# DEVELOPMENT OF A MOBILE AUGMENTED REALITY APPLICATION TO ENHANCE YOUTH ENGAGEMENT IN DESIGNING PUBLIC SPACES

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## DECLARATION

I declare that this is my work and this thesis/dissertation does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 14.04.2025

The above candidate has carried out research for the PhD/MPhil/Master's thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. Chathura De Silva

Signature of the Supervisor: Date: 12/09/2025

Name of Supervisor: Dr. Nayomi Kankanamge

Signature of the Supervisor: Date: 12/09/2025

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# ABSTRACT

Public spaces play a crucial role in shaping the quality of urban life. However, these spaces are often designed by professionals with minimal community involvement in the design process. Even when engagement occurs, traditional methods such as hand drawings, manual mapping, or public discussions limit the general public's ability to visualize and effectively communicate their ideas. This study examines the application of Mobile Augmented Reality as a means to enhance public, specifically youth, involvement in designing public spaces, thereby addressing the existing gap. This research aims to develop and test CityBuildAR, a mobile AR application that enables users to visualize and design public spaces through their smartphones. The methodology comprised a) A systematic literature review, b) A review of existing AR applications in urban design, and c) the development of CityBuildAR using Unity Real-Time Development Platform for Android devices, followed by d) app demonstrations and validation with user groups. Participants were divided into three categories: professionals, university students, and the general public based on their spatial design knowledge: limited, transitional, and professional. The open cafeteria (Sentra Court) at the University of Moratuwa, Sri Lanka, was selected as the study site. The study findings revealed that: (a) Mobile Augmented Reality is an effective way to engage people with limited knowledge in public space design to express their design thinking, (b) Compared to professionals, the general public wanted to have more green elements in the public space; (c) Even though M-AR has the potential to enhance community engagement in designing public spaces, it cannot replace the conventional approaches completely. The study demonstrates the potential of AR in democratizing urban design processes and recommends its integration into future public engagement initiatives. By bridging the gap between professionals and the general public, tools like CityBuildAR offer a novel pathway toward inclusive and participatory urban development.

**Keywords**: Mobile Augmented Reality, Public Participation, Youth Engagement, Public Spaces, Urban Planning

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# LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| AR | Augmented Reality |
| M-AR | Mobile Augmented Reality |
| URA | Urban Redevelopment Authority |
| VR | Virtual Reality |
| GPS | Global Positioning System |
| PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analyses |
| BSB | Backward Snowballing |
| FSB | Forward Snowballing |
| UI | User Interface |
| HCI | Human Computer Interactions |
| GIS | Geographic Information Systems |
| UDA | Urban Development Authority |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

### 1.1.1 Public Participation in Urban Planning

Public participation in urban planning has been historically challenging, particularly due to the complexity of planning processes, limited access to information, and communication barriers (Barthelemy et al., 2013). Conventional approaches often struggled to engage a wide range of individuals in the planning process, which led to unequal representation and exclusion of marginalized communities (Islam, 2011). However, with the emergence of technology, e-participation and digital tangible approaches were introduced for public participation and using technologies such as Augmented Reality (AR), the gap between the decision makers and communities has been reduced (Ben-Joseph et al., 2001a), enabling an inclusive participatory planning (Othengrafen et al., 2023a). AR facilitates the active and inclusive participation of diverse groups, including the ones with limited technical expertise in the planning process, ensuring a wider range of participants are involved and their requirements are considered (Wilson et al., 2019).

According to UN-Habitat (2018), public participation fosters a positive relationship between a government and the public by communicating effectively and solving conflicts collaboratively. Furthermore, Krueger et al. (2001) discuss the perspectives of the general public regarding good participatory planning processes such as maintaining legitimacy and facilitating ideological discussions. It is conceptualized as a power struggle between local landowners and outsiders. Participatory planning is significant to enhance inclusivity and representation in decision-making. For example, in Porto Alegre, Brazil, citizens have been directly involved in the urban planning and budget process since 1989.

The participatory planning approach came into discussion during the 1960s, which integrates citizens in the planning process to create the neighborhoods in the way the community expected to live. Participatory planning highlights the need to get opinions from potential investors and the citizens living in a particular area (Ducci, 2018).

### 1.1.2 Traditional Participatory Planning Approaches

In the beginning, urban planning followed a top-down approach which involved a centralized decision-making process where urban planning is directed by government authorities, planning professionals, and field experts who were at the higher level of the hierarchy (Pissourios, 2014). Nevertheless, the limitations of the top-down approach have been identified due to the complexity of city planning and the dynamics that are difficult to understand through central planning (Barthelemy et al., 2013). As an example, Paris in France had to undergo large modifications that were supervised by a central authority, which was known as the 'Haussmann Period' (Barthelemy et al., 2013). Furthermore, in Singapore, urban planning is influenced by a top-down government-initiated system supported by three tiers island-wide conceptual plan, district-wide land use plan, and site-specific urban design guidelines (Yuen, 2009).

The top-down approach is followed by techniques such as 'master planning' which develops comprehensive plans by the urban planning professionals and government authorities. The 'zoning regulations' developed by such planners and professionals were mostly focused on the legal frameworks that designate specific land uses for different areas in the city such as residential, commercial, and industrial zones (Dyckman, 2018). In Singapore, master planning is used by the Urban Redevelopment Authority (URA) to manage land use to enhance sustainable growth (Soh & Yuen, 2006). Furthermore, the top-down approach follows theoretical techniques that are not compatible with the common knowledge of people. Use of complex and less flexible tools that require technical expertise can be identified as limitations of the so-called top-down approach (Pissourios, 2014).

The bottom-up approaches, and techniques used in different case studies are public hearings, stakeholder meetings, community workshops, and consultations. In Boston, planning charrettes were used in neighborhood planning to obtain community inputs (Dimitri et al., 2023). In Toronto, Canada public hearings are a part of the urban planning approval procedure (Glossary of Terms, 1998). Urban Living Labs and online platforms have been used recently to involve community participation and test ideas of projects before implementation. Amsterdam's Living Labs are popular in creating solutions for urban issues such as mobility and sustainability by the citizens, but a mismatch between the expectations of policymakers, industry, citizens, and other stakeholders has been identified as a limitation (Ersoy & Van Bueren, 2020). Furthermore, the existing participatory techniques are not accessible to all individuals due to time and mobility constraints which can result in a lack of representation of the community in the process (Swapan, 2016).

According to Innes and Booher (2000), decisions can be made by incorporating the public's knowledge into the decision's calculus. As an example, the local community knows about the crimes or traffic problems in a particular area, and that knowledge can be taken into consideration by the planners through participatory planning. Recently, the necessity of having collaborative planning platforms that combine both top-down and bottom-up approaches has been highlighted (Pissourios, 2014; Semeraro et al., 2020).

### 1.1.3 Community Engagement in Designing Public Spaces

Public spaces in urban areas play a vital role in promoting sustainable growth and enhancing the quality of life. When properly designed to incorporate community needs, they can help ensure equal opportunities and support social mobility (Njunge & Asilsoy, 2020). Designing public spaces aims to enrich the social dimension of cities by fostering new and diverse perspectives (Cicalò, 2013). Public space design ought to encourage the facilitation of interactions among people to enhance their sense of community. Spaces should function as places for socializing, community engagement, and cultural activities, therefore improving social capital in urban settings (Ramos-Vidal & Domínguez de la Ossa, 2023). According to Chvyrova & Vasylenko (2023), designing public spaces needs local involvement to ensure they address community requirements. This process involves analyzing the surroundings, expanding green spaces, minimizing paved surfaces, restricting automobile access, and creating interconnected networks such as alleyways and pedestrian pathways to improve functionality (Chvyrova & Vasylenko, 2023).

The set of principles considered when designing public spaces, such as environmental interaction, structure, optimization, continuity, and harmonization, assures that public spaces are functional, accessible, and meet the expectations of various user groups (Yarmosh & Babaeva, 2021). Therefore, the significance of community engagement lies in promoting community-led designs, fostering long-term involvement, and minimizing social disparities through empowerment, making it essential in the design of public spaces (Fateminasab & Moayerian, 2025). Accordingly, the existing tools that are used to incorporate community requirements into designing public spaces include web-based applications like public participation geographic information systems (PPGIS) and online 3D modeling platforms, such as Beta.Speckle facilitates sharing parametric design spaces and collecting citizen input effectively, but also causes inadequate integration of community inputs with expert designs sometimes (Knecht et al., 2019). According to Fredericks et al. (2015), this limitation can be addressed through digital tools, as digital technologies serve as effective tools for community engagement in public spaces by combining digital interfaces with physical pop-ups to attract diverse participation and enable immediate feedback during consultations. Advanced technologies such as plug-in interfaces (Hespanhol & Tomitsch, 2019), interactive displays and multisensory installations (Carter, 2024) enhance community engagement in public spaces meanwhile improving the urban regeneration process. Therefore, the significance of community engagement in designing public spaces and the necessity of tangible, digital tools to keep citizens engaged in the process can be identified.

### 1.1.4 Augmented Reality (AR)

AR is when someone looks at the real world through devices such as a mobile phone AR Lens, to see extra things such as images, information, objects, and animations added to it (Carmigniani & Furht, 2011). For instance, the Pokémon GO AR game allows 'Pokémon' to appear in and around the real-world environment right in front of the player. Accordingly, AR enhances the real environment with digital computer-generated data and mixes both real and virtual environments to provide users a new experience (Carmigniani & Furht, 2011). Oppositely, virtual reality (VR) replaces the real world with a simulated one, providing an immersive environment for users. Littlstar is an example of an exceptional virtual reality video app that enables users to watch 360-degree videos and VR movies on their mobile devices.

The origin of AR dates to the 1960s with Ivan Sutherland's invention of the first head-mounted display system. However, the term "augmented reality" was officially introduced by Tom Caudell in the early 1990s (Azuma, 1997). In the beginning, using AR as a participatory planning tool has been limited due to high development costs for software, hardware, and maintenance (Reinwald et al., 2014b) and the acquisition of accurate and comprehensive geospatial data has also been costly and logistically challenging (Othengrafen et al., 2023c). Technical limitations such as lagging, poor graphic quality, and limited functionality were also identified in the AR systems in the beginning (Reinwald et al., 2014c).

However, the popularity of mobile devices such as smartphones, tablets, wearable computers, and immersion technologies (optical see-through, AR contact lens) made advances in the mobile computing industry afterward providing the potential to use AR in different disciplines. Consequently, AR technology is now popular in different disciplines such as the education sector (Kesim & Ozarslan, 2012), healthcare sector (Azuma, 1997), urban planning (Cirulis & Brigmanis, 2013), entertainment (Azuma, 1997; Hung et al., 2021), cultural and heritage sector (Han et al., 2013). Education sector researchers recognized the growing applicability of AR technology in various contexts for engaging people and enhancing community participation.

AR in the education sector allows students to interact with digital components overlayed in their real environment providing an immersive learning experience and deep understanding of complex subject matters (Syahidi et al., 2019; Kesim & Ozarslan, 2012). In the healthcare sector, AR applications assist medical professionals in training, diagnosing, and treating patients (Klinker et al., 2020). In the cultural heritage and tourism sector, AR enhances tourists' experience by providing interactive information and a platform for immersive storytelling, while also guiding them through the place with correct information (Han et al., 2019; Fritz & Susperregui, 2005). In urban planning and architecture, AR can visualize proposed developments in real-world contexts, enhancing inclusive decision-making processes and encouraging communities to contribute and share their ideas regarding the design of their neighborhood, public spaces, and towns (Othengrafen et al., 2023; Yagol et al., 2018; Williams et al., 2020).

Given the importance of using AR applications in a wide range of disciplines, researchers recognized the capabilities of using AR applications in urban planning. This is mostly to bridge the gap between the experts and the citizens in the planning process. AR applications enhance communication, interactions, and understanding of communities. AR serves as a platform to identify the needs and problems of neighborhoods due to its ability to integrate with the real ground environment realistically, providing an overview of the issues in the actual context. (Schrenk, 2023).

### 1.1.5 Mobile-Augmented Reality (M-AR)

Mobile-augmented reality (M-AR) is an interactive technology that superimposes computer-generated visuals and, occasionally, audio onto the real-world environment through mobile devices such as smartphones and tablets. Although M-AR primarily depends on mobile devices for their accessibility and cost-effectiveness, it can also be augmented by AR headsets such as Meta Quest, offering a more immersive user experience by integrating the physical and digital realms (Carmigniani & Furht, 2011c). In M-AR interfaces, three-dimensional virtual images and objects are easily integrated into real-world environments using mobile phone cameras, enabling users to interact with both simultaneously (Singh, 2024b). For example, M-AR allows architects and planners to visualize urban projects in realistic environments, facilitating improved communication of concepts through their mobile devices at any time (Cirulis & Brigmanis, 2013). This ability promotes comprehension and decision-making while expanding participation by bringing complicated design concepts accessible to non-experts.

M-AR technology can be grouped into several groups, each offering specific characteristics and applications across multiple sectors such as (a) Marker-Based AR, (b) Projection-Based AR, and (c) Superimposition-Based Augmented Reality. Marker-Based Augmented Reality use visual markers, such as QR codes, to superimpose digital material over the real world. Education widely use it to generate engaging and problem-solving-oriented learning experiences (Shree & Selvarani, 2024; Blazhko & Shtefan, 2023). The HoloHuman AR application allows medical students to explore and interact with 3D anatomical models by scanning markers on anatomical charts. This interaction enables them to rotate, zoom, and dissect virtual structures, fostering a deeper comprehension of complex human anatomy (Dhar et al., 2021). Similarly, Quiver Vision enhances language learning by animating children's colored artwork with 3D effects and sounds, creating an engaging way to explore vocabulary, grammar, and cultural concepts (Kisno et al., 2022). Unlike marker-based AR, markerless AR does not rely on predefined markers. Instead, it leverages GPS, accelerometers, and digital compasses to deliver immersive and flexible experiences, making it particularly effective for applications in gaming, navigation, and urban planning (Antoro & Anistyasari, 2022; Messi et al., 2024; Yigitcanlar et al., 2021). A well-known example is Pokémon GO (version 0.91.1 for Android/version 1.61.1 for iOS), a game demonstrating how mobile device sensors can encourage outdoor exploration and increase pedestrian movement in urban areas (Lateef et al., 2018).

Another category, projection-based AR, projects digital imagery onto physical surfaces, allowing users to interact with virtual content within real-world settings. This approach is particularly beneficial in design and architecture, where it facilitates the visualization of concepts in realistic environments (Prananta et al., 2024; Uhrík et al., 2022). Superimposition-based AR, on the other hand, enhances or replaces elements of the physical world with digital overlays. This technique is widely used in medical training and maintenance tasks, providing real-time, context-aware information (Aggarwal & Singhal, 2019). These different AR classifications highlight the technology's diverse applications and its potential to transform various industries.

### 1.1.6 Youth Engagement in Designing Public Spaces Using AR

Meaningful youth engagement in designing public spaces is essential as young people can lead to more inclusive, dynamic, and vibrant environments (Isla & Samantela, 2024). Youth represent a diverse demographic with varying needs and interests that must be considered in the design of public spaces. For instance, girls often face specific challenges related to safety, accessibility, and inclusion (Spinnoy et al., 2024). According to Khalifa et al. (2022) teens' preferences are shaped by their cognitive, emotional, and social development. Key factors influencing their use and perception of public spaces include a sense of freedom, safety, self-identity, enjoyment, thrill-seeking, and the importance of peer relationships (Khalifa et al., 2022). Addressing these factors is essential to creating inclusive and youth-friendly public environments.

