D-ARE: A LOCATION-BASED AUGMENTED REALITY TOOL FOR PUBLIC ENGAGEMENT IN DESIGN OF BUILT ENVIRONMENTS

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Abstract. In this paper, we explore the systems for engaging the public in evaluating the design proposals by questioning means to improve the democratisation of designing built environments. We argue that a democratic and participatory design can be achieved when community members are motivated to contribute actively to the design process of shaping their environment. Our goal is to provide a critical understanding of how existing tools have integrated or failed to motivate the public to be part of design decision-making and collect feedback effectively. Grounded in our literature review, we propose a location-based mobile-AR prototype to create an inclusive, data-informed design process. The mobile platforms are suitable for an AR application because of their accessibility, familiarity, and ability to support in-situ awareness notices. The tool features include interactive and in-situ form views in AR, performance data views, and interfaces for sharing insights through discussion threads. A challenge for such solutions is transforming complex design data for different non-specialist users through an interactive AR experience. The proposed AR interface is a step towards bridging the gap between designers and community members, ensuring that built environments are created with the perspectives of those for whom they serve.

Keywords. Location-based AR, design data democratisation, public engagement, built environment design, urban design, design analytics.

1. Introduction

Public engagement involves various activities and strategies to gather input, share information, and foster dialogue for inclusive decision-making. The term refers to the process of engaging a community as stakeholders in the planning and decision-making through, e.g., meetings, workshops, surveys, focus groups, and online platforms. As an umbrella term, it constitutes approaches for understanding the opinion of a community toward finding solutions for the problems that will impact their lives (Nabatchi and Amsler, 2014; Chow and Leiringer, 2020). The objective is to address shared challenges, meet individual needs, enhance outcomes, and foster social cohesion

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between planners, designers, policymakers, and the community (Cascetta and Pagliara, 2013). In the context of built environment design, the term typically entails collective decision-making wherein diverse stakeholders, serving as community representatives, actively engage across various project phases. As defined by Næss (2016), the built environment encompasses more than the physical buildings and urban spaces. It also involves the interactive dynamics between these physical elements and how they influence and are influenced by human behaviour and social interactions.

Public engagement in built environment design faces various challenges, including reaching and maintaining engagement with a distinct and often diverse audience. Designers must navigate communication barriers and ensure representation from different demographic groups, considering age, socioeconomic status, and cultural backgrounds. Balancing competing interests and opinions within the community poses another challenge, as well as managing expectations and potential conflicts. Limited resources can hinder engagement efforts in terms of time and budget. Additionally, there might be scepticism or distrust among the public regarding the impact of their input on the final decisions, requiring efforts to build transparency and credibility (Konsti-Laakso and Rantala, 2018). Overcoming these challenges is crucial to realising the benefits of public engagement in creating more responsive, inclusive, and successful designs (Cascetta and Pagliara, 2013).

Web applications can be a means to reach a wider and diverse audience, enabling virtual participation for those who may be excluded otherwise. Increasing participation can promote equality and inclusion while creating connections between stakeholders and decision-makers (Hovik and Giannoumis, 2022). For example, social web applications tailored for design reviews can allow stakeholders to assess the proposed design ideas from their perspectives while seeing and replying to others' (Alsalman and Erhan, 2022). Augmented with data analysis, identifying patterns in comments can guide the decision-makers when reviewing opinions (Leyden et al., 2017; Katika et al., 2021; Alissandrakis and Reski, 2017; Awang et al., 2020; Wu et al., 2021).

Immersive Virtual (VR) or Augmented Reality (AR) environments have been increasingly used throughout the design and planning phases, enabling designers to visualise their design and allowing the stakeholders to experience higher levels of engagement (Saßmannshausen et al. 2021; Kayla et al., 2021; Farshid et al., 2018; Boos et al. 2023). We explore tool features that can motivate and engage design stakeholders in a built-environment project based on AR methods for in-situ design visualisation and assessment. For this purpose, our study seeks to answer the following questions:

- How can multiple design alternatives and their associated data be shared in an in-situ AR environment to enable and enhance stakeholders' engagement?
- What tools are used for public engagement relevant to the built environment's design, independent from their solution platform?
- What are the characteristics of interfaces that could be used to engage design stakeholders in in-situ feedback sharing?

