# Citizen Engagement through Design Space Exploration

## *Integrating citizen knowledge and expert design in computational urban planning*

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*A common understanding exists that citizens should become more involved in the design, planning, and governance of the city. Due to a lack of common platforms and difficulties in the meaningful integration of the participatory input, however, the tools and methods currently employed in citizen engagement are often ill connected to the design and governance tools and processes used by experts. In this paper we describe a Grasshopper and Rhino based approach, which allows designers to share a subset of the design space formed by parametric design variants with citizens via the online interface Beta.Speckle. In a user study we evaluated the usability of the tool as well as studied the design choices of participants, which were found to be influenced by preferences for visual order and underlying economic, social, and environmental values. For the future design of participatory exercises, it was concluded that indicators relating to citizens' values and preferences will allow for a more effective exploration of the design space and increase the meaningfulness of results.*

**Keywords:** *design space exploration, citizen engagement, parametric urban design, computational urban planning, space matrix*

## INTRODUCTION

A common understanding exists that citizens should become more involved in the design, planning, and governance of the city. However, although citizens are often consulted, it was found that their contributions are rarely employed and considered in planning and decision making due to a lack of integration of engagement activities into the planning process itself (Hasler et al. 2017). The development of engagement tools that allow for a better integration into existing planning and governance practices has consequently been described as a challenge in the field (Ertiö 2015).

Especially in the development of urban design projects, citizen engagement is very often limited to gathering feedback on or informing the public about

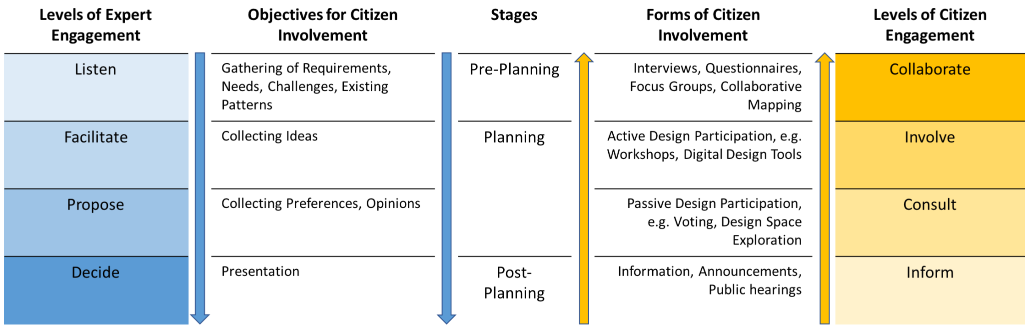


Figure 1
Mapping of the relationship between expert involvement and objectives for engaging citizens in different planning stages (see Brody et al. 2003), as well as the forms and levels of citizen involvement and engagement [1] in design and planning.

finished design proposals rather than involving citizens more actively in the design process (Klosterman 2013). Parametric design has been hailed as a useful tool to help bridge the gap between experts and laypeople and support citizen participation in the urban design process (Steinø et al. 2013).

In this paper we describe a Grasshopper and Rhino based approach, which allows designers to share a subset of a parametric design space with other stakeholders via an online design space exploration interface called Beta.Speckle [6]. This paper further presents the results of a user study, in which the approach was tested and feedback on the usability of the tool was collected as well as the reasons underlying specific design choices were evaluated. This paper concludes with a discussion on how the integration of citizens in urban planning via parametric design space exploration can be better curated and explores the impacts on the design process from the designer's perspective.

## BACKGROUND

The engagement of citizens allows to integrate important local and community knowledge into the planning process, which can improve the quality of designs as well as the relevance of decisions to the community (Sanoff 2006). Therefore, the involvement of citizens in urban planning and decision-making processes has been considered a requisite, but its objectives, the information that is provided to citizens, the stage of the planning process citizens can get involved in and the techniques that are used to do so vary widely (Brody et al. 2003) (see figure 1).