More importantly, youth and children's engagement in designing public spaces is enhanced and motivated through AR as it helps their design proposals come to a reality with an understanding of the planning context (Reaver, 2023; Nekoui & Roig, 2022). For instance, the ‘Play the City’ project in Amsterdam engaged children and young people in urban planning by integrating AR with interactive games. Here, the participants used AR applications on smartphones and tablets to see proposed designs for parks, playgrounds, and streets overlayed on real ground (Niederer & Priester, 2016). According to Cilliers & Timmermans (2014), meaningful public participation in the decision-making process is necessary for (a) upholding public democracy, (b) the effectiveness of the planning process and the quality of the outcome, and (c) improving the quality and validation of the decision-making process.

In the global context, AR has been evaluated with communities, including youth and children, to interact with communities in the planning and designing process with more knowledge and understanding. As an example, in Oslo, Norway, youth used AR as a participatory planning tool to plan a portion of Oslo with 100,000 trees (Reaver, 2023). This incorporated various activities films, images, drawings, interviews, recorded presentations, etc. using AR. Reaver (2023) highlighted that AR facilitated the design proposals and encouraged young people to understand and feel confident about using AR for urban planning and design. In Bandung City, Indonesia, AR has been used to engage students in data collection and research to reveal the urban planning issues in their surroundings (Argo et al., 2016).

## 1.2. Problem Statement

Accordingly, community engagement is crucial in designing public spaces, enabling communities to engage in designing spaces and decision-making processes. Nevertheless, conventional approaches can encounter considerable limitations, especially in effectively involving diverse people. Conventional participatory techniques provide accessibility issues, especially for marginalized and geographically isolated populations (Brown & Kyttä, 2014). Public consultations often require physical attendance, therefore restricting participation for persons with mobility issues or those unable to attend due to limited time (Innes & Booher, 2004). Moreover, limitations related to language and technical expertise may marginalize specific groups, limiting equal representation in decision-making (Arnstein, 1969).

Tools frequently used in participatory planning, like maps, drawings, and physical models, may provide interpretative challenges for the general public (Al-Kodmany, 1999). Many stakeholders, particularly those lacking planning expertise, find it challenging to conceptualize suggested modifications and their impact on urban settings (Healey, 1997). This cognitive challenge frequently leads to a top-down planning approach, wherein expert perspectives dominate and public contributions are limited or simply symbolic (Legacy, 2017).

When it comes to designing public spaces, youth often show a lack of encouragement due to factors including less awareness, lack of interest, or the absence of accessible platforms that align with their experiences (Checkoway, 2011). Traditional methods, such as public meetings, surveys, and workshops, are frequently targeted at older demographics and do not effectively engage younger participants (Lydon & Garcia, 2015). Therefore, the necessity of technology-driven solutions to address these limitations and to enhance community engagement in designing public spaces, especially among youth, is discussed in this study. The ability of M-AR to bridge the gap by offering an immersive, interactive, and accessible platform for everyone to engage in planning and designing is significant (Billinghurst et al., 2015).

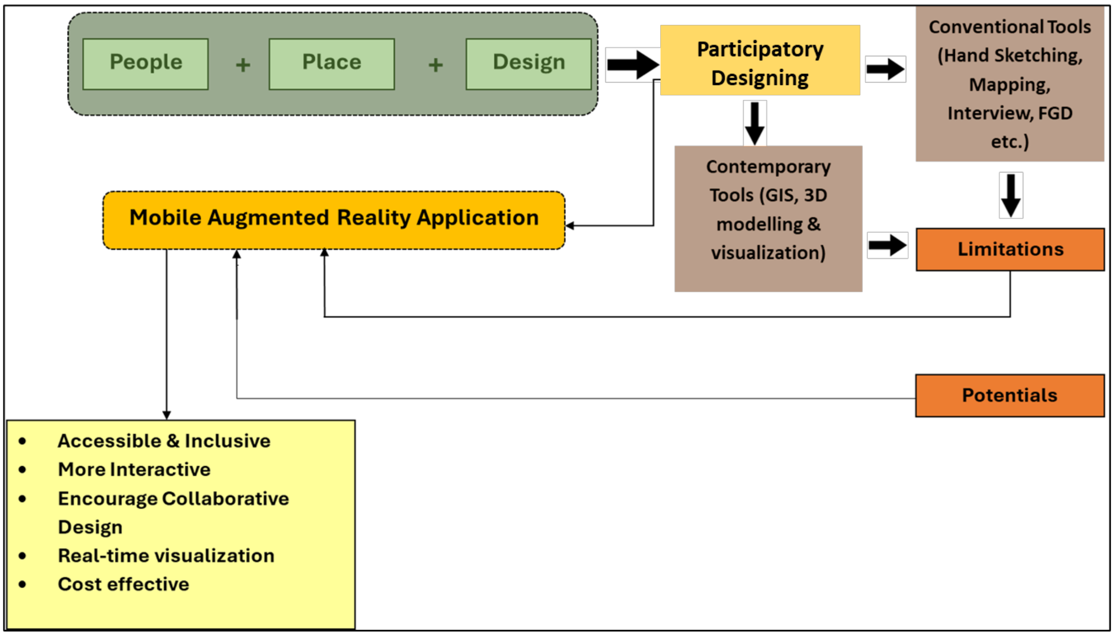
This study examines the significant gap in participatory urban planning by investigating the effectiveness of AR applications in encouraging engagement, especially among the youth. Utilizing AR's interactive features can render urban planning processes more inclusive, accessible, and engaging, resulting in more democratic and representative urban design outcomes (Iversen & Dindler, 2014).

## 1.3. Research Gap

As discussed above, this study examines a methodological gap that underscores the necessity for innovative tools that might render the process of designing public spaces more inclusive, accessible, and engaging. This study employs Mobile Augmented Reality (M-AR) as an effective way to mitigate these restrictions, facilitating real-time, on-site visualization and enhancing user-friendly design possibilities. This study aims to examine how M-AR technology could improve meaningful community engagement in designing public spaces and integrate professional urban planners' expertise with the needs and creativity of the general public. As indicated in Figure 1.1, this study examines the limitations of both conventional and contemporary tools for engaging the community in designing public spaces, as well as the potential of M-AR to address these limitations.

**Figure 1.1**

*Research Gap*




## 1.4. Objectives of Study

The primary objective of this study is to develop a mobile augmented reality application to design and modify public open spaces, enhancing youth engagement in the process.

- To identify and evaluate existing tools used in designing public spaces and assess their effectiveness in engaging communities.
- To explore the potential of M-AR as a tool to design public spaces and its effectiveness in engaging communities, particularly youth.
- To assess how the City BuildAR app (version 1.0) facilitates collaboration between professionals and the general public in the process of designing public spaces.

## 1.5. Research Questions

To achieve the objectives of this study, the following research questions were developed.

1. What are the existing tools used in designing public spaces, and their effectiveness in engaging communities?
2. How to utilize M-AR as a tool to plan and design public spaces and its effectiveness in engaging communities, including youth?
3. How does the City BuildAR app (version 1.0) bridge the gap between professionals and the general public in designing public spaces?

# CHAPTER 2

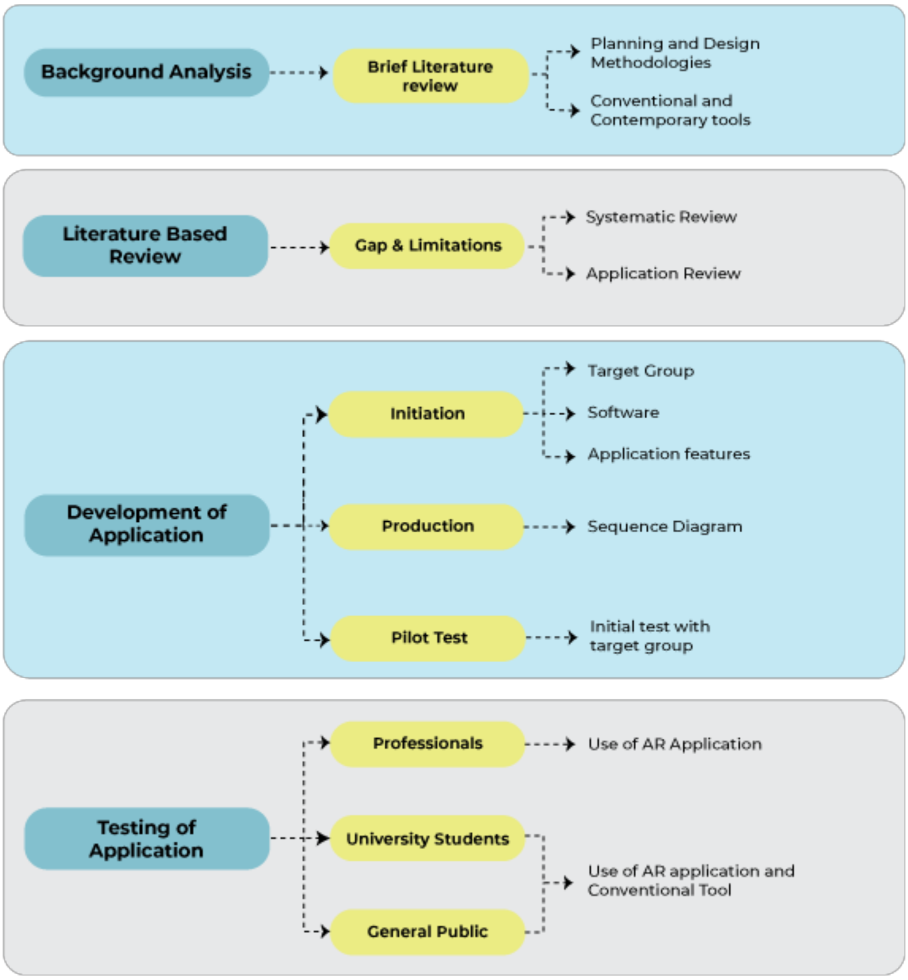
# METHODOLOGY

## 2.1 Overall Methodology of the Study

This research was conducted in four phases, as shown in Figure 2.1. The first phase involved a background literature review, and then a literature-based review, along with a systematic review and an application review, was conducted in the second phase. The next phase consists of the development of a mobile AR application based on the findings of the literature review and the initial test. In the final stage, multiple testing rounds incorporating the participants' feedback were conducted, ensuring that the application was evaluated for usability, effectiveness, and user experience.

**Figure 2.1**

*Overall Methodology*



## 2.2 Background Literature Review

The background analysis establishes the basis of this study, delivering an essential understanding of planning methodologies and formulating the research hypothesis. This phase involves an extensive review of planning and design approaches, investigating both theoretical and practical frameworks that enable participatory planning processes. Furthermore, contemporary and conventional tools used for participatory planning are analysed to determine their advantages, limitations, and significance in involving various stakeholders. This research contextualizes the study within current urban planning processes and emphasizes the potential of upcoming technologies, such as augmented reality, to enhance participatory approaches.

## 2.3 Systematic Literature Review

In the second phase, a systematic literature review was performed to identify the use of AR applications to enhance public participation in the urban planning process. Under this study, selected studies were reviewed to understand the significance of AR as a participatory urban planning tool. This systematic literature review adheres to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) format, which has been developed by a consortium of medical authors to enhance the transparency, reliability, and accuracy of systematic literature reviews (Moher et al., 2010). The PRISMA guidelines consist of a four-phase flow diagram and a 27-item checklist. The flow diagram describes the identification, screening, eligibility, and inclusion criteria of the reports that fall under the scope of a review (Selcuk, 2019).

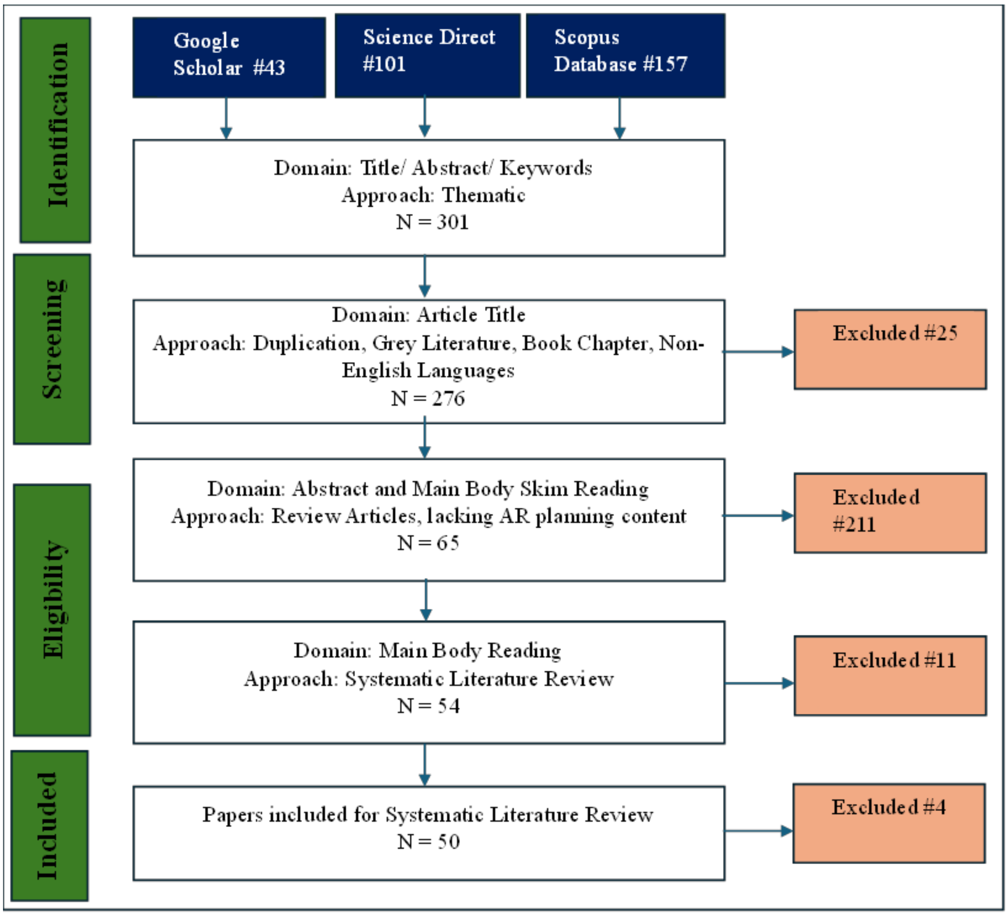
To conduct this systematic literature review, initially, the research plan was developed, including the research hypothesis, set of keywords, and inclusion and exclusion criteria. The research aim was to identify the traditional and contemporary participatory planning techniques and their limitations and to examine the use of AR to engage the community in the planning process. The keywords used were ‘Youth’, ‘Participation’, ‘Augmented Reality’, ‘Planning’, and ‘Public Spaces’. Peer-reviewed articles, journal papers, and conference papers written in the English language which were available for open access have been identified as the inclusion criteria for selecting the research papers for this study. The Boolean search strings technique enables finding more relevant articles compared to the free text query in a short time

(Muhammad, 2017) was used for this study in the Google Scholar, Scopus, and Science Direct databases to find the relevant literature. Further, adopting the snowballing method, reference list (backward snowballing – BSB), and citations (forward snowballing – FSB) (Badampudi et al., 2015) were reviewed used to identify new papers related to the study.