Building on a literature review and investigating the existing digital solutions, we present requirements for system features addressing design democratisation through AR. We developed D-ARE, an AR-based social-web tool prototype, demonstrating

how AR-driven, data-informed design democratisation can be realised. We also reflect on experiences and share the lessons learnt for others.

2. Tools for Engaging Public

Effective public engagement can lead to successful and sustainable built environments by considering diverse perspectives, addressing community concerns, and creating a sense of ownership among the stakeholders. One of the goals is to ensure that the decisions made address the needs of the people, promoting a sense of place and enhancing the overall quality of life (Konsti-Laakso and Rantala, 2018). Below, we summarise and compare four public engagement systems: ChangeExplorer (Wilson, Tewdwr and Comber, 2019), Metropolis (Aguilar et al., 2021), D-ART (Alsalman and Erhan, 2022), and #MySydney (Williamson and Ruming, 2020). We aim to propose system ideas to improve public engagement based on our findings from analysing these tools.

2.1. CHANGEEXPLORER

ChangeExplorer, a public engagement application for smartwatches, tracks the users' location and notifies them when they are around the vicinity of new urban changes (Wilson, Tewdwr and Comber, 2019). The notifications ask the users to provide feedback by responding to a short on-screen questionnaire. Notifications and in-situ interactions helped engage citizens to share their immediate but less informed reactions. Its evaluation revealed a tension between the opportunity for a quick interaction and the need to access detailed information about the changes for those interested in an in-depth engagement. For the latter, ChangeExplorer running on a smartwatch was unsuitable, e.g., for written comments with pictures and annotations. It highlights that while the participants responded positively to in-situ reviews, the platform's form factor constrained a deeper interaction for personalised feedback.

2.2. METROPOLIS

Aguilar et al. (2021) studied urban patterns and citizen behaviours within the context of a smart city through a mobile app called Metropolis. Their research demonstrated how a collaborative approach influences urban planning and citizen satisfaction. Metropolis is a serious game application that allows users to decide about city development based on their preferences by presenting two distinct cases: one involving social communities with similar interests and another requiring collaboration among individuals with different characteristics. The study's findings showed that Metropolis is effectively used for the formation of urban zones and patterns based on collective player decisions. The positive impact of collaboration resulted in higher satisfaction among the users, positioning the serious game approach as a contender for participation, collaboration, and democratic decision-making. However, it lacks in-situ and comparative review features of different scenarios.

2.3. D-ART

D-ART, developed by Alsalman and Erhan (2022), is a web-based platform for supporting collaborative and data-driven design reviews of design alternatives. D-ART integrates customisable and interactive visualisations augmented by feedback sharing about and comparative analytics of form, performance, and design objectives data. By presenting the design alternative through five main views—namely projects browser, project view, alternatives and comparison view, and building block view—D-ART enables the design stakeholders to share their feedback in a discussion thread, typically seen in social web applications. The stakeholders can interact with each other while commenting on the proposed designs. Feedback sharing is limited to textual and outside of the visualisations, which detaches comments from context. Although alternative comparison features were considered valuable, the evaluation of the system revealed the difficulty in developing a mental model of the flow due to the modal navigation between views, interrupting the flow.

2.4. #MYSYDNEY

Williamson and Ruming (2020) analysed the #MySydney campaign by Sydney's Department of Planning and Environment, which aimed to involve citizens in district planning through social media channels as part of an overarching digital marketing strategy. Their study pointed out that despite the broad outreach, the engagement was predominantly one-directional, with the department collecting data without resulting in significant interactive dialogue. They identified issues with data representation linked to privacy settings and low engagement. A particular issue was using a generic hashtag, #MySydney, which was quickly co-opted by single-issue groups, diverting attention from the intended dialogue. As they concluded, the campaign showed a lack of genuine engagement and suggested the planning agencies being responsive and prepared for unexpected concerns brought up by citizens. The researchers also stressed the need for a multidisciplinary team to engage the public.