In the past decades, the advancements in information and communication technology (ICT) have led to the development of new digital tools to complement more traditional participation methods, such as face-to-face meetings and workshops, focus groups and surveys (Kleinhans et al. 2015). One of the earliest examples of digitally enabled participatory design is that of PARTIAL, a parametric CAD system devised by Robert Aish and Jan Fleming in 1977. PARTIAL provided a context in which both professional designers and the end-users could collaboratively design and evaluate a particular building typology. Specifically, it consisted of a space-planning drawing interface that was accessible by both architects and lay persons. As the end user would evolve her or his design, it would be simultaneously evaluated by a certain set of criteria that were relevant to the typology itself (noise, accessibility, lighting). Nevertheless, the evaluation was not meant to trump human judgement, but augment it: *"[PARTIAL] provided a context where the designers/participants could combine their own subjective design ideas with the necessary technical requirements"* (Aish and Fleming 1977).

In 1977, PARTIAL could not leverage the potential for outreach offered by the internet, as it did not exist; consequently, its users needed to be co-located physically with the computer itself. The advent of web-based tools for public participation in recent years has allowed to address and reach a larger and more varied audience (Bizjak 2012). Web-based engagement applications include so-called public participation geographic information systems (PPGIS), such as Maptionnaire [2], which allow to collect information on existing needs and challenges through participatory mapping and have been employed in the preplanning stages of urban design. Online 3D modelling applications, such as Minecraft [8], have supported the active involvement of citizens in design and planning projects.

Also, planning support systems for expert designers have moved towards web-based services in recent years. Existing Grasshopper (GH) plugins and related applications that support the online viewing and sharing of parametric models and design spaces can be distinguished into three categories: web-based viewers, web-based collaboration platforms, and plugins connecting to other existing online visualisation and mapping platforms.

GH plugins in connection with custom web-based viewers and services primarily allow the sharing of parametric models and design spaces with stakeholders. In this category belongs ShapeDiver [4], which has found its main application area in providing online product configurators on websites. More advanced online interfaces for the exploration of parametric design spaces additionally provide means to filter or strategically traverse the design solution space. Examples include the Design Explorer (Thornton Tomasetti 2015) as well as the Design Space Explorer (Fuchkina et al. 2018). A different type of application in the field focuses on connecting to and visualising parametric models on existing online platforms, such as the plug-in Giraffe (Leung et al. 2019), which allows to visualise and interact with geo-located parametric models in Mapbox [3].

GH plugins and toolboxes for online within or across platform collaboration help establish communication and collaboration workflows to support design and development processes in the architecture, engineering and construction industry (AEC). An example of such a platform is Speckle [5]. It posits itself as a data platform for the AEC industry that facilitates design communication and coordination. Currently, it offers several software specific integrations that allow data ingress and egress from GH, Dynamo, Rhino, etc., as well as management and coordination functionality. Speckle's online viewer, similar to other solutions, serves as visualisation and communication platform for exchange within design teams but also with other stakeholders from non-design related domains.

Although web-based applications and platforms for citizen engagement in urban design and those supporting design collaboration, visualisation and sharing in AEC pursue similar goals in as such that they try to engage and connect different stakeholders in the design process, the connection between the two has to the authors' knowledge not been tested before. In this paper, we therefore present an approach that positions the use of online DSE applications in citizen engagement as a way to facilitate participation in urban design.

## MATERIALS AND METHODOLOGY

In the scope of a user study we tested the applicability of the existing design space exploration tool and GH plug-in Beta.Speckle [6] for citizen design engagement. For the user study we implemented a design exercise, which provided a set of design alternatives for the development of the neighbourhood next to the upcoming Cantonment MRT station at Tanjong Pagar in Singapore. The exercise formed part of the "Ideas for Tanjong Pagar" study [9], which provided a platform for the testing of several online exercises (see also Tomarchio et al. 2019).