Following that, the initial findings followed a comprehensive filtering process based on the eligibility criteria. The following step required thoroughly examining the articles, titles, abstracts, and keywords to identify and exclude publications that were not relevant to the study. After a thorough review of the remaining papers, the new articles of the study were selected and incorporated applying the snowballing approach. articles Articles that did not correspond with the research aim were eliminated from the study, and the final database of articles related to this topic was identified.

**Figure 2.2**

*PRISMA Flow Diagram*



As shown in Figure 2.2, a total of 301 articles were identified in the initial search using the keywords. Then, 25 articles were excluded due to exclusion criteria such as grey literature, book chapters, and non-English languages. After that, a total of 211 articles were excluded after the abstract and main body skim reading due to a lack of AR and planning content. Then another 11 articles were excluded after reading the main body. Finally, based on the relevance of the content of articles to the study, 50 papers were selected for the systematic review.

By reviewing 50 selected papers, 33 AR applications developed and tested to enhance community engagement in various aspects of urban planning and placemaking were identified. The CityBuildAR app was developed by building on the strengths of these existing applications and addressing their limitations when used as a placemaking tool.

## 2.4 Development of M-AR Application

The development of the application consisted of two phases: initiation and production. The initiation phase involved determining the target group, selecting software, and developing the app's key features. The production phase covered the development of a sequence diagram that defines the entire concept of the application, incorporating both front-end and back-end functionalities.

### 2.4.1. Target Group

The primary target audience for this application is the general public. The application aims to be user-friendly and accessible, allowing non-technical users to engage with its features and actively participate in urban planning processes. To enhance user-friendliness, the program incorporates an easy UI with simple navigation to other basic crowdsourcing applications, along with clear guidance throughout the process to mitigate the learning curve for novice users in the future.

Furthermore, accessibility is enhanced by customizing the application for common mobile devices, like smartphones and tablets, without requiring advanced hardware or specialized equipment. Spatial literacy is enhanced by the integration of basic, interactive visual aids that simplify complicated spatial data, facilitating user comprehension. Moreover, the application improves users' comprehension of the current spatial environment by offering precise scale representations and high-definition virtual objects, facilitating a more realistic design experience.

### 2.4.2. Software

The AR application was developed using Unity 3D, which is preferred for its user-friendly interface and is ideal for novice developers. Unity's ability to export projects to several platforms, including iOS, Android, and the web, makes it suitable for reaching a wide range of users. The program includes essential components to develop AR-based applications, such as the AR Foundation package, which provides extensive support for AR functions. Additionally, 3D models required for the application were downloaded from the Unity Asset Store, enabling efficient prototyping and development. User engagement is improved by the design options available in Unity 3D and AR Foundation, including real-time AR visualization, simple user interfaces, and particularly the placement of objects in the real-world setting. Moreover, user-friendly navigation and adjustable options are provided to ensure equal accessibility and understanding for both expert and novice users.

### 2.4.3. Application Features

The application includes many elements to enhance participatory urban planning and placemaking. The research identified essential components in the public spaces, such as trees, benches, tables, light posts, waste bins, and shrubs, based on the literature review. Therefore, a similar set of components was incorporated into the CityBuildAR app, as shown in Figure 2.3. These components allow users to design and visualize urban environments interactively in AR. The tool enables users to capture images of their designs, accordingly, enhancing documentation and communication of their concepts. This feature enhances user engagement and encourages collaborative planning by providing a visual representation of proposed ideas.

**Figure 2.3**

*Public Space Elements used in the Application*

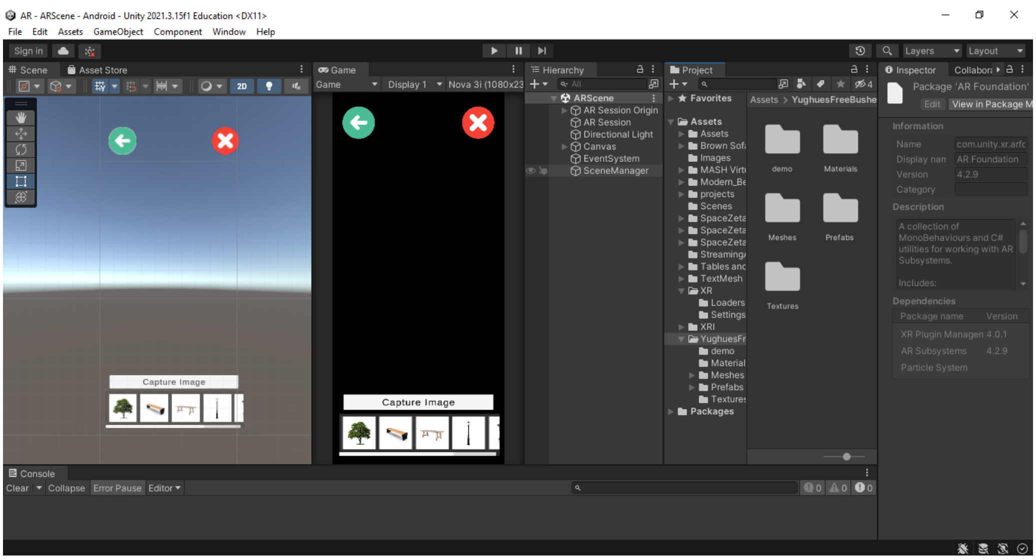
### 2.4.4. Application Production

The production step involves creating the application prototype, designed specifically for the Android operating system. The application was developed using Unity Engine version 2021.3.15f1, leveraging its solid features for AR programming. Several Unity packages were incorporated to provide AR functionality: AR Foundation version 4.2.9, ARCore XR Plugin version 4.2.9, ARKit XR Plugin version 4.2.9, and XR Interaction Toolkit version 2.0.4.

These tools enabled the integration of advanced AR features and ensured compatibility among AR-capable devices. Sequence diagrams were utilized in the development process to clarify user interactions and application functions, hence enhancing a smooth and intuitive user experience. Figure 2.4 depicts the Unity 3D interface, which facilitated the incorporation of AR capabilities in the application development process.

**Figure 2.4**

*Unity 3D Interface*




The app sequence diagram was developed initially, before leading to the development of the app prototype based on it. The author originally developed the sequence diagram based on the inadequacies and limitations identified from the literature-based application review. The 'CityBuildAR' application was developed to address these issues, serving as a crowdsourcing platform that enables users to create personal profiles, register or log in, and engage in placemaking by designing locations based on their preferences. "CityBuildAR" incorporates placemaking components, such as trees, benches, and light posts, directly into the augmented reality environment, allowing users to generate interactive ideas and save them in a cloud-based system for further evaluation by expert urban planners. This application facilitates community-driven placemaking by utilizing mobile devices as the only required device.

In the following stage, a preliminary demonstration was conducted to assess the application's functionality, its compatibility with the Sri Lankan context, and the effectiveness of utilizing an M-AR application as a placemaking tool.

### 2.4.5. Testing the Application

The open café area (Sentra Court) of the University of Moratuwa (Figure 2.5) was selected as the location for the study, providing a familiar and accessible environment for participants and the researcher. This familiarity facilitated a deeper understanding of the site's spatial dynamics and informed decision-making for the organization of the surrounding area. Furthermore, as a semi-public space within an academic institution, the cafeteria provides a suitable setting to examine participatory urban design interventions in a controlled yet socially engaged environment.

**Figure 2.5**

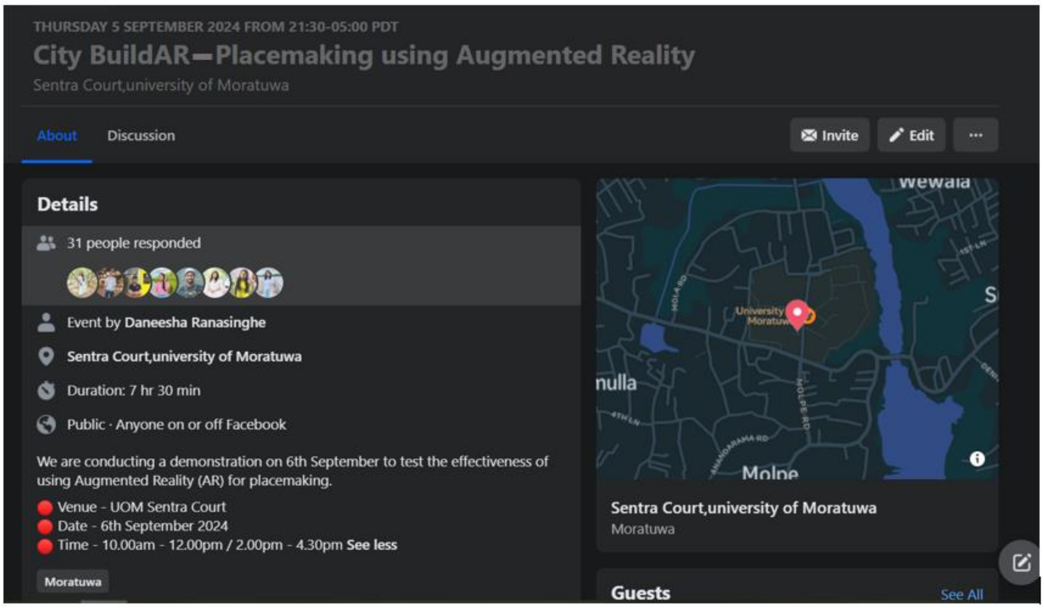
*Location for the study – Sentra Court, UOM*

At first, the CityBuildAR app underwent initial testing with a group of university students and academics to identify bugs and other issues affecting the user experience. Then, the application was tested with three user groups: professionals, university students, and the general public. The rationale for selecting these three groups is based on their levels of knowledge and experience with placemaking. Professionals were selected for testing due to their active involvement in placemaking across both academic contexts and real-world settings. University students represent a transitional group, acquiring theoretical knowledge through academic modules while anticipating its eventual application. The general public have limited academic knowledge or experience about placemaking concepts, with their perceptions shaped by everyday encounters. Incorporating a diversified participant profile facilitates a comprehensive outcome in placemaking by addressing a wide range of perspectives.

To engage a wider audience, all individuals interested in placemaking utilizing M-AR were invited to participate through a Facebook event (Figure 2.6), and additional information was provided via WhatsApp groups. Consent from all participants to engage in the demonstration had been obtained before they participated in the test. All participants were informed that the data collected would be utilized solely for research purposes and that their personal information would remain confidential.

**Figure 2.6**

*Invitation through Facebook*



The demonstration consisted of two sessions, Session A for the university students and general public, and Session B for the professionals. During session A, a registration form was distributed among participants, which collected the participant's basic information including age, gender, present role/status at the university, and the field of study/profession. Accordingly, the registration form collected data regarding their expertise and experience in placemaking and AR, familiarity with the location, preparedness to utilize AR for placemaking – designing the open café space, and their preference in using other alternative placemaking, design tools such as hand sketching and 3D SketchUp software, or any other they prefer. Sketching and 3D modelling using SketchUp were employed as the primary design methods in the initial testing sessions. These tools were selected based on their widespread use among urban planning undergraduates at the University of Moratuwa, ensuring a baseline familiarity among participants. While traditional methods, such as surveys or interviews, can gather perceptions, they do not facilitate active spatial design. Physical models, although effective, require significant time and resources. Compared to these, hand sketching, digital modelling and AR provided a more accessible, engaging, and contextually grounded approach to participatory design, particularly suitable for a university community familiar with basic design tools.

**Figure 2.7**

*Designing using Sketchup Modelling and Hand Sketching*

After that, as shown in the Figure 2.7, all the participants were asked to design the open area of the Sentra Court using their preferred tools & methods. The necessary tools for hand sketching and 3D modelling software were provided during the demo.

Secondly, they were given instructions to utilize the City BuildAR application to redesign that same space. In the end, feedback was collected. Table 2.1 presents a summary of the feedback form.

**Table 2.1**

*Overview of the feedback form*

| No | Question Type | Question | Metric |
|---|---|---|---|
| Q1 | Closed-ended | How comfortable were you using hand sketching (2D drawing) techniques for placemaking? | 5-Point Likert Scale |
| Q2 | Mixed | What are the positives you experienced while using hand sketching (2D drawing) for placemaking? | Multiple checkboxes and text |
| Q3 | Mixed | What challenges did you face while using hand sketching (2D drawing) for placemaking? | Multiple checkboxes and text |
| Q4 | Closed-ended | How comfortable were you using SketchUp software (3D modelling) techniques for placemaking? | 5-Point Likert Scale |
| Q5 | Mixed | What are the positives you experienced while SketchUp software (3D modelling) for placemaking? | Multiple checkboxes and text |
| Q6 | Mixed | What challenges did you face while using hand sketching (2D drawing)/SketchUp software (3D modelling) for placemaking? | Multiple checkboxes and text |
| Q7 | Closed-ended | To what extent do you think AR is effective in visualizing and understanding placemaking concepts? | 5-Point Likert Scale |
| Q8 | Closed-ended | How easy was it to navigate and use the AR application for placemaking? | 5-Point Likert Scale |
| Q9 | Mixed | What challenges did you face, and positives did you experience while using the AR app for placemaking? | Multiple checkboxes and text |

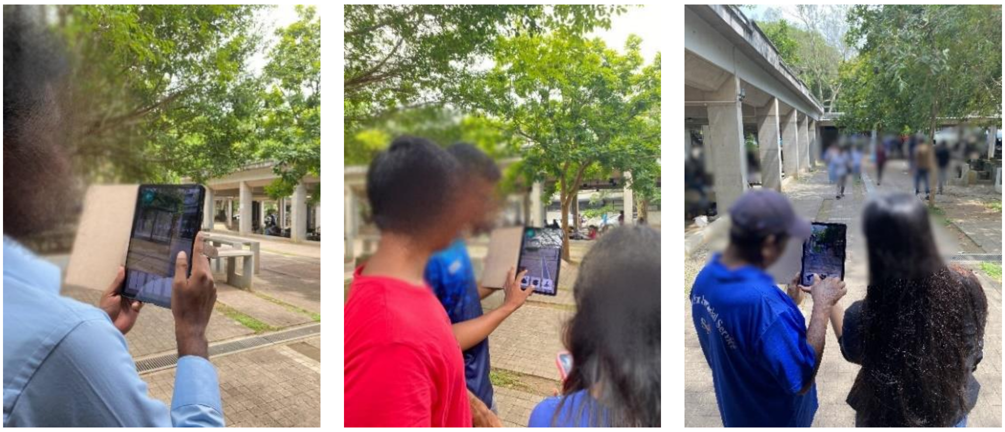
| | | | |
|---|---|---|---|
| Q10 | Closed-ended | Compared to hand sketching/3D modelling software, do you find AR to be a better tool for placemaking? | 5-Point Likert Scale |
| Q11 | Closed-ended | Do you believe that AR can enhance your involvement in urban planning and placemaking? | 5-Point Likert Scale |
| Q12 | Closed-ended | Rate your interaction and experience with “Activities—Diversity, People’s activities, Cafes etc.” during placemaking activity using these tools. | 3-Point Likert Scale |
| Q13 | Closed-ended | Rate your interaction and experience with “Physical Setting—Human and Building scale, walkability, accessibility etc.” during placemaking activity using these tools. | 3-Point Likert Scale |
| Q14 | Closed-ended | Rate your interaction and experience with “Imageability—attractiveness, physical comfort, attachment etc.” during placemaking activity using these tools. | 3-Point Likert Scale |
| Q15 | Closed-ended | Rate app features according to your experience | 3-Point Likert Scale |
| Q16 | Open-ended | Are there any features you believe should be added or modified in the AR app? | Text |
| Q17 | Closed-ended | How willing are you to use AR applications for placemaking activities in the future? | 5-Point Likert Scale |

Unlike session A, session B excluded the initial designing part using sketching and 3D modelling as the professionals who participated in the workshop are practicing placemaking using the existing tools and methods with their knowledge and experience. Therefore, the CityBuildAR app was directly introduced to them along with a brief about its functionality, elements, and navigation to design the Sentra Court area. At the end of the session, the feedback form was shared to collect their feedback.

