulgar et al., 2021; Qiu and Zhu, 2021; Veitch et al., 2006, 2007; Finney and Atkinson, 2020); enabling social cohesion and neighborhood support, and the fear of strangers or other groups of people (Aarts et al., 2010; Qiu and Zhu, 2021; Truong et al., 2022; Veitch et al., 2006, 2007); influence of temporalities (Finney and Atkinson, 2020); need for spaces nearby (Finney and

Atkinson, 2020; Perez-Del-Pulgar et al., 2021; Veitch et al., 2006); playing (and conflicts) with peers (Finney and Atkinson, 2020; Qiu and Zhu, 2021; Veitch et al., 2006, 2007); quantity, quality, size and noisiness of play spaces (Finney and Atkinson, 2020; Qiu and Zhu, 2021); enabling safe routes via protected sidewalks and bike lanes (Qiu and Zhu, 2021); safety concerns for play near water (Truong et al., 2023); and children's love for nature (Veitch et al., 2007; Sundevall and Jansson, 2020).

Our findings indicate surprising differences in how greenspaces can either limit or promote children's play based on their character, size, and type of vegetation, and thus provide a plausible explanation for why parents are more likely to let their children play in parks, rather than, say, forests and woodlands (Truong et al., 2022), and how small parks can also be beneficial to mental health (Wood et al., 2017).

When we compare our child's play metric to two widely used baseline equivalents, namely, Euclidean and network-distance buffer zones (Labib et al., 2020; Wang et al., 2021), we see differences in outcomes, as shown in Fig. 5. When Euclidean distance buffer zones are used, it is estimated that 90% of children have access to playgrounds from their home in the visualized part of Utrecht West (Fig. 5A), compared to 79% when network-distance buffer zones are used around playgrounds (Fig. 5B), 94% when network-distance buffer zones are used around a range of play spaces (Fig. 5C), and 81% when barriers are incorporated as well (i.e., our child's play accessibility metric) (Fig. 5D).

Fig. 4 Child's play accessibility metric: zones with access to playgrounds, schoolyards, or small parks within a 300-meter walk for unsupervised play without crossing barriers. Implemented in three urban areas: A) Utrecht West; B) Milan between central station and city center; C) Ljubljana city center.