### *The Design Space Exploration Application Beta.Speckle*

Beta.Speckle [6] is an early version of the more advanced Speckle platform [5]. It consists of a set of GH components and an online viewing platform, which allows to explore a range of pre-computed variations based on a set of input parameters that can be ex-

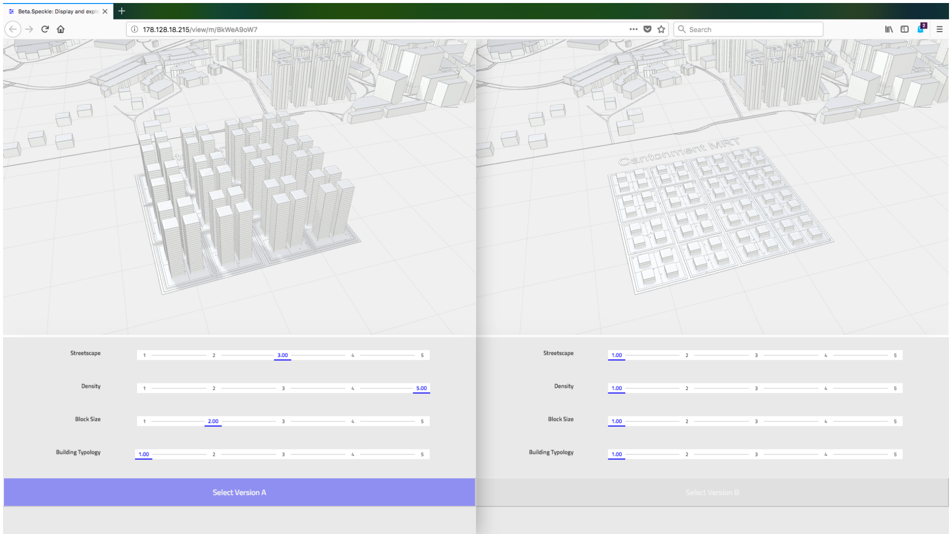


Figure 2
The DSE Beta.Speckle application and exercise.

plored choosing different options on a slider-like input mask. Although Beta.Speckle allowed to export and display coloured meshes, we decided to use a plain model for a higher performance of the application. For the study, the online interface provided a comparative view, which allowed to compare two selected designs side by side (figure 2).

## *The Design Exercise*

The design exercise consisted in the choice of a preferred layout for the site next to the new Cantonment MRT station. The underlying parametric model allowed to explore layout variations, which were derived from SpaceMatrix characteristics (Berghauser-Pont and Haupt 2010) and included variations in building intensity, i.e. the floor space index (FSI) or gross plot ratio (GPR), in network density (Nf) and street profile width (b), as well as of coverage, i.e. the ground space index (GSI). Participants were presented with the following parameters for exploration:

- **Streetscape**: the profile and width of the main streets, from pedestrian friendly neighbourhood street to cycling friendly main street to public transport boulevard.
- **Block Size**: the amount and size of urban blocks in the neighbourhood.
- **Building Typology**: the typology of the buildings, from point, row to block buildings.
- **Density**: the density on the site, i.e. the amount of floor space available for people to work and live in the neighbourhood.

Participants could vary the layouts by choosing one of five options for each of the four parameters (see figure 3). In total, the model thus provided 5ˆ4 = 625 design variations. The options for building typologies were based on Martin and March (1972 in Berghauser-Pont and Haupt 2010, p. 172) and included a point or tower typology; strip or row housing; and court or block types. The streetscapes ranged from neighbourhood and main streets to boulevard profiles, which could be distinguished by their varying number and arrangement of car, bicycle, and public transport lanes.

The design space of the model is depicted in the SpaceMatrix diagrams for FSI and GSI as well as Nf and b in figures 4 and 5. The urban layout variants are clustered in five vertically distributed bands, which are determined in the first diagram by the density and in the second by the block size. The profile width of the five streetscape options determines the horizontal distribution of the design variants in figure 5.