Figure 2.8 indicates a few examples of the users' engaging in designing the UOM Sentra Court area using the CityBuildAR app. Accordingly, some participants gathered as groups to discuss the requirements of the space while designing and some of the participants were interested in designing on their own.

**Figure 2.8**

*Users engaging in designing using the CityBuildAR app*



### 2.4.6 Validating the Application

After testing with the different user groups, the CityBuildAR app went through a debugging process to hinder technical issues such as lagging, navigation errors, delete option, etc. identified during the test run. After developing the application based on the feedback received during the test, version 2.0 was used for the app validation representing the target group of the study 'youth'.

At first, an introductory session about the task and the app functionalities, navigation, and the set of elements available in the app was briefed to the participants as shown in the Figure 2.9. Then the app was installed on compatible Android devices and after that, the designing activity was performed as shown in Figure 2.9. Accordingly, 37 participants from the newly enrolled batch at the University of Moratuwa were given access to the CityBuildAR app to redesign the university's front space. They were given the freedom to choose the design tool or method they preferred. Among the design alternatives, most of them engaged in hand-sketching, and some used AI tools (Leonardo AI, ChatGpt) to generate images and almost all of them used the CityBuildAR app to visualize their ideas.

**Figure 2.9**

*Introductory session & users engaging in designing using the CityBuildAR app*

# CHAPTER 3

# RESULTS AND DISCUSSION

## 3.1 Systematic Literature Review

Altogether 50 papers were reviewed. The reviewed papers were categorized into three main themes, (a) public engagement and inclusive public participation (22 articles), (b) data visualization and participatory planning methods (13 articles), (c) practical applications of AR in urban planning (case studies) (15 articles). Under this literature review, different aspects of using AR and digital tools to enhance public awareness and participation in urban planning, with an emphasis on both conventional and contemporary methodologies have been examined. The majority of articles, (70%), discuss the significance of public participation in urban planning and the necessity of introducing user friendly tools to enhance visualization in participatory urban planning. The development of technology and its ability to utilize AR as a collaborative approach of both conventional and contemporary planning techniques have been highlighted in the articles.

Accordingly, this review identified the significance of using AR to bridge the gap between urban planners and communities by making abstract concepts, and maps into digital and tangible things, with its challenges and recommendations to consider in future research. This study includes a substantial number of case studies that highlight the practical application of AR in the urban planning context.

The emergence of Human-Computer Interactions (HCI) and the use of AR as a participatory planning tool for community engagement was first discussed by (Azuma, 1995). With the years of technological innovations and using different tools (Head-mounted displays, Web-based AR, AR lens) contemporary studies highlight the use of mobile devices for planning with mobile AR applications. A set of AR applications (37 Apps) was identified in this study. The limitations identified in these apps were that most of them were developed for one-way communication (community-authorities, authorities-communities, authorities-stakeholders) and also most of these applications did not allow the users to participate in the urban planning process directly but rather focus on tourist destinations, cultural heritages, walkability, etc. The review determines that though AR has made significant improvements in urban planning, ongoing efforts are required to overcome its limitations and ensure wider usability and accessibility for every individual of the community.

### 3.1.1. Community engagement in different sectors using AR

According to the literature, AR can be integrated into existing participation processes effectively (Saßmannshausen et al., 2021), and more importantly, the ability to enable citizens to explore, understand, and communicate complex urban planning concepts, bridging the cultural gaps in inclusive participation is highlighted (Morgado et al., 2015 ; Hincapié et al., 2021). The emergence of HCI affected the fields that require public participation (Azuma, 1995), and discussed the importance of using AR in fields like medicine, manufacturing, entertainment, and the military. Moreover, Suchita & Sujata (2019), explore AR applications in various sectors like education, tourism, and marketing and integrate them with the AR application in smart city infrastructure design with specific references. According to Fegert et al. (2019), AR enhances citizen involvement in construction projects, and the prototypes allow users to suggest designs and discuss with others which encourages co-creation and contribution to the construction processes. While offering transparency in decision-making over public projects, AR provides easy, barrier-free access for individuals with lower experience levels.

Additionally, the literature demonstrates AR's effectiveness in architectural field studies for urban planning. The use of AR applications for real-time adjustments, reinstalling scenes with different compositions, comparison of zoning conflicts in architectural studies, and the use of AR for tours have been highlighted (Shih & Chen, 2020). Also, the Smart AR app fosters participatory design for public art projects (Sanaeipoor & Emami, 2020a).

According to Hincapié et al. (2021), AR apps enhance cultural heritage learning outcomes and provide insights for reactivating cultural heritage that can be applied globally. AR technology can be utilized for long-term marketing strategies. According to Wang et al. (2023), firms should focus on sociability when promoting AR apps and shared experiences from social AR can improve individual well-being as well. Augmented Reality Participatory Platform (ARPP) was developed to enhance community engagement for walkability improvements in under-resourced neighborhoods and it provided easy, barrier-free access for individuals with lower experience levels (Ahmadi Oloonabadi & Baran, 2023).

Therefore, according to the literature, AR is not limited to the urban planning and participation field but is widespread in other fields as an effective methodology to enhance community attainment and interaction in a particular field. It is highlighted that the AR platform motivates individuals and enhances engagement in the activities.

### 3.1.2. M-AR as a participatory tool

M-AR has been recognized as a productive participatory tool, improving interaction, engagement, and comprehension across different fields by incorporating digital elements into physical contexts (Jindal, 2024). This technology enhances the ability of people and groups to visualize and interact with complex information, particularly in collaborative and decision-making scenarios using mobile devices such as smartphones and tablets. M-AR is transforming individual and community engagement with projects, discussions, and solutions across several sectors, including education, healthcare, design, and public participation (Reinwald et al., 2014). With the rapidly increasing use of mobile phones, M-AR transforms traditional decision-making tools into contemporary digital solutions, incorporating AR, Virtual Reality (VR), and Geographic Information Systems (GIS) to create dynamic, portable platforms for collaborative participation (Cirulis & Brigmanis, 2013). Despite its potential, M-AR is comparatively less popular because of technological barriers including limited device compatibility, high computing requirements, and the necessity for reliable internet access (Braud et al., 2017). Moreover, its acceptance has been limited by inadequate user familiarity, high development costs, and the lack of standardized frameworks, which constrain its widespread implementation and scalability.

M-AR has developed into an effective participatory planning tool, facilitating a more inclusive, interactive, and accessible methodology for urban and spatial planning. Augmented Reality (AR) improves visualization, interaction, and understanding for planning professionals, stakeholders, and community members by overlaying digital components onto the real environment (Reinwald et al., 2014). Conventional participatory approaches, that rely on static tools such as paper maps, drawings, and physical models, often fail to accurately convey the complicated details and spatial dynamics of urban projects. For example, MIT's CityScope project combines AR with 3D physical models, enabling stakeholders to interactively examine urban alternatives, such as modifications to transit networks or housing projects, in a comprehensible format (Baeza et al., 2021).

AR has been widely used as a participatory tool to involve people in the urban planning process, enabling an interactive platform for learning and contributing to urban planning projects. In Amsterdam, several grassroots initiatives have utilized digital technologies, including websites and interactive software, to enhance citizen participation in urban development. These technologies enable communities to tackle urban challenges, collaborate on solutions, and monitor project outcomes, thereby enhancing their ability to provide informed feedback (Niederer & Priester, 2016). In Oslo, Norway, AR was employed to facilitate community-driven planning for urban green projects, including the proposal to plant 100,000 trees. This effort included participation activities such as visual presentations, drawings, and augmented reality simulations, enabling community members to observe and engage with suggested improvements in real time (Reaver, 2023) and emphasizing that AR enabled community understanding and enhanced participation. Similarly, in Bandung City, Indonesia, community members engaged in data collecting and research to identify and resolve urban planning challenges in their local context (Argo et al., 2016).

### 3.1.3. Literature-based application review

Among the 33 augmented reality applications identified in the literature (Table 1), five relate to urban planning and community participation. These apps aim to better urban design, promote community engagement, and improve planning procedures through interactive and immersive technology. A thorough review of the applications identified through the literature review is presented below. In-Citu AR enables users to visualize urban plans in real-time, enhancing collaboration between planners and people; at present, it depends on precise mapping data and has accessibility issues.

**Table 3.1**

*Overview of 33 AR applications*

| No | AR Application | Type | Focus | Developer |
|---|---|---|---|---|
| 1 | ways2gether | Mobile | Traffic Planning | Jauschneg & Stoik—Vienna |
| 2 | Augmented Reality UJI (ARUJI) | Mobile | AR guiding app for the students and visitors around the University of Jaume I and available for Android devices as an unsigned application | Francisco Ramos, Sergio Trilles, Joaquín Torres-Sospedra, and Francisco J. Perales—Malaysia |
| 3 | Green Living Augmented + virtual ReAlity (GLARA) | Mobile | Microclimatic effects | Fluxguide—Slovenia |
| 4 | Smart [AR] Mini-Application | Mobile | Digital placemaking app | Samaneh Sanaeipoor; Khashayar Hojjati Emami—Romania |
| 5 | City 3D-AR | Web/ Mobile | Provide 3D object placement in real space for enhanced visualization | Arnis Cirulisa, Kristaps Brigis Brigmanisb—Latvia. |
| 6 | Junaio | Web/ Mobile | Create, explore and share information in a completely new way using augmented reality | Metaio—web browser used in many countries, Latvia, Spain etc. |
| 7 | Change Explorer | Watch/ mobile/web | A smartphone app that notifies the public when they are close to an area that has plans for redevelopment | Alexander Wilson—UK |
| 8 | In-Citu AR | Mobile | City Governments. Make urban development accessible and visible using AR, city-wide | Dana Chermesh-Reshef—US |
| 9 | CitySense App | Mobile | Co-creation of buildings, spaces | H2020 European Projects—Italy |

| | | | | |
|---|---|---|---|---|
| 10 | Augmented Reality Participatory Platform (ARPP) | Mobile | Platform uses mobile augmented reality (M-AR) to engage residents, particularly in under-resourced communities, in identifying the design improvements necessary to enhance neighborhood walkability | Saeed Ahmadi Oloonabadi, Perver Baran—US, UK, Netherlands, Germany |
| 11 | Tinmith-Metro | Mobile | Visualisation of designed buildings | Thomas, Piekarski, and Gunther |
| 12 | StudierStubeES Software (StbES) | Mobile | Tracking and visualisation framework | Schmalstieg and Wagner |
| 13 | City View AR | Mobile | Disaster Visualization—Earthquake | Mark Billinghurst, Gun Lee, Jason Mill, Rob Lindeman, Adrian Clark, Thammathip Piumsomboon, Rory Clifford, Shunsuke Fukuden—Austrailia |
| 14 | Architeque—3D and AR | Mobile | Platform for Product Presentations in 3D and Augmented Reality | Architeque LLC—Germany |
| 15 | Vidente | Mobile | Demonstrating underground infrastructure virtualization in the field | Schall & Mendez |
| 16 | Urban Sketcher | Computer Based | Users can directly alter the real scene by sketching 2D images which are then applied to the 3D surfaces of the augmented scene | Sareika & Schmalstieg |
| 17 | Wikitude | Mobile | M-AR application which captures images from the surrounding environment (e.g., sights, restaurants, streets, and shops) and displays relevant information, on the screen of the mobile device | Wikitude GmbH—Athens Greece |

| | | | | |
|---|---|---|---|---|
| 18 | Nokia city lens | Mobile | Uses your device's camera to display nearby restaurants, stores, and other notable locations in augmented reality style | Andrew Webster |
| 19 | ARQuake game | Computer Based | ARQuake is an Augmented Reality (AR)version of the popular Quake game. Augmented Reality is the overlaying of computer-generated information onto the real world | Thomas & Piekarski—Austrailia |
| 20 | Archeoguide | Mobile | Augmented Reality based Cultural Heritage On-site GUIDE | Vlahakis, Ioannidis, Karigiannis, Tsotros, Gounaris, Stricker, Gleue, Daehne & Almeida—Italy |
| 21 | Mentira | Mobile | Example of location-based M-AR for Albuquerque city. The purpose of the game is learning Spanish as a foreign language and addresses visitors among others | Prof. Chris Holden, Prof. Julie Sykes—Albuquerque |
| 22 | LocatAR | Mobile | Personal tour guide using location data to identify points of interest in AR | Chowdhury & Iqbal—Bangladesh & Pakistan |
| 23 | Frequency 1550 | Mobile | City mobile game enabling students to learn about the history of Amsterdam | Montessori Scholengemeenschap Amsterdam, IVLOS, Uva -ILO, OSB Open Schoolgemeenschap, Bijlmer—Amsterdam |
| 24 | Dow Day | Mobile | Uses a journalistic narration genre and player takes the role of a news reporter and investigate the different perceptions of virtual characters who participated in protests against Dow Chemical Corporation for making napalm for the war in 1967 | Aris Games—Vietnam |

| | | | | |
|---|---|---|---|---|
| 25 | Road of Rhodes game | | A game application which introduces the user in the cultural history of the island, and it was created using the ARIS authoring tool | Aris Games—Greece |
| 26 | CityScope | Mobile | Community engagement platform | MIT Media Lab's Changing Places Group (CPG) |
| 27 | Urban CoBuilder | Mobile | Outdoor urban simulation tool based on AR | Hyekyung Imottesjo, Jaan-Henrik Kai—Germany |
| 28 | EduPARK | Mobile | Use image-based AR, with marker-based tracking, to display mainly botanical content | Lúcia Pombo, Margarida Morais Marques—Portugal |
| 29 | ARGarden | Mobile | Enabling AR handheld device with multi-user interaction to create 3D outdoor designs | F E Fadzli, M A Mohd Yusof, A W Ismail, M S Hj Salam and N Aismail—Malaysia |
| 30 | Vítica | Mobile | Reactivation of Cisneros Market Square's cultural heritage and its surroundings using GPS and augmented reality | Mauricio Hincapi, Christian Díaz, Maria-Isabel Zapata-Cardenas, Henry de Jesus Toro Rios, Dalia Valencia, David Güemes-Castorena |
| 31 | Magical Park | Mobile | Encourages children to explore the park and run around, by engaging them in games played inside a blended virtual environment | GEO AR Games |
| 32 | Minecraft Earth | Mobile | This game brings the blocky construction set into the physical world. Minecraft Earth users do not pursue any specific goal; they can merely create, build, and explore in freedom while playing alone or cooperatively in a real territory or in an environment created by the players | Mojang Studios in 2009 |

| | | | | |
|---|---|---|---|---|
| 33 | Geocaching | Web Based | This high-tech treasure hunting game, users hide a cache (typically a small waterproof container) in some location and post its coordinates along with some clues on the Internet | Stuart Aldrich, Erika Zhou, Thomas M., Thomas Manoka, Ruhais Li |

The CitySense App offers real-time representation of urban variables, including air quality and traffic, enhancing awareness while potentially causing information overload and restricting user understanding. Even though ARPP involves the public in the planning process through interactive participation in urban design, and enhancing transparency, limitations such as resource-intensive and issues linked to digital literacy and access to devices have been identified. Urban Sketcher fosters community creativity in urban design and promotes collaboration, while it may be deficient in the professional tools required for detailed planning. Wikitude superimposes data onto real-world landscapes, enhancing public comprehension of urban areas; yet its dependence on precise data and possible privacy issues may constrain its efficacy. Schrenk (2023) developed the GLARA (Green Living Augmented+Virtual Reality) XR application to support climate-friendly urban design projects and it improved communication, new initiatives within the neighborhood, enhanced understanding of needs and problems of both residents and visitors, and increased knowledge about the green city initiatives among participants.