2.5. SUMMARY OF TOOL ANALYSIS

The comparison of the public engagement tools reveals distinct features and functionalities (Table 1). ChangeExplorer stands out for its emphasis on quick and in-situ feedback, making it a valuable approach for understanding design implications within specific environments. In contrast, #MySydney, aimed at encouraging public engagement in urban planning through commonly used social media, fell short in being focused and collecting relevant or meaningful consensus. D-ART, with its unique focus on design review focusing on data of alternative solutions, proves particularly useful for projects requiring a detailed evaluation by its stakeholders. On the other hand, Metropolis distinguishes itself by combining engagement and fun, appealing to users seeking an enjoyable experience while contributing to design decision-making. Both ChangeExplorer and Metropolis have dedicated mobile applications, enhancing accessibility and user reach. Each tool caters to different aspects of the design decision process, offering diverse features that can be strategically chosen considering the project characteristics and the goals for public engagement.

3. Data-informed and AR-Based Design Democratization

We aim to create an engaging and inclusive AR application for mobile platforms where design proposals can be shared with their stakeholders in situ to engage them in sharing their insights and feedback by reviewing design data. This choice is deliberately based on mobile platforms' potential for immediate availability. Drawing insights from literature, we assert that people are more likely to share their opinions when present in the same context. Mobile platforms are a practical choice because of their in-situ awareness and notification capability.

Table 1. A comparison of the four systems for public engagement (3, 5) helps public participants make informed judgments (1, 2, 4) or leads to reaching a wider audience (6).

System Features	ChangeExplorer (Wilson, 2019)	#MySydney (Williamson, 2020)	D-ART (Alsalman, 2021)	Metropolis (Aguilar, 2021)
1. Design comparison	no	no	yes	no
2. Provide detailed data	no	--	yes	yes
3. Collaboration	no	yes	no	yes
4. In-situ/contextual feedback	yes	no	no	no
5. Engagement and Fun	yes	yes	--	yes
6. Working prototype system	yes	no	yes	yes

We developed D-ARE as a low-fidelity system to explore features for location- and AR-based public engagement tools. D-ARE stands for Design Democratization through AR-based Evaluation. Running on mobile devices, the D-ARE aims in-situ feedback sharing through interfaces for viewing design proposals, their data on demand, and feedback sharing (Figure 1).

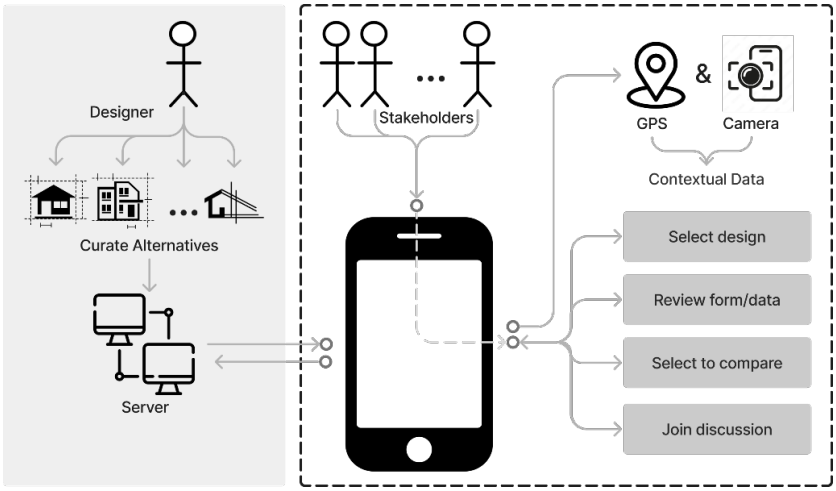

Figure 1. The D-ARE components and information exchange schema.

3.1. THE PREMISE OF D-ARE FOR IN-SITU PUBLIC ENGAGEMENT

AR applications on mobile platforms show potential for collaboration among various design stakeholders due to their accessibility and features for combining the physical and virtual views augmented by rich interaction affordances. Overlaying the views into the real context offers an advantage for immersion (Shin, 2019). On mobile devices, they can provide first-hand user experience for reviewing proposals viewed virtually, imposed on physical real-time views. They can also offer a perspective closer to the final appearance of a project, even in its conceptual development, incorporating subtle factors like sky, light, and movement, which are often overlooked in traditional methods. Another advantage lies in the replaceability and repeatability of AR content, enabling continuous design adjustments, risk reduction, and conflict resolution in the decision-making phases, potentially saving effort and cost (Wang and Lin, 2023). Therefore, an AR experience becomes more relevant, offering a clear vision for evaluating and reflecting on how design proposals could affect their environment.