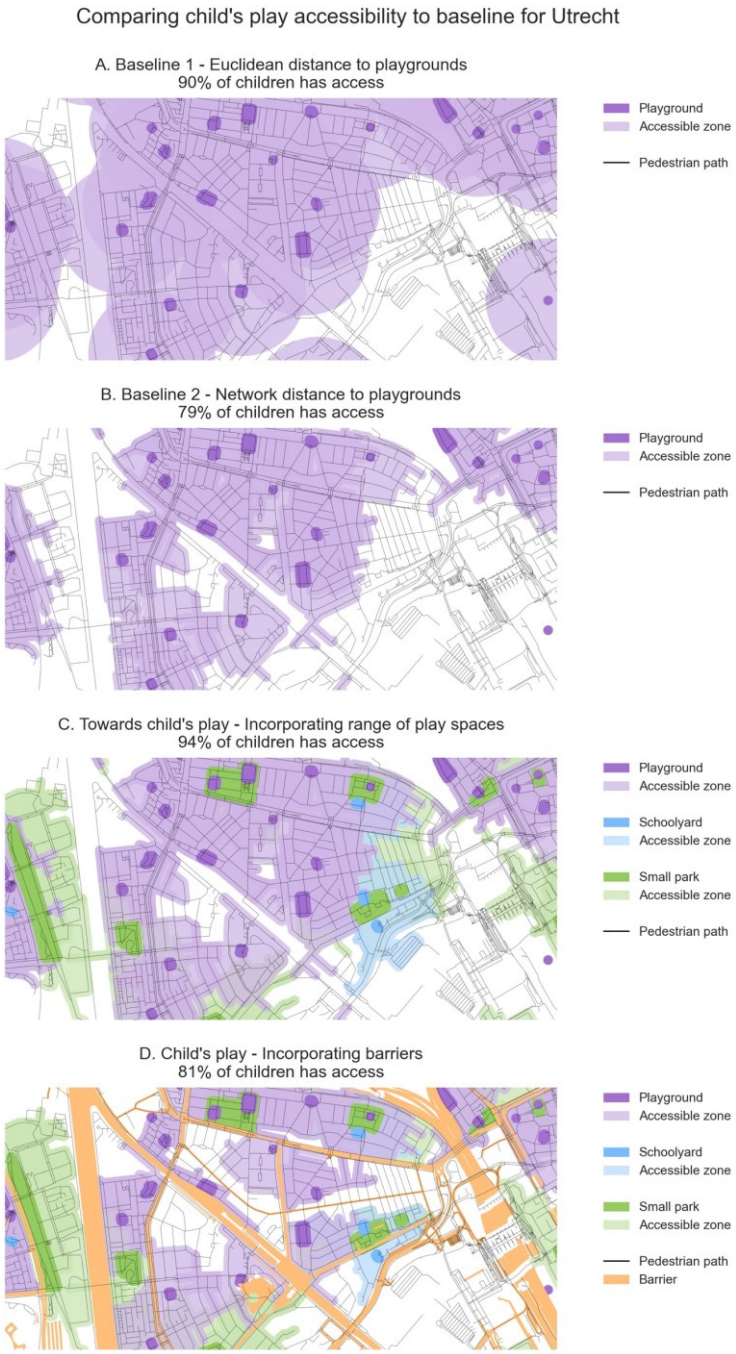

Fig. 5 Child's play accessibility metric for the Utrecht area (D) in comparison to: (A) Euclidean distance to playgrounds; (B) network distance to playgrounds; and (C) network distance to a range of play spaces.

5.2 Strengths and limitations

Participants see potential in our metric to speed up play-space accessibility assessment (*"you can just run such a scan over it at once and these kinds of areas pop out where maybe really attention [is needed]"* (BE, The Netherlands)) and our spatial data triggered them to reflect on potential equality and equity issues regarding access to play space (*"the concentration of playgrounds is uneven, yeah it depends maybe on the people living there or whatever ... young families are coming too, and they need more"* (CH, Slovakia)). As such, the computational results of our metric can be used to inform urban planning interventions that promote children's ubiquitous access to play space.

However, there is more that influences children's play than what is represented in the spatial data we used, and thus we cannot include it in our metric. Examples include the nuanced qualities (e.g., presence of peers, challenging equipment, materials) that make a space playful; family structure and raising practices; social cohesion and control, and natural surveillance; variations between cultures, seasons, and times of day; and the distractions of the digital era.

Furthermore, as brought up by our participants as well, maps or street level imagery, as we used as materials in the sessions, do not always reflect the realworld situation: *"the knowledge out of the neighborhood is just necessary to really be able to assess it"* (BE, The Netherlands); *"as a non-local person you cannot know this just from the map"* (CH, Slovenia).

Lastly, we focused on three case study cities. While these are spread over three European countries, care with generalising our results beyond remains necessary. However, we implemented our metric using world-wide open-source data and software, to allow transferability and adaptation to other geographical contexts.

5.3 From here on: a call to action

Based on our findings, we urge global organizations such as UNICEF and WHO, as well as local and regional governments, and urban planning and public health associations

- to adopt our child's play accessibility metric to determine which children's residential environments or schools in the city have access to play space, to identify associated equity issues, and to investigate how our metric can help us understand the effects of play-space access on children's health.
- to critically reflect on how to measure accessibility by different population groups in ways that reflect their day-to-day practice, taking into account people's preferences and potential constraints.
- and to conduct field work and collect children's and parent's perspectives on access to play space in cities, so as to complement our scalable metric with local nuances, such as quality of equipment, social interactions, and cultural context.

6 Conclusion

In this paper, we introduced a *child's play* accessibility metric, which measures the ease with which children can reach urban play space without supervision. We developed this metric through an iterative co-design process with 20 European experts on children's health and the built environment and implemented it using open data. Our metric accounts for traffic and natural barriers, that children may not be allowed to cross due to parental safety concerns, and it incorporates a range of play spaces, from equipped playgrounds and schoolyards to small greenspaces. Participants see potential in our metric to support assessments of children's play-space accessibility at scale, and were triggered to consider associated equality and equity issues after seeing our preliminary results. Field work and involving the voices of (young) local citizens remains an essential followup to our approach. By understanding all local nuances that limit, enable, or promote access to play, we hope to see cities bustling with healthy, outdoor, unsupervised child's play.

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