Despite progress, AR applications encounter significant constraints. Elevated production expenses limit accessibility and scalability for community-driven initiatives. Technical issues, including battery drain, GPS inaccuracy, and network outages, undermine the reliability of AR in dynamic outdoor contexts, as shown by the Edu-PARK App. Marker-based tracking frequently proves less successful in real environments, as dynamic elements and sunlight interference limit effectiveness. Urban Co Builder represents that inclusivity appears to be a significant issue because constraints including digital literacy, device accessibility, and technological complexity marginalize minority voices in participatory processes. In some cases, privacy issues and reliance on high-quality data further limit AR implementation.

To take full advantage of the potential of AR, these critical issues must be resolved. Improving accessibility through cost-effective, user-friendly solutions that are compatible with standard devices and addressing connection challenges is essential for real-time collaboration using AR. Establishing standardized frameworks for AR tools that incorporate features for continuous feedback from the public could combine visualization with active participation. Moreover, resolving technological performance challenges, such as GPS reliability and marker tracking, will improve AR's use in various urban environments.

### 3.1.4. Case studies of using AR as a participatory planning tool

According to the literature review, the articles discussed the significance of replacing the typical participatory planning methods which rely on face-to-face interactions and are not capable of supporting comprehensive analysis along with how it fills the existing gap in participation using the digital-tangible interfaces (Schrenk, 2023; Ben-Joseph et al., 2001a; Sabah et al., 2023). The authors highlighted that using technologically advanced applications (AR, VR) can support professionals in creating an inclusive and accessible participatory planning methodology for all citizens including students as well. (Sabah et al., 2023; Cilliers & Timmermans, 2014). Based on the importance of engaging communities and kids in the planning and data-collecting processes, AR has been utilized in several case studies, including "Bandung City, Indonesia (Argo et al., 2016). It highlights the benefits of hands-on participation in data collection for students' skill development and students' participation in data collection, preparation for participation approaches to research, analyses of data, and exposure to wider audiences.

Moreover, the “Mashhad City” case study explores the AR app impact on place-making, and it discusses that AR solutions enhance engagement tools for public service (Sanaeipoor & Emami, 2020b), and in “India” with the rapid tech transformation, evaluated the significance of AR in Smart City planning (Suchita & Sujata, 2019). In the “Lukang, Taiwan” case study AR application was developed for the on-site comparison of facades and used the AR ability to facilitate the field study with real-time 3D model adjustments and highlighted the AR’s effectiveness in reinstalling scenes and diverse compositions (Shih & Chen, 2020). The “Oslo, Norway” case study shows how AR aided in design proposals and increased understanding of urban planning among youth which supported engagement in urban planning with 100,000 trees using AR (Reaver, 2023). AR can bridge the gap between experts and citizens in planning because the youth participants involved in this project showed confidence and control in the planning process.

## 3.2. Development of Application

Figure 3.1 shows that the application was developed in three fundamental phases: user registration/login, placemaking using the provided components, and design archiving for reference by other users or experts.

**Figure 3.1**

*App Sequence Diagram*

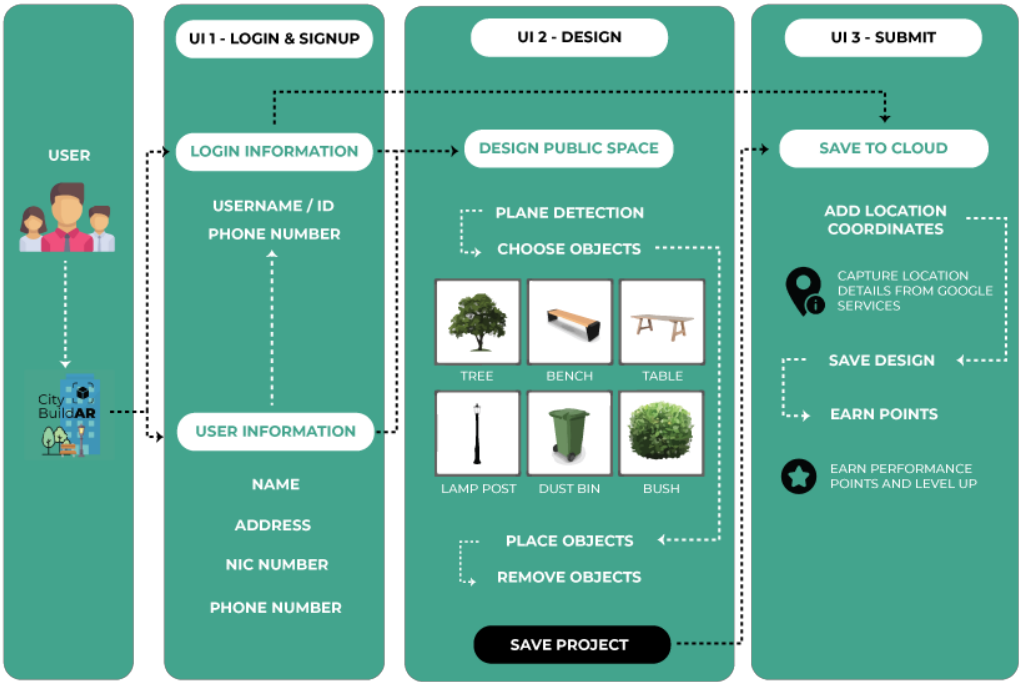
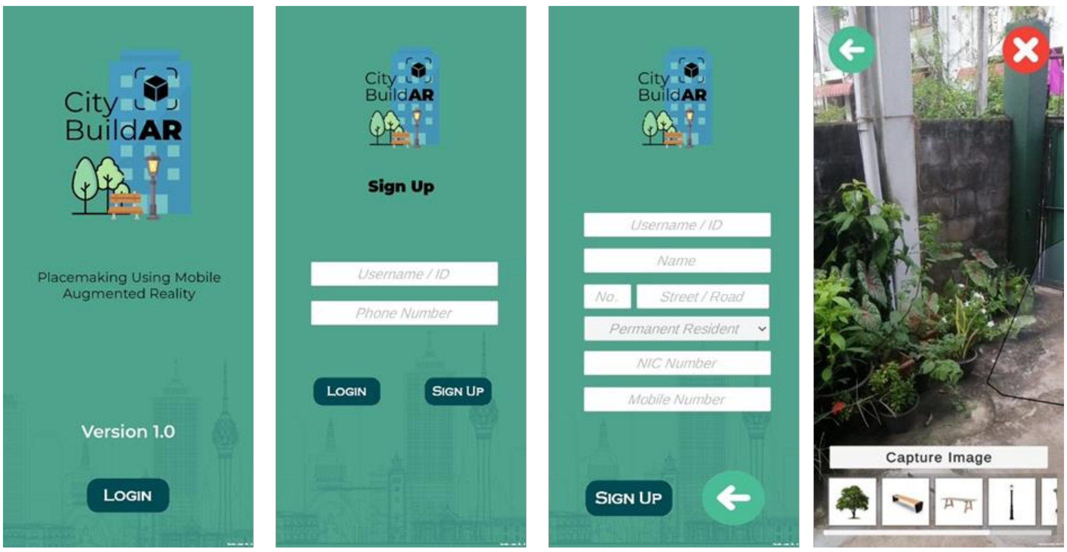



**Figure 3.2**

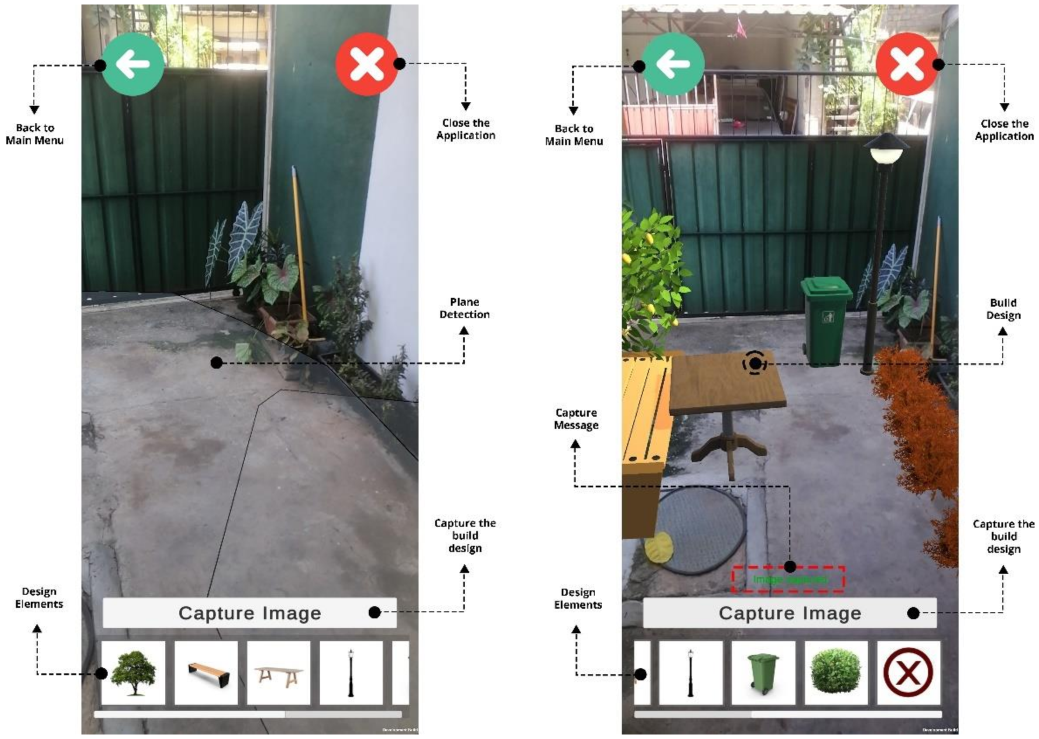
*App Prototype Development*



Prototype has been developed as seen in Figure 3.2, and all user interfaces have been designed to enhance the app's usability. The selection of colors for the user interfaces and the designated placemaking elements are meant to enhance engagement with the application.

**Figure 3.3**

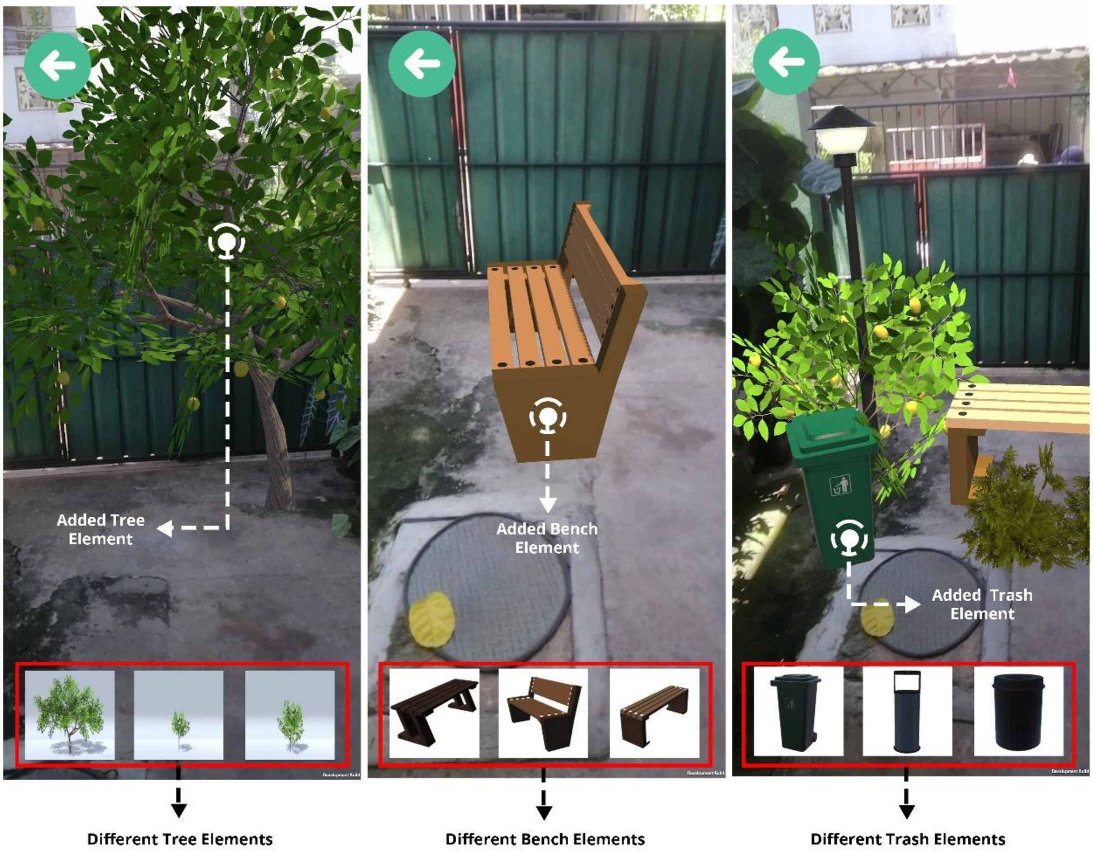
*Mobile Application Interface*




After logging onto the application, the user must identify the plane for which they want to create the design. As seen in figure 3.3, the plane will be identified and delineated with a black border. Detecting the plane is essential before the user may include design components into the interface. Clicking on the design elements will conclude the plane detection process. Prior to adding the design elements, the user must identify the planes that need design.

**Figure 3.4**

*Adding design elements*

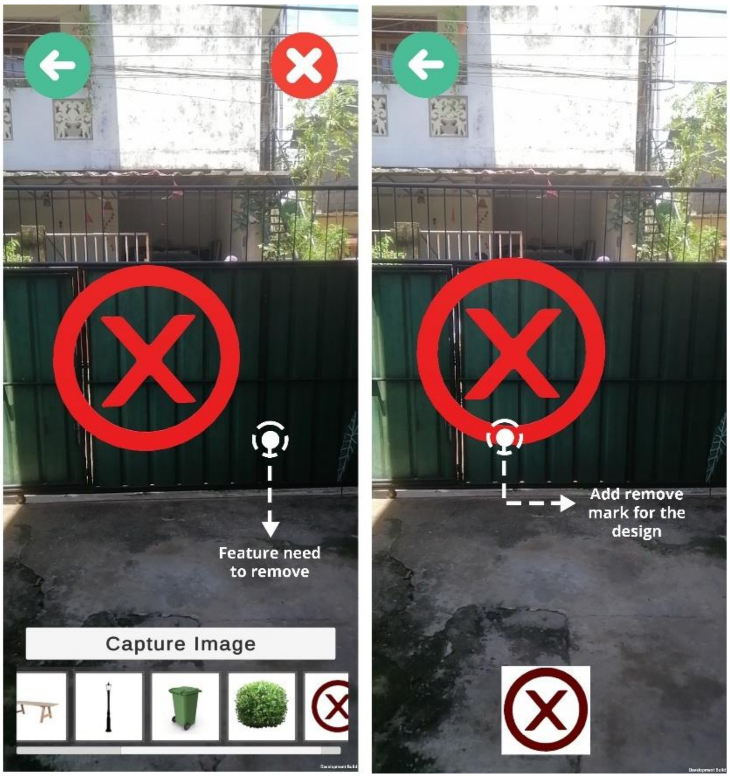



Upon detecting the plane, the user can add the provided elements. The user must pick the item to be placed and touch the designated location for its placement. The element has three designs as seen in Figure 3.4. After adding, you may rotate the piece by holding and dragging it. To remove a previously added item, the user can click to delete it.