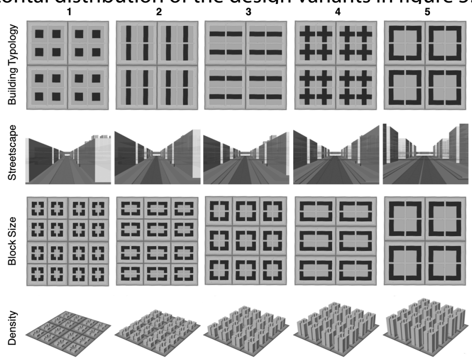


Figure 3
Overview of the design parameters and options, which form the solution space of the parametric model.

### *Participants*
Thirty-two participants (16 female, 15 male, 1 other) took part in the main study, which took place in June 2018. The majority of participants were bachelor or master degree level students (29 out of 32) and had no background in urban planning (31 out of 32). The average age of participants was 24 years.

### *Study Set-Up and Data Collection*
The user study was organised in groups of up to four participants. The DSE exercise was completed as one of three exercises in varying order, with the other two exercises based on the Quick Analysis Kit (Mueller et al. 2018). Prior to the start of the study, the exercises were set up as tabs in Google Chrome on laptops.

After a short introduction, participants were asked to first explore the different urban design propositions provided by the application and to then submit their preferred layout for the site. The instructions deliberately left room for interpretation to understand the decision and meaning making processes underlying the selection of a specific design proposal. The exercise took about 10 minutes to complete. After submission, participants were asked to fill in a questionnaire. The survey consisted of a mix of open and closed questions, which asked for user feedback on the design choice, the application and exercise, as well as for demographic information of participants. To evaluate the usability of the tool, we employed the system usability scale (SUS) developed by Brooke (1996). It has been widely applied, as it is technology independent and reliable, easy to use and to understand (Brooke 2013).

## RESULTS
This section presents the results of the user study, which include an analysis of the selection of design variants and the underlying reasons for specific design choices, as well as an analysis of the usability of the application, the user experience and an overview of participants' suggestions for improvement.

### *Selected Design Variants and Reasons Underlying the Choice of Specific Parameter Options*
The participants submitted a total of 30 unique preferred design variants, which spread over the design space of the parametric model. The distribution of the chosen options for each of the four model parameters can be seen in figure 6.

Analysis of the collected qualitative feedback elicited different motives and reasons for the selection of specific parameter options. Reported considerations in respect to density fell primarily into two categories: either participants selected high density and high-rise options (4 or 5) in response to the Singaporean challenges of land scarcity and increasing population size, or they selected moderate density and low- to mid-rise options (2 or 3) in response to the context with similarly, moderately dense areas to the north of the site. The majority of participants (18 out of 32 votes) decided for the latter further citing aspects of spaciousness, comfort and liveability underlying their decision in favour of the low-rise option 2 and the balance between density and spaciousness, considerations of natural light and shading, natural ventilation and urban heat island effect (UHI) in the case of density option 3.

In respect to the building typology, analysis of submissions found a preference for perimeter blocks (option 5, 12 votes) and point buildings (option 1, 10 votes). Point buildings were selected for their perceived aesthetic appeal and associated with sophistication, timelessness, and simplicity: *"The square-ish type building shape (1) that I have selected will be timeless, so the design of the buildings will not pale in comparison to the fast-paced development of the neighbouring district."* (P18)

Layouts with point typology were perceived as less crowded and cluttered, as more familiar, better