3.2. SYSTEM REQUIREMENTS ELICITATION

We developed D-ARE through iterative and incremental phases. In the initial phase, we conducted a focus group study involving six architects to define the high-level system requirements by asking them to consider specifically the potential of AR combined with mobile platforms for a location-based application. As part of this inquiry, the focus group was instructed to express their opinion on how stakeholders could use their current location to explore and compare different design proposals. The group discussed the tool features for engaging individuals with varying experience levels and interests to foster active participation.

The focus group inquiry led us to develop user stories as small testable parts of potential use cases capturing the functional requirements for the D-ARE's design. The user stories evolved through two-week sprints spanning over three months, as in Scrum methodology, and parallel to user interface design. Each sprint concluded with a formative evaluation in the research team; due to the time constraint, running evaluation sessions with participants was impractical. The following section presents the system features we developed following this iterative process.

3.3. AR-BASED SYSTEM FEATURES

3.3.1. Interactive engagement level

In terms of interaction, we offer stakeholders varying levels of engagement. D-ARE tracks the location of its users. It can present design proposals on-demand or through in-situ notifications in an interface similar to social media applications. The designs can be in any environment at any scale (Figure 2-left). Switching to the map view, the users can identify the location of the new proposals around their vicinity and see the paths to reaching the sites (Figure 2-centre, right). The design proposals can be viewed overlayed on their proposed physical location with a close-to-realistic scale and view while presenting access to any other data the design team shares. Such data can be numerical, such as

cost, usable area, occupancy load, or categorical, such as function, style, and options. The users can navigate between views by translucent overlayed interfaces, e.g., for revealing geometric form data on graph visualisations. This multi-level interaction aims to cater to diverse user preferences.

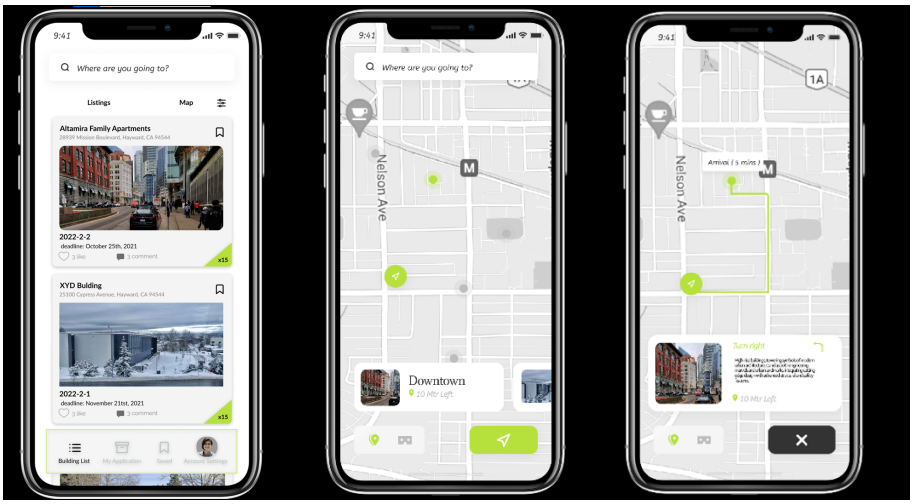

Figure 2. D-ARE interfaces include a social-media-like view (left) of existing projects in situ (centre) and the ways to reach them through path suggestions (right).

Figure 3. An In-situ virtual view of a design proposal can be viewed from different angles (left), while an on-demand view of relevant data summary can be shown as expandable data visualization (centre). The stakeholders can share their comments on a social-media thread in D-ARE (right).

3.3.2. Design Data Presentation

D-ARE presents curated design data in two main categories: form and performance

data. The 3D models are embedded in the view of the surroundings, allowing individuals to explore various perspectives by walking around the proposals. Additionally, it can provide on-demand data specific to each project through simple charts and text, engaging stakeholders to choose the aspects of design they wish to review and comment on. It is not uncommon to have multiple proposals presented when engaging the public. Therefore, the D-ARE users can switch between different alternatives within the context. The designers curate alternatives and their relevant data to determine how the stakeholders respond to the proposals (Figure 3-left, centre).