Since the application uses M-AR as the tool to design, the application will not be able to remove or delete the real ground features. For that, the application has a remove element as in Figure 3.5. The elements or features that need to be removed from the real world can be mentioned or highlighted using this tool.

**Figure 3.5**

*Remove element*




After finalizing the design, the user may take images by clicking the "capture image" button. Upon clicking the button, the user will be unable to modify the design. Following successful capture, a message will appear as seen in figure 3.3. The image will be stored with metadata including location, time, and date.

## 3.3. Testing of the application with the target group

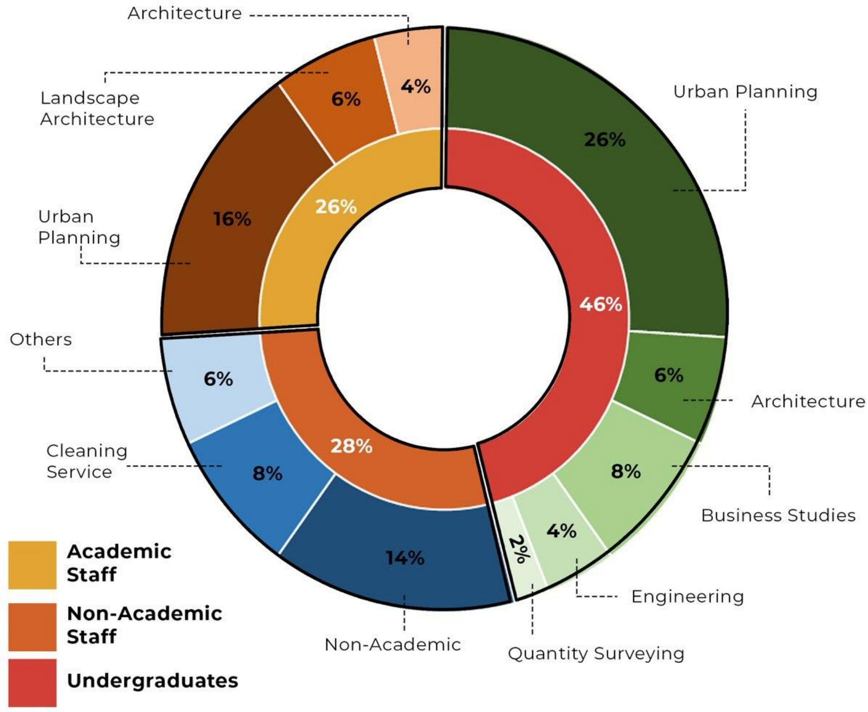
Two testing sessions were held to get comments and perspectives from the participants.

- Session A – University undergraduates and Non-academic staff
- Session B – University Academic staff

Figure 3.6 illustrates the distribution of participants among three groups—university students, professionals, and the general public—analyzed in the research. Twenty-three undergraduates aged 18 to 34 participated in Session A. Figure 3.6 illustrates that the participants were from several educational disciplines: urban planning (26%), architecture (6%), business studies (8%), engineering (4%), and quantity surveying (2%).

**Figure 3.6**

*Participants' Profile*




The majority of participants were somewhat familiar (54.5%) with the placemaking concept, while a smaller proportion were very familiar (21.3%). Most participants encountered the concept through different means, including academic modules or studies (80%), professionals or authorities (32%), and social media (40%), suggesting that some were exposed to it through multiple methods. Conversely, 24.2% of the participants were unaware of the concept.

The non-academic staff members, including technical assistants, drivers, and cleaning staff, participated in session A to convey the public's perspective on using augmented reality for placemaking. Figure 3.6 illustrates that 14 participants participated in the demonstration, including seven non-academic members (14%), four cleaning service personnel (8%), and three others (6%), all aged 35–54. Of the attendees, just three were aware of placemaking, and only one participated in a placemaking initiative through an organized workshop.

Academic staff from urban planning, architecture, landscape architecture, and engineering were engaged to assess the CityBuildAR application for the design of the university cafeteria at the University of Moratuwa during session B. Thirteen academic staff members participated in the demonstration, mostly from urban planning (eight participants—16%), landscape architecture (three participants—6%), and architecture (two participants—4%). Their input indicates that a significant majority are acquainted with placemaking (84.6%), mostly via academic modules (68.1%), interactions with experts and authorities in the area (81.3%), stakeholder meetings and workshops (56.3%), and to a lesser extent through media (18.8%).

The professionals' involvement in prior placemaking initiatives entailed actively participating in the design and planning of green and recreational spaces by incorporating community feedback, offering technical expertise for infrastructure enhancements, and engaging with stakeholders through workshops and urban planning projects, honed through academic coursework and practical experiences. Frequently used placemaking approaches included participatory mapping, stakeholder meetings, and conversations, while the design tools utilized included hand sketching, AutoCAD 2024, SketchUp 2024 modelling, physical models, and ArcGIS (10.8.2) tools.

The participants' familiarity with the location selected (university cafeteria) for the study was evaluated. The majority of university students (78.8%—18), the general public (92.86%—13), and professionals (84.6%—11) who participated were acquainted with the place, while the remaining participants indicated a moderate familiarity with it. University students and professionals used the cafeteria space for eating, socializing, using ATMs, and engaging in recreational activities, whilst the general public focused on dining and maintaining cleanliness in the area. Furthermore, the willingness to participate in placemaking via M-AR has been evaluated, revealing that a majority of university students (55.9%) expressed strong desire, whilst professionals (52.6%) and the general public (51.5%) indicated moderate interest.

### 3.3.1. Comparing Hand Sketching, Software with CityBuildAR

Figures 3.7 and 3.8 show the replies for Q1–Q3, which assessed university students' perspectives on using hand sketches for picturing and designing the open café spaces during session A.

**Figure 3.7**

*Positive aspects of using hand sketching for designing—university students*

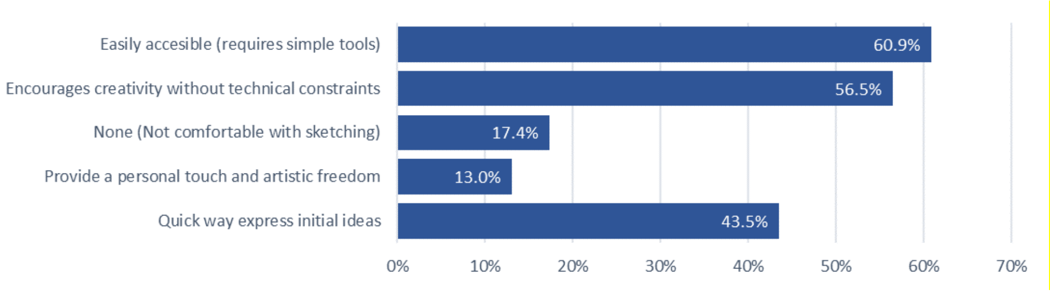
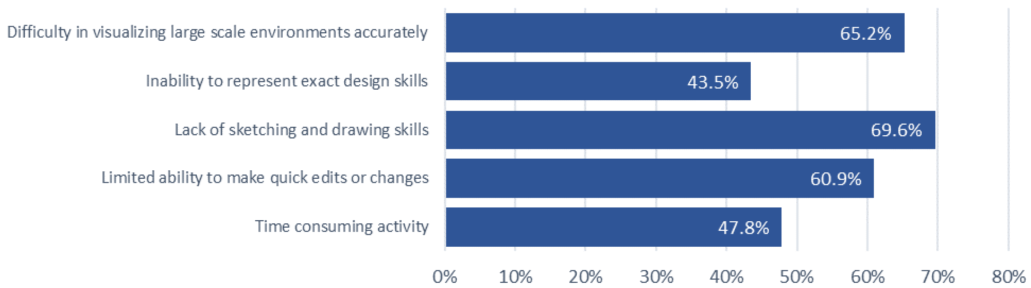



**Figure 3.8**

*Challenges of using hand sketching for designing—university students*




Consequently, the majority of university students opted for hand drawing, with a significant portion expressing comfort (43.5%), while a minority reported discomfort (17.4%) with the practice. Nonetheless, 60.9% of respondents saw sketching as an approachable technique that offers artistic freedom and fosters creativity without technical limitations (56.5%), as seen in Figure 3.7. Participants reported challenges, as seen in Figure 3.8, including difficulties in visualizing (65.2%), constraints in editing the design (60.9%), time consumption (47.8%), and insufficient drawing abilities (69.6%).

Q4-Q6 assessed university students' input about 3D modelling using the SketchUp program throughout the study. Figure 3.9 illustrates that university students recognized the advantages of 3D modelling over hand sketching, including the capacity to visualize designs from various perspectives (60.9%), enable rapid modifications (73.9%), and accommodate intricate details (texture, lighting, etc.) (60.9%). However, they also noted the difficulties encountered while utilizing SketchUp 3D modelling during the demonstration, as depicted in Figure 3.10.

**Figure 3.9**

*Positive aspects of using 3D modelling—university students*

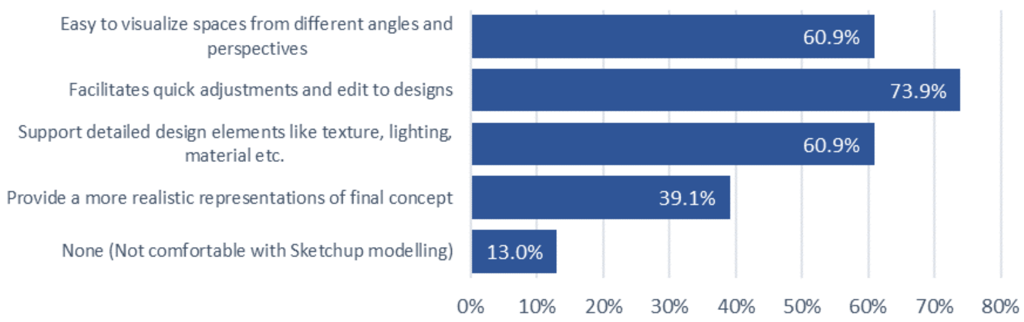
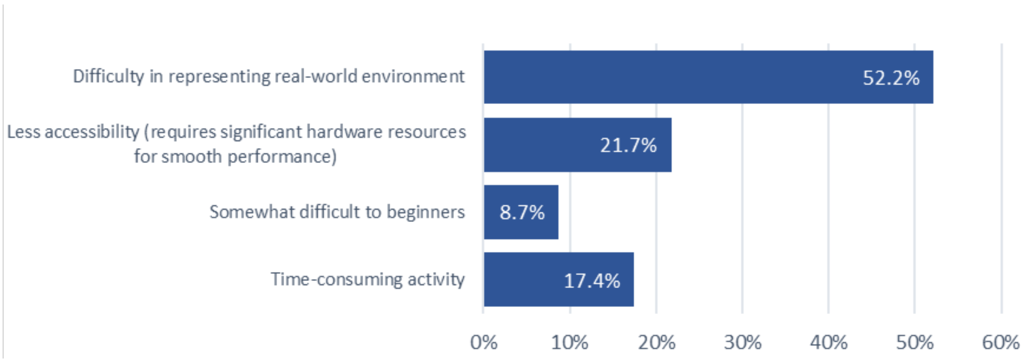



**Figure 3.10**

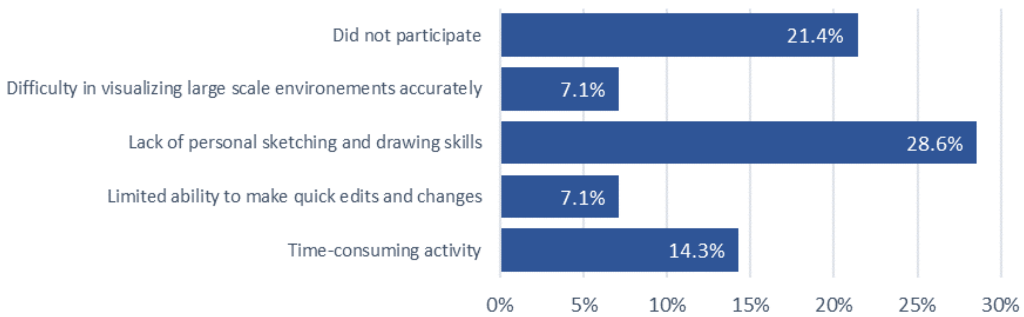
*Challenges of using 3D modelling—university students.*




Nonetheless, none of the participants from the general public group felt at ease with the two choices presented during session A—hand sketching and SketchUp 3D modelling. Figure 3.11 illustrates that the majority cited insufficient personal sketching abilities and characterized it as a time-intensive activity. Moreover, they have not engaged in placemaking activities using these technologies, presenting a difficulty for them.

**Figure 3.11**

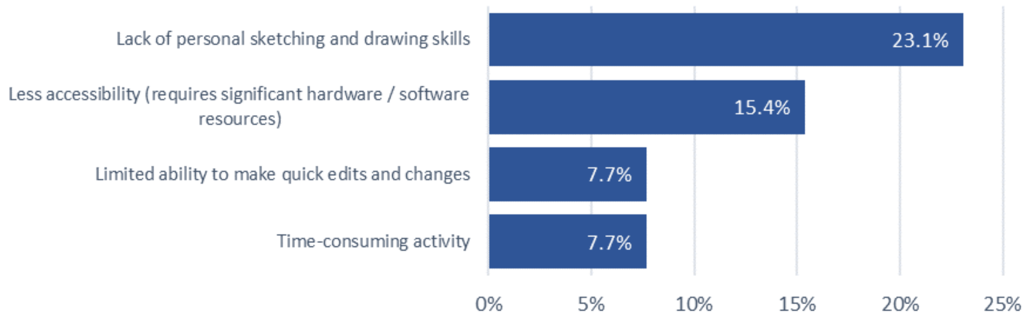
*Challenges of using hand sketching for designing—general public*



The study originally omitted Session A for professionals with placemaking expertise, supposing their adeptness in sketching; nonetheless, participants identified challenges arising from their inadequate drawing abilities to properly depict and customize designs—Figure 3.12. Furthermore, 15.4% of experts highlighted the need for specialized software for design, indicating that current tools provide difficulties in placemaking applications.