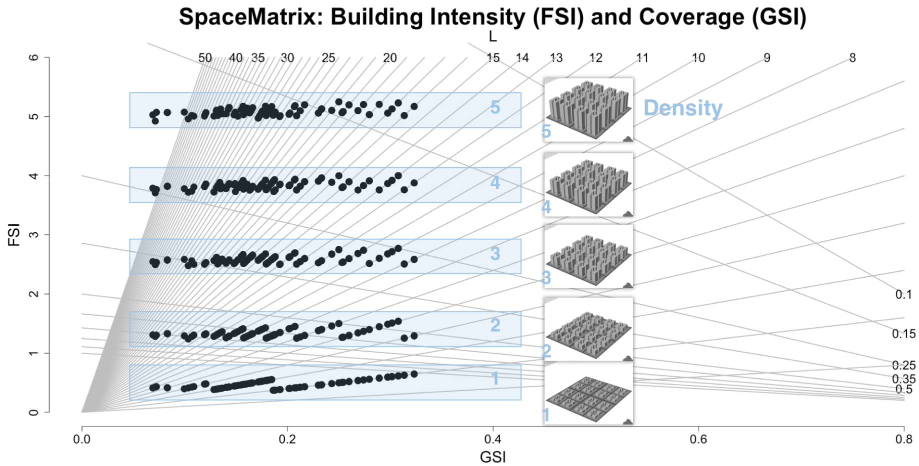


Figure 4
Distribution and design space of the model and its generated variations plotted in the SpaceMatrix diagram for building intensity and coverage. Five vertical bands are distinguishable, which represent the five density parameter options.

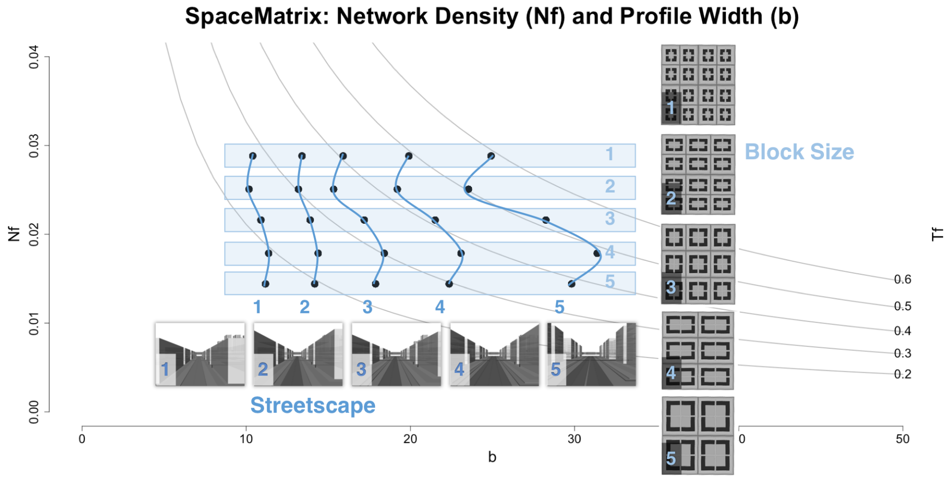


Figure 5
Distribution and design space of the model and its generated variations plotted in the SpaceMatrix diagram for network density and profile width. The five block size parameter options are distributed in five vertical bands, whereas the five streetscape options form horizontal bands.

fitting in with the context and more organised. Block buildings were selected because of the public spaces they enclosed, which could serve as communal areas and host playgrounds, fitness and sports facilities, and because of the perceived opportunities for neighbourhood interaction that could ensue. Strip buildings were chosen because of their orientation and directionality, either facing the MRT (option 2, 4 votes) or facing the CBD (option 3, 3 votes). The form was also considered to allow for more natural light entering the building. The plus-shaped typology (option 4, 3 votes) was primarily chosen for its uniqueness in form and the possibility to connect the buildings via skybridges.

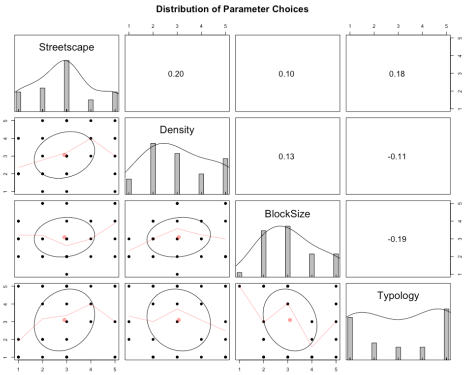


Figure 6
Distribution of chosen options for each of the four model parameters and correlation between parameter pairs.