3.3.3. Feedback and Insight Sharing

D-ARE provides a social-media-like interaction for the users to give feedback and engage in conversations. They can share their comments with the option to upload pictures and add annotations (Figure 3-right). We envision this feature will help gather diverse perspectives from stakeholders informed by assessing how the proposed built environment can exist within the physical structure, contributing to a richer and more informed design discourse.

3.3.4. Design Review and Updates

We conducted continuous and formative in-team evaluations as we developed system ideas on the low-fi prototype. A recurring theme in these reviews emerged towards developing simplified views and interactions for comparative analysis of the proposals, possibly on a side-by-side, juxtaposed view, while providing affordances for accessing their form and performance data. Two critical challenges to achieving these goals are information overload and interaction (e.g., navigation) on small-screen mobile devices. Although we have yet to address these challenges, we updated the D-ARE comparison view (Figure 4). Another theme for improving design democratisation centred around feedback collection. The interfaces must be inclusive so diverse users can express their opinions through 'ranking', 'liking', or 'voting' rather than writing comments. We experimented on how this can be achieved on an updated D-ARE (Figure 4).

Figure 4. Proposed changes for reviewing alternatives side-by-side. The discussion interface includes feedback sharing while enabling responses by commenting and annotation input in situ.

4. Discussions and Conclusion

We presented a study questioning how to improve public engagement when evaluating and making decisions on built environment design proposals. Our literature review and analysis of four tools demonstrated a consensus on the importance of public engagement and the need for novel tools for inclusive and engaged participation. However, it also revealed that there are challenges for public participation, such as reaching and maintaining engagement with diverse stakeholders with competing interests, reaching out to different groups to ensure equal representation, limited resources, and distrust. Overcoming such challenges is not trivial, requiring efforts to build transparency and credibility. As part of our research, we propose partially addressing some of these challenges through a location-based augmented reality (AR) application called D-ARE. Among our goals, first, we aim to provide 'transparency' for the design decisions that will affect the public through in-situ and data-informed evaluation of design proposals. Secondly, we demonstrate accessibility to information on-demand without any formal, scheduled, or biased public gathering and enable the public to interact with each other and the design decision-makers by sharing their feedback. Third, tools like D-ARE should be 'fun' or 'inviting' to encourage evaluating the proposals and building a community.

D-ARE has four distinct interface features: an in-situ AR view of the design form providing an immersive experience, design-data visualisations familiar to non-specialists, a comparison view (if applicable) to see proposals juxtaposed and a social interaction view where the public can share their feedback. We refined the feedback-sharing features by providing the stakeholders with focused and in-depth feedback mechanisms and quick responses using 'Like', 'Rate', and 'Rank' options. To initiate a rich feedback-sharing experience, we aim to motivate dialogue among the stakeholders is necessary. On D-ARE, the stakeholders can access, read, and interact with each other, ensuring consensus and satisfaction of the final design decision. Users of D-ARE are expected to have a basic understanding of their surroundings, be able to use smartphones, and interpret basic graphs like bar charts or line graphs. While smartphones are suggested for convenience, we understand that certain demographics may not have access to them or cannot use all their features. Additionally, individuals less familiar with digital technology may find such systems overwhelming, and those with cognitive, visual, or motor control impairments may face challenges in navigating mobile interfaces. To ensure inclusive engagement in built environments, alternative systems must be developed to cater specifically to the needs of diverse user groups. To promote inclusive engagement in built environments, alternative systems must be explored to cater to the specific needs of diverse users.

As a future study, we will implement a minimally viable version of D-ARE to study its potential for increasing public engagement and meaningful feedback sharing by acknowledging the social and personal challenges in achieving this. Emerging technologies, such as AI-based discourse analysis, can reduce the labour for feedback assessment. Next, we will focus on compiling, summarising, analysing and reporting the stakeholders' feedback through another system tailored for designers.

References

Aguilar, J., Díaz, F., Altamiranda, J., Cordero, J., Chavez, D., and Gutierrez, J. (2021). Metropolis: Emergence in a Serious Game to Enhance the Participation in Smart City Urban Planning. *Journal of the Knowledge Economy*, 12(4), 1594–1617.