**Figure 3.12**

*Challenges of using existing tools for designing—professionals.*

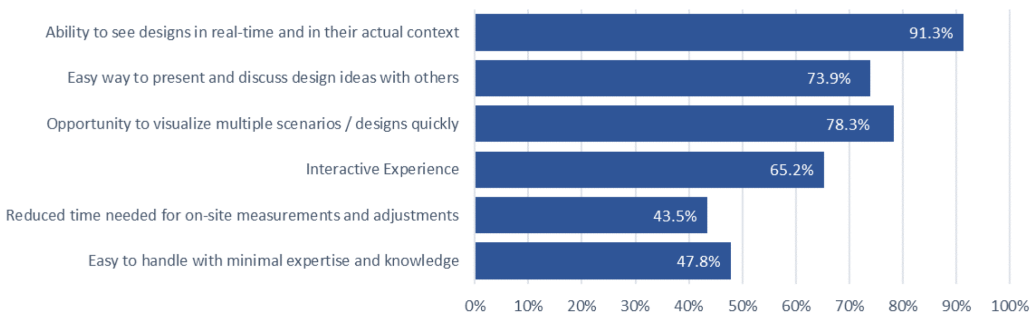



### 3.3.2. Designing public spaces with CityBuildAR

The feedback form sent post-session A addressed questions Q7-Q13, which explored participants' experiences with designing public spaces with CityBuildAR.

**Figure 3.13**

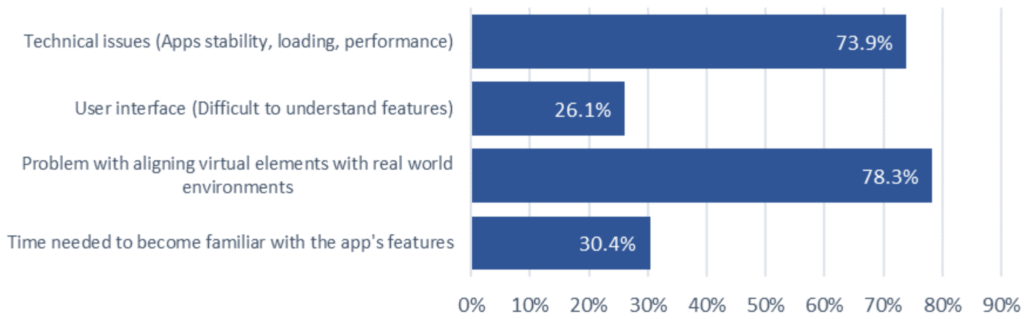
*Positive aspects of using AR—university students*




The comments from university students revealed that the majority found the AR application simple (43.5%) or very easy (17.4%) to navigate and utilize for placemaking, while the remaining respondents expressed a neutral stance (39.1%). Figure 3.13 illustrates that the capacity to visualize designs in real-time, the immersive experience within a real setting, and the capability to create several scenarios within a constrained timeframe were seen as advantages. According to Figure 3.14, university students reported technical problems with the application such as instability, loading delays, performance deficiencies, and challenges in aligning virtual items with the real-world surroundings when using the AR app for designing public spaces.

**Figure 3.14**

*Challenges of using AR—university students*




Among the 14 individuals representing the general public, seven have previously utilized AR applications for gaming (e.g., Pokémon Go, developed by Niantic, Inc. in San Francisco, California, USA), advertising (e.g., Dilmah Tea, a Sri Lankan beverage company in Peliyagoda, Western Province, SL; Coca-Cola's AR billboard for Christmas in Finland), and other purposes (e.g., University Vesak Lantern App, created by the Department of Computer Science Engineering at the University of Moratuwa, Sri Lanka). All 14 participants agreed that the user-friendliness and accessibility of AR applications provide a significant incentive for using AR in placemaking.

**Figure 3.15**

*Positive aspects of using AR—general public*

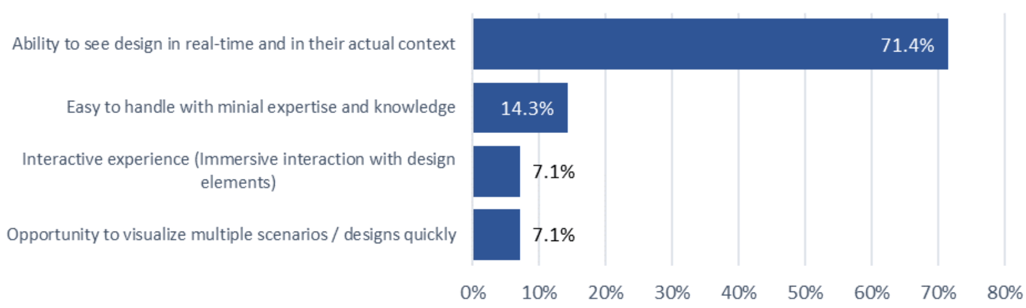


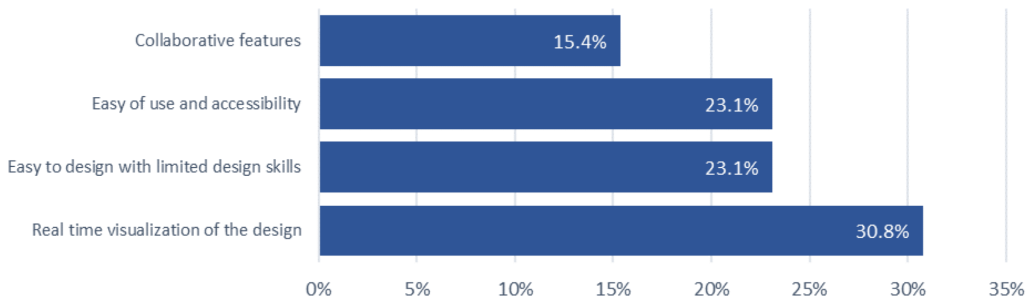

Figure 3.15 illustrates that the general public perceives augmented reality (AR) as a chance to see designs in real time, which is manageable with limited skill and

understanding of the subject. Nonetheless, after their experience with the CityBuildAR app, all participants have recognized problems as drawbacks, including the complexity of comprehending the application's elements and functionalities (such as rotate and delete), necessitating time to familiarize with the software before beginning design.

A total of ten professionals who participated had previously used AR applications for gaming, advertising, infrastructure project simulations, and storytelling (DEVAR app). The motivating aspects for professionals to use AR in placemaking include the capacity to view designs in real-time, the capability to create spaces with little expertise, user-friendliness, and accessibility, as well as the collaborative capabilities of the application, as shown in Figure 3.16.

**Figure 3.16**

*Motivations for using AR—professionals*




Nonetheless, following the utilization of the AR application, the professionals articulated the challenges encountered, including technical difficulties (app stability, loading, performance) and the struggle to align virtual objects with the real ground conditions. Most emphasized the necessity for additional time to adapt to the application prior to commencing the design process. Professionals assessed the app's features, including user interface (colors, graphics), functionalities (rotate, remove), and design elements (tables, chairs, trees, benches, waste bins, etc.) as excellent (64.23%), bad (15.38%), and neutral (15.38%).

The app demonstration conducted with three groups—professionals, university students, and the general public—revealed that professionals predominantly favoured existing tools like 3D software over the AR application, citing its limited features that hinder the creation of distinctive designs. University students recognized augmented reality (AR) as a more convenient instrument for placemaking due to its accessibility and the absence of requisite technical experience or sketching abilities. Furthermore, it emphasized its capacity to collaborate and see the design in real time. The general public expressed that the AR app for placemaking is more inclusive and accessible than current techniques; yet, its effectiveness might be limited by the lack of suitable smartphones to operate the app. All three groups have indicated a need for further time to familiarize to the app prior to beginning the design process, and they have noted that the app necessitates adjustments, including enhanced design components and functionalities such as scaling and movement.

### 3.3.3. Image Analysis

The aim of image analysis is to identify similarities and variations in design approaches across various groups and assess the influence of M-AR technology on design outcomes. Figures 3.17 – 3.19 illustrate the visual representations of university cafeteria designs developed by the three groups during the application demonstration. This document includes three designs from each participant group to illustrate how the groups uniquely used design components, assessed the existing context, and integrated placemaking features.

**Figure 3.17**

*Exemplary visualizations completed using CityBuildAR by Professionals*

(a) Design 1 (b) Design 2 (c) Design 3

**Figure 3.18**

*Exemplary visualizations completed using CityBuildAR by Undergraduates*



(a) Design 1 (b) Design 2 (c) Design 3

**Figure 3.19**

*Exemplary visualizations completed using CityBuildAR by General Public*



(a) Design 1 (b) Design 2 (c) Design 3

Table 3.2 categorizes the designs into three classifications and assesses them based on certain criteria: element use, functionality, user interaction, and integration of AR features. Table 3.2 offers a comprehensive enumeration of the element counts corresponding to each design requirement, explaining the specific elements included in each unique design.

**Table 3.2**

*Image analysis*

| Criteria | | Professional | University Student | General Public |
|---|---|---|---|---|
| Use of element | Tree | 23 (1.77) [1] | 43 (1.87) | 33 (2.36) |
| | Bushes | 55 (4.23) | 104 (4.52) | 30 (2.14) |
| | Table | 10 (0.77) | 26 (1.13) | 13 (0.93) |
| | Benches | 37 (2.85) | 87 (3.78) | 28 (2.00) |
| | Lamp posts | 15 (1.15) | 35 (1.52) | 11 (0.79) |
| | Garbage bins | 1 (0.08) | 15 (0.65) | 7 (0.50) |
| Functionality | Seating | Y—11, N—2 | Y—23, N—0 | Y—11, N—3 |
| | Walking | Y—13, N—0 | Y—17, N—6 | Y—8, N—6 |
| | Lighting | Y—7, N—6 | Y—19, N—4 | Y—8, N—6 |
| | Greenery | Y—7, N—6 | Y—20, N—3 | Y—11, N—3 |
| User Interaction | Physical Setting | Y—13, N—0, M—0 | Y—23, N—0, M—0 | Y—6, N—0, M—8 |
| | Sociability | Y—10, N—0, M—3 | Y—18, N—0, M—5 | Y—2, N—4, M—8 |
| | Imageability | Y—7, N—0, M—6 | Y—21, N—0, M—2 | Y—5, N—8, M—1 |
| Incorporating AR features | Designing | Y—9, N—0, M—4 | Y—23, N—0, M—0 | Y—5, N—0, M—8 |
| | Visualizing | Y—0, N—0, M—13 | Y—23, N—0, M—0 | Y—5, N—0, M—8 |

[1] Count (Mean), Y = Yes/ N = No/M = Moderate.

Table 3.2 demonstrated that professionals included a restricted array of elements in the designs, including a single garbage bin throughout all designs, with a mere 15 lampposts, 37 benches, and 10 tables. In comparison, university students included more features into the design, including trees (45), bushes (104), tables (26), benches (87), lampposts (35), and garbage bins (15). The general public contributed aspects that were relatively more than those of professionals but lesser than those of university students.

Greenery was included into seven (53.8%) designs of occupations without altering the current cafeteria environment. The ideas proposed by university students emphasize their needs for more seats (100%) and enhanced lighting (82.6%) in the area. The incorporation of shade trees is often highlighted in all designs, whilst the bushes are positioned for aesthetic enhancement. The ideas proposed by the general public exhibit recognizable configurations, such shaded sitting areas accompanied by nearby garbage bins, mirroring established patterns. University students emphasized their needs to convene in aesthetically pleasing and comfortable environments.

Table 3.2 illustrates that university students prioritized functionality—encompassing seating, walking paths, lighting, and greenery—in their design. In contrast, the general public's design considerations were relatively minimal, as existing paths were utilized without provision for shade in the seating area. University students emphasized aesthetic appeal and comfort, disregarding the actual ground environment, while professionals placed significant emphasis on the existing layout, opting not to include several components into the design. The general public regarded utility by including standard necessities, such as seating in this area.

The analysis of user interaction with placemaking and community participation throughout the designing of the space was conducted based on the criteria of physical setting, sociability, and imageability. Professionals deemed the current environment to be more than just appealing, including both physical and social comfort. University students have evaluated the physical environment, including factors such as accessibility, walkability, temperature comfort, and spatial attributes. Moreover, visual appeal, beauty, and comfort, embodying imageability, were prominently included in the designs. Nevertheless, the general public group overlooked the accessibility and walkability of the area. University students addressed the sociability factor by integrating density, spatial variety, and furniture availability; nevertheless, professionals contributed little to improving diversity or density in the environment. The general public somewhat regarded sociability by integrating density and practicality into the design, although neglected the factor of imageability.

All three groups—professionals, university students, and the general public—integrated AR aspects and features in the design and visualization of the environment.

University students used AR to develop innovative and experimental designs, whilst professionals concentrated on improving the current layout with little modifications. In contrast to university students and professionals, the general population used fewer design components and concentrated on familiar layouts, leading to simplistic representations.

The image analysis uncovered several design techniques shaped by participants' backgrounds and the use of AR as a placemaking tool to facilitate the visualization of design concepts.

### 3.3.4. Opinion Analysis

The participants provided comments about their placemaking exercise via the CityBuildAR application. Among all participants, 81% had articulated their ideas. The research analysed all open-ended replies and categorized them into three categories according to their nature. Of them, 43% have expressed favourable views toward the app.

#### 3.3.4.1.Ability to Visualize and Design with Limited Skills

Several participants recognized the CityBuildAR app as a useful tool for visualization, facilitating space design for people with less sketching abilities, technical knowledge, and reduced hardware/software requirements.

- Opinion 1—“I have limited drawing skills, so I usually engaged in collaborating with ideas as a group member while another member will visualize. But using this AR app I can do my own design by myself. But the list of elements and features should expand to make a unique design.”
- Opinion 2—“I really liked the interface and elements of the app. It creates a nice de-sign of myself with limited skills. Wish I had more time to get familiar with this app.”
- Opinion 3—“Simple and effective for non-designers.”

#### 3.3.4.2.Impact on Creativity of Users

The majority of participants said that the few features and possibilities available had hindered distinctive design and unique characteristics. Moreover, the application crashes have often disrupted the design process.

- Opinion 4—"Great concept for enhancing placemaking through real-time visualization. However, the limited design options and occasional bugs limit its potential in professional landscape projects. Expanding its feature set would make it more versa-tile."
- Opinion 5—"App doesn't allow us to create & visualize unique designs. It generalizes the designs and with the given elements, it's limited to create my own design. Realtime visualization is interesting somehow."
- Opinion 6—"Expanding the range of features and addressing performance concerns would make it a highly effective tool for professional urban planning and participatory processes."

The aforementioned viewpoints suggest that the AR software has constrained participants' creativity and necessitates alterations in its aspects, functionality, and scalability to improve design originality.