Participants based their choice of a specific block size on the number of resulting buildings, the impression of spaciousness and the resulting amount of green and open space. Larger block sizes resulted in less buildings (options 4 and 5, 5 votes each), which were associated with a larger central area within or between buildings and reduced complexity of the layout, and was expected to support navigation. However, the majority of participants chose options 2 (10 votes) or 3 (11 votes) offering medium block sizes, which were still associated with an acceptable degree of spaciousness, but were considered to provide a better balance between built up and open space: *"There has to be a balance in between optimum land use, social coherence, space openness and street spaces, which remained the basis for this design."* (P31)

In the choice of a streetscape, participants took into account the profile width of the different options as well as expected traffic flow and density, perceived walkability and accessibility, as well as the amount of space consumed. Streetscape option 3 received the highest number of votes (13 votes), as participants tried to achieve a balance between different spatial, mobility- and traffic-related considerations.

Narrower streetscapes, such as options 1 (5 votes) and 2 (6 votes) were associated with better walkability, comfort and liveability, whereas the wide streetscape of option 5 (5 votes) was associated with easier navigation and with the greater distance between buildings allowing the street space to be used for other, temporary functionalities, such as street malls and parades.

## *Usability of the Tool, User Experience and Suggestions for Improvement*

As stated before, participants were asked to evaluate the usability of the tool according to the SUS. The SUS returns a score in between 0 and 100, which does not represent percentages but percentiles. The usability of the application was rated at 66, which is situated in the second quartile, at the lower end of acceptable in the acceptability range and in between the adjective attributes of 'ok' and 'good' defined by Bangor et al. (2009).

Although participants found the application easy to use and easy to learn, a time lag in loading the model between parameter changes affected the user experience and efficiency of use. Participants perceived the time lag as disruptive, inhibiting the workflow. Furthermore, the participants discussed the usefulness of the exercise critically. They felt the depicted design was very generic and repetitive, and thus did not address urban design in its complexity. In respect to the set-up and framing of the exercise, participants mentioned they would have required additional contextual information and clearer instructions.

Furthermore, the tool was perceived as a tool for expert users. Participants found it difficult to envision what the proposed designs would look like in reality and to understand what the design parameters meant and how they affected the design. Also, they could not discern differences between some of the options and would have required explanations of individual parameter options. Furthermore, they felt that the linear scale misrepresented the functionality of the interface element and the relationship between the different options, which did not actually constitute a continuous scale, but a selection of discrete values. In respect to functionality, participants commented negatively on the lack of variations in the designs and the limited choices. The lack of creative freedom was perceived as a shortcoming and a limitation of the tool.

Accordingly, participants suggested improvements, which regarded the design representation, the user interface and functionality of the tool. Participants strongly suggested using colours for the model and letting users explore the model from an on-ground perspective rather than the bird's eye view, as this could help to make designs more accessible to non-expert users. They further suggested to provide more detailed explanations of the parameters and their impact. In respect to the functionality, participants suggested to increase the level of creative freedom by allowing buildings to be adjusted individually or to be moved freely on the site.

## DISCUSSION

The feedback collected during the user study shed light on the preferences and values underlying design decisions of participants. As had been previously established by Gjerde (2017), visual order was also found in this study to be an important factor underlying participants' choices in respect to urban arrangements. This manifested itself in the avoidance of perceptually cluttered and crowded designs and in a preference for more visually organised and balanced proposal; organised in respect to the choice of simple, point typologies and balanced in respect to the visual balance between built up and open space. Aspects of visual order also underlay the preference for proposals with a reduced level of complexity regarding the number of buildings and resulted in the choice of specific density values to allow for a consistency in height in relation to the urban context.

Participants' decisions were further based on values and expressed themselves in the choice of a solution or option, which was perceived to uphold these. Value categories found in urban development are economic, environmental, or social in nature (Friedman et al. 2008, p. 11). In our user study, economic values manifested themselves in considerations related to land scarcity and land consumption leading to the choice of higher density options. Environmental values surfaced in form of considerations related to the sustainable development of the site aiming to capitalise on solutions providing natural lighting, shading, and ventilation and reducing the UHI effect, whereas the social value of community surfaced in the reasons given for the choice of the block typology. Its courtyard was perceived to provide spaces for the community and opportunities for neighbourhood interaction. Further values that were exhibited regarded a walkable neighbourhood, which resulted in the selection of less wide street profiles, as well as a green and liveable, but at the same time accessible neighbourhood, which was linked to the aim of achieving an economic, environmental, and functional balance between built up, street as well as open/green spaces resulting in the selection of streetscapes and block sizes of medium width and size.