Alissandrakis, A., and Reski, N. (2017). Using Mobile Augmented Reality to Facilitate Public Engagement. 2021, 99–109. https://urn.kb.se/resolve?urn=urn:nbn:se:lnu:diva-69265

Alsalman, O., and Erhan, H. (2022). D-ART for collaboration in evaluating design alternatives. International Journal of Architectural Computing, 20(1), 114-128.

Awang, A. J., Majid, M. R., and Rusli, N. (2020). Augmented Reality (AR) for Promoting Public Participation in Urban Planning. Built Environment Journal, 17(3), 51.

Boos, U. C., Reichenbacher, T., Kiefer, P., and Sailer, C. (2023). An augmented reality study for public participation in urban planning. J. of Location Based Services, 17(1), 48–77.

Cascetta, E., and Pagliara, F. (2013). Public engagement for planning and designing transportation systems. Procedia-Social and Behavioural Sciences, 87, 103–116.

Chow, V., and Leiringer, R. (2020). The practice of public engagement on projects: From managing external stakeholders to facilitating active contributors. Project Man. J., 51(1).

Farshid, M., Paschen, J., Eriksson, T., and Kietzmann, J. (2018). Go boldly!: Explore augmented reality (AR), virtual reality (VR), and mixed reality (MR) for business. Bus. Horizons 61 (5), 657–663.

Hovik, S., Giannoumis, G. A., Reichborn-Kjennerud, K., Ruano, J. M., McShane, I., and Legard, S. (2022). Citizen Participation in the Information Society: Comparing Participatory Channels in Urban Development (p. 196). Springer Nature.

Irvin, R. A., and Stansbury, J. (2004). Citizen participation in decision making: is it worth the effort? Public administration review, 64(1), 55-65.

Katika, T., Bolierakis, S. N., Tousert, N., Karaseitanidis, I., and Amditis, A. (2021). Building a Mobile AR Engagement Tool: Evaluation of Citizens Attitude Towards a Sustainable Future. In *Virtual Reality and Mixed Reality* (pp. 109–125). Springer Int. Pub.

Konsti-Laakso, S., and Rantala, T. (2018). Managing community engagement: A process model for urban planning. *European J. of Operational Research*, 268(3), 1040–1049.

Kaya Alpan, Z. B., and Çatak, G. (2021). Use of Virtual Reality in Participatory Urban Design. *In Proc. of PUDCAD* 2020 (pp. 193-203). Springer Int. Pub.

Leyden, K. M., Slevin, A., Grey, T., Hynes, M., Frisbaek, F., and Silke, R. (2017). Public and stakeholder engagement and the built environment: a review. Current environmental health reports, 4, 267-277.

Nabatchi, T., and Amsler, L. B. (2014). Direct Public Engagement in Local Government. The American Review of Public Administration, 44(4_suppl), 63S-88S.

Næss, P. (2016). Built environment, causality and urban planning. Planning Theory and Practice, 17(1), 52-71.

Saßmannshausen, S. M., Radtke, J., Bohn, N., Hussein, H., Randall, D., and Pipek, V. (2021). Citizen-Centered Design in Urban Planning: How Augmented Reality can be used in Citizen Participation Processes. Designing Interactive Sys. Conference 2021, 250–265.

Shin, D. (2019). How does immersion work in augmented reality games? A user-centric view of immersion and engagement. Inf. Commun. Soc. 22 (9), 1212–1229.

Wang Y and Lin Y-S (2023) Public participation in urban design with augmented reality technology based on indicator evaluation. Front. Virtual Real. 4:1071355.

Williamson, W., and Ruming, K. (2020). Can social media support large scale public participation in urban planning? The case of the #MySydney digital engagement campaign. International Planning Studies, 25(4), 355–371.

Wilson, A., Tewdwr-Jones, M., and Comber, R. (2019). Urban planning, public participation, and digital technology: App development as a method of generating citizen involvement in local planning processes. Env. and Plan. B: Urban A. and City Sc., 46(2), 286–302.

Wu, Y., Che, W., and Huang, B. (2021). An Improved 3D Registration Method of Mobile Augmented Reality for Urban Built Environment. Int. J. of Comp. Games Tech., 2021.