In the future design of participatory exercises it will be important that the designer is aware of the values and preferences underlying and driving design decisions of laypeople and pays attention to these in their framing. Friedman et al. (2008) suggested to offer a range of indicators in interface design that clearly relate to and address the values of the user group. Our exercise lacked clearly identifiable indicators, which manifested itself in participants criticising the lack of information and explanations on the impact of the available parameters on the design. This affected the effectiveness with which participants could select a solution matching their design intentions and goals. The provision of relevant indicators, either as input parameter to guide the design space exploration process or as output parameters in form of design feedback and performance characteristics, will consequently allow laypersons to more effectively express and attain their goals.

Furthermore, the definition of clear and attainable participation and engagement objectives is important to ensure that the input provided by non-experts provides meaningful insights and value to the designer (Sanders, Brandt, and Binder 2010). However, it is important to note that the limitations of the medium of exchange employed act both on the designer as well as the end-user. From the designer's point of view, authoring a parametric model that can be efficiently translated into a web-based exploration framework, such as, in the case of this current study, the Beta.Speckle interface, imply sacrificing some of the initial fluidity and sophistication that the original authoring tool (Grasshopper) offers. Other frameworks, while offering a more flexible tool to the end-user, partially relinquish the precision, control, and evaluation methods that a parametric model offers. Similarly, from the point of view of an end-user, engaging with such a tool implies a potentially onerous task of understanding an abstract representation that the designer enabled, one that does not necessarily match a lay-person's expectations.

Consequently, one must not underestimate implications on the design process that such tools might have. Like with every other tool, digital or not, Beta.Speckle imposed certain limitations on the authors in how they could define the parametric model; similarly, it imposed a certain mental effort on the participants due to its available representation qualities. Furthermore, some constraints, such as the size of the solution space exploration, can be seen as having opposing values: for example, from the designer's point of view, a larger solution space is seen as a positive quality; conversely, for an end-user, a larger solution space may introduce further mental fatigue through the appearance of "choice paralysis" (Barry 2004). Nevertheless, given the current pace at which the underlying technology evolves, the trade-offs will, most probably, have a diminishing impact as the frameworks progress.

## CONCLUSION

This paper described an approach for citizen engagement, which allows designers to share a parametric design space via the online interface and application Beta.Speckle with a lay-audience. The approach was tested and evaluated in a user study, in which participants were asked to select a preferred urban layout for a site in Tanjong Pagar. Participants could explore the given design space by varying building typology, density, streetscape and block size.

Analysis of the design exercise uncovered the preferences and values of participants and how these affected the choice of specific design variants. A preference for visual order resulted in the selection of visually simple, organised and balanced proposals, as well as proposals that provided visual consistency in relation to the surrounding context. Values of walkability resulted in a preference of narrower streetscapes, values of an accessible, green, sustainable and liveable urban neighbourhood in a balanced distribution of built-up, open, and street spaces with limited density. Economic considerations related to land scarcity led to the choice of high density layouts and the social value of community resulted in a preference for the block typology offering communal spaces. For the future design of exercises it was therefore concluded that the definition of indicators relating to citizens' values and preferences will allow for a more effective exploration of the design space and provide more meaningful results.

Although Beta.Speckle was considered easy to use, issues with the usability and usefulness were detected. Possible improvements relate to the presentation of the model, as well as the user interface and functionality of the tool. Nevertheless, the investigation has shown that the approach provides an interesting avenue to support the exchange between expert and laypeople in urban design. Future work in the area should include investigations into the impact of the approach on the expert design process.

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