#### 3.3.4.3.Technical Constraints

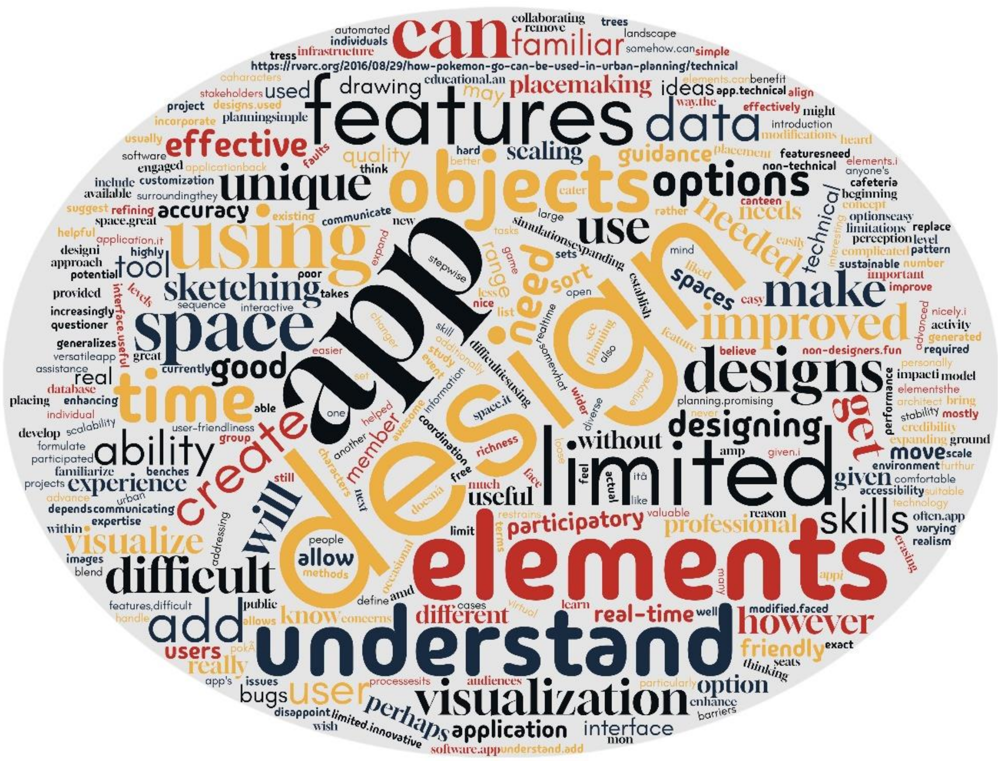
In addition to the aforementioned restricted features and aspects, most participants expressed their concerns over the insufficient time allocated to familiarize themselves with the app prior to the design process. Their comments indicate that familiarity with the app is crucial for developing an appropriate design.

- Opinion 7—"App elements are difficult to understand in the beginning, needed assistance to understand. I had the ability to do a design for cafeteria using this app, which I wouldn't be able to do with sketching or other software."
- Opinion 8—"Expanding the range of features and addressing performance concerns would make it a highly effective tool for professional urban planning and participatory processes."
- Opinion 9—"Using app for designing is good for me because I have poor drawing skills. However, it is difficult to understand and design within this limited time given."

Participants' response underscored the app's potential as a placemaking tool, particularly for fostering community involvement across varying levels of knowledge and expertise. Nevertheless, as seen in Figure 3.20, technical challenges, including restricted components and initial comprehension difficulties, must be resolved to achieve more innovative and distinctive designs.

**Figure 3.20**

*Word Cloud representing participant opinions*



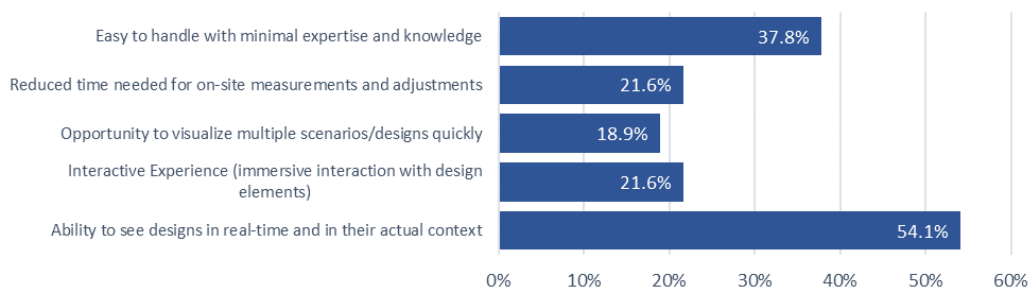

## 3.4 Validation with Target Group - Youth

37 participants completed the feedback form and expressed their comments about the generated application. 89.2% of the participants had their first experience with placemaking or urban design activities, and 91.9% of participants haven’t used any AR applications before as well. This has provided a valuable sample for comparison with other target groups possessing relevant backgrounds in urban design and placemaking.

The 37 participants assessed the ease of understanding and using the AR app on a 1-5 Likert scale, with 5 indicating extremely simple. The app has received an overall rating of 3.46, indicating it has some issues among participants. 32.4% of users assert that the application has enhanced their ability to envision their design concepts more effectively. While 54.1% believe that it has provided just minimal assistance.

**Figure 3.21**

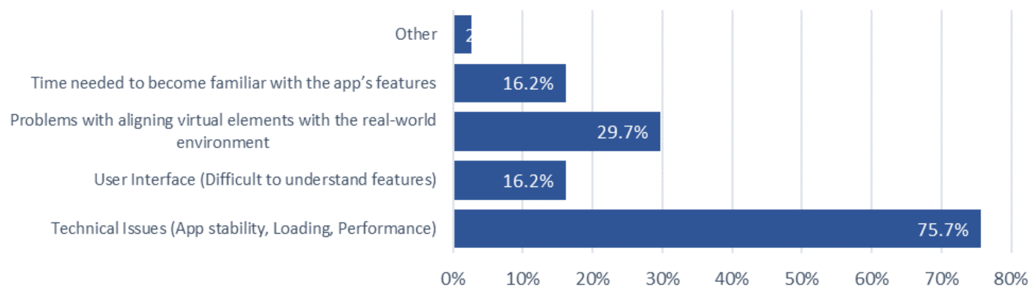
*Positives experienced while using the AR app for designing - Validation*




According to figure 3.21, 54.1% of participants stated that ability to see designs in real-time and in their actual context as the main positive experience through the AR application while another 37.8% participants stated it was the minimal expertise and knowledge made their experience positive. According to figure 3.22, many had faced technical issues such related to app stability, loading and performance.

**Figure 3.22**

*Challenges faced while using the AR app for designing - Validation*




Features include user interface, user login and registration, plane recognition, augmented reality components, visuals and colors, as well as rotation and removal functionalities received neutral ratings from over 45% of the participants. Merely 10% of individuals said that such aspects are the most interactive.

Many have indicated that the application will need many adjustments; yet, it shows much promise.

Response 1: “It's a good application as v1. Also, it's better to improve area tracking and surface analysis. Much better if it had more objects to place or common blueprints like objects. Also, it's better if it had some AI features like suggesting relevant objects to place by analysing the area. Overall good concept.”

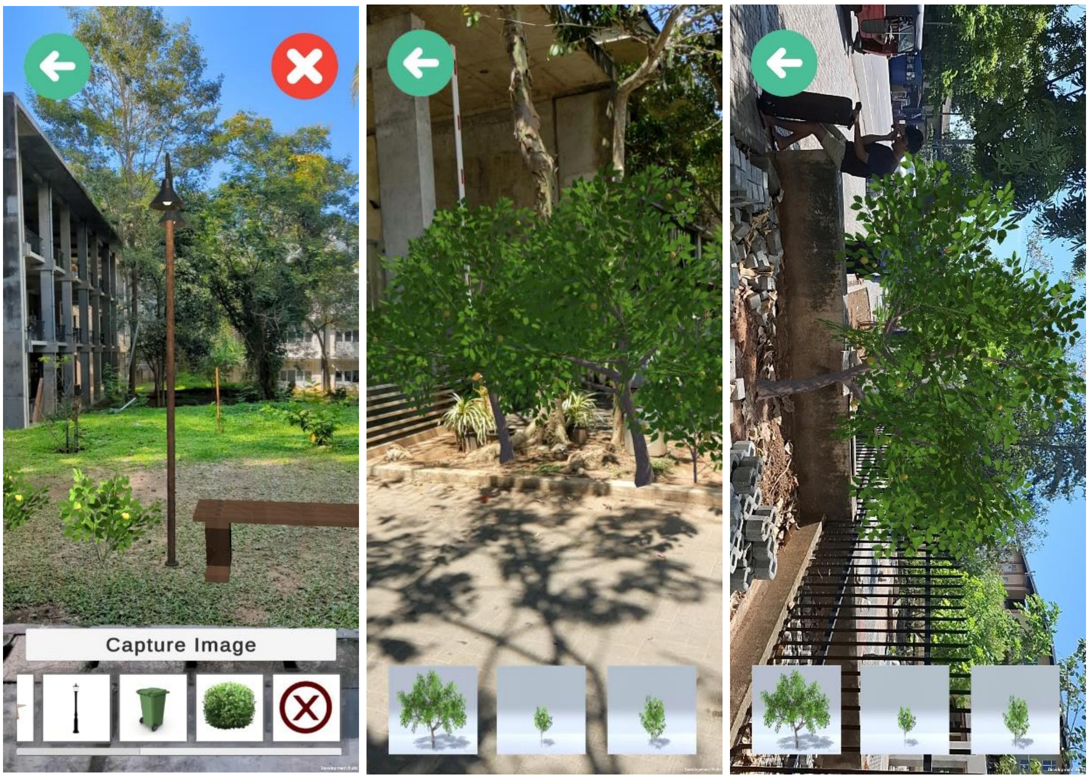
Response 2: “Excellent as a new application. But need to improve to compete with world-class AR apps.”

Response 3: “It was a new experience, working with AR technology, and we can see how we can use it efficiently to design and plan certain elements of places.”

However, as their first experience with augmented reality, the participants had difficulties in navigating the program. Figure 3.23 illustrates a few designs they have created using this app.

**Figure 3.23**

*Designs created for the UOM front area using the CityBuildAR App*



# CHAPTER 4

# CONCLUSION

This study aimed to investigate the use of M-AR as a participatory planning to enhance youth involvement in designing public spaces, framed by three fundamental research questions. These questions concentrated on assessing the effectiveness of current participatory planning tools, the formulation of an M-AR application designed for youth involvement, and the appraisal of its influence on engagement and spatial comprehension. The concept, development, and testing of the CityBuildAR app highlighted how augmented reality enhances communication, visualization, and inclusion in urban planning. This chapter synthesizes the principal findings from the research and emphasizes the study's contribution to the enhancement of technology-driven, youth-oriented participatory planning methodologies.

## 4.1 Leveraging M-AR to create an inclusive and accessible platform for community engagement in urban planning

This study intends to examine how to utilize M-AR as a tool to design public spaces and its effectiveness in engaging communities, including youth, as mentioned in the research questions above. According to this study, AR can support civic engagement in urban planning by making complex procedures more accessible. Leveraging mobile devices, it creates an inclusive and user-friendly platform for public participation. Most importantly, AR can engage the community in neighbourhood planning and design by providing a spectrum of services that range from visualizing spatial information on-site to collecting spatial data in situ, enhancing the overall user experience with the space (Ahmadi Oloonabadi & Baran, 2023; Wilson et al., 2019a; Hunter et al., 2021). Using AR for designing public spaces enables citizens to view proposed modifications and designs in their neighbourhoods through their mobile devices. They can provide feedback, share suggestions, or communicate their needs directly via the AR app, which is significantly more user-friendly than traditional complex tools that require technical expertise (Sabah et al., 2023; Pombo & Marques, 2017).

The in-situ visualization of suggested street features and design alternatives in their actual locations improved spatial literacy and communication between the community and the decision-makers. According to Noyman et al. (2017), digital tools were recognized as highly supportive of public participation, and citizens experienced them as partners rather than participants. Furthermore, planners identified citizen comments made through AR platforms as applicable for early policy formation and regeneration (Wilson et al., 2019c). Mobile AR applications empowered citizens to make informed decisions and contribute to urban planning with design ideas and suggestions (Boos et al., 2023; Imottesjo & Kain, 2018) and also promoted learning and citizens emotional connection to the cities (Markouzis & Fessaki, 2015).

AR enabled the inclusivity and accessibility of multiple stakeholders in the urban planning process. Mobile AR provided a platform for collaborative evaluation, negotiation, and crowdsourced data collection, enabling collective decision-making in urban planning (Saßmannshausen et al., 2021 ;Imottesjo & Kain, 2018b ;Sabah et al., 2023). It positively impacted the engagement of senior citizens and differently abled persons in planning activities by motivating them to be more active outdoors through immersive technology (Angelini et al., 2020). According to Saßmannshausen et al. (2021), AR enhances the collaborative design process among young citizens as well, which answers the second research question related to engaging communities, including youth. Additionally, children's urban spatial perception and interaction are also enhanced through AR and it enables children to develop skills like collaboration, exploration, and adventure (Nekoui & Roig, 2022).

## 4.2 Challenges and barriers in implementing M-AR as a tool to design public spaces in urban planning

In addition to exploring the potential of using M-AR for designing public spaces, this study examined the challenges that hinder its maximum effectiveness under the second research question, which focuses on investigating the effectiveness of M-AR as a participatory tool. Accordingly, the most challenging aspect of using technical approaches is that the tech trends are developing and rapidly changing. The probability of an approach being outdated within a shorter period is challenging. This study leads to examining AR's role as a participatory planning tool amongst rapidly changing technology. The availability of the necessary devices is crucial when using AR as a participatory planning tool. AR has become a more convenient approach to engage all the communities in the decision-making process due to advanced technology and the availability of resources such as mobile phones, internet facilities, and digital wearables, i.e., Smart Watches, among most individuals at present (Cirulis & Brigmanis, 2013). Apart from mobile devices and web devices, the availability of other AR methods like Optical See-Through and Projective AR has been discussed as alternatives that can be commonly used by participants (Broschart & Zeile, 2014).

Although AR has enormous potential and a positive impact as a participatory planning tool, certain challenges and barriers emerge when integrating AR into the urban planning process. AR participatory platforms face challenges in reducing barriers to digital participation, such as inadequate digital literacy and technological proficiency, which could discourage marginalized communities from accessing and efficiently utilizing AR technology (Ahmadi Oloonabadi & Baran, 2023). Therefore, despite efforts to bridge the digital divide, significant barriers remain that prevent underprivileged people from accessing digital technology, which limits the effectiveness of augmented reality as a tool for participation (Ahmadi Oloonabadi & Baran, 2023). Therefore, in answering the third research question of this study, the findings highlight that AR is not fully capable of bridging the gap between professionals and the general public due to the issues and limitations identified.

According to Fegert et al. (2019), it is necessary to have user-friendly participation procedures when implementing AR as a participatory planning tool. Moreover, the age gap in familiarity with mobile devices and technology influenced user responses when using smartphone-based AR in urban planning (Allen et al., 2011). Additionally, technical complexity and high costs significantly affected the quality of the content production using AR (Sabah et al., 2023; Silva et al., 2023). Challenges included battery drain, weather unpredictability, time constraints, and network failures when using AR for urban planning (Silva et al., 2023 ; Shih & Chen, 2020), sunlight and reflections affected the quality of the AR experience (Goudarznia et al., 2017), performance depended on image quality when using devices (Sabah et al., 2023), and limited AR app support to android devices only (Ramos et al., 2018; Markouzis & Fessaki, 2015).

Furthermore, technical barriers such as lack of GPS accuracy, and hardware memory constraints have been identified (Santana et al., 2017; Allbach Benjamin et al., 2011).

Most of these challenges occur when AR is generally used in various platforms including head-mounted devices, optical AR lenses, desktop computers, and rendering units. But still, M-AR addresses the challenges regarding high costs, complexity, and accessibility to the AR platforms enabling an inclusive, user-friendly participatory approach in urban planning (Allen et al., 2011; Imottesjo & Kain, 2018a; Ertiö, 2015).

According to (Hunter et al., 2021b), the oversimplification of citizen roles through technology has been identified as a challenge and the potential for power imbalances in decision-making has been identified as a result of this process (Gudowsky et al., 2023). The challenges related to power imbalance and citizens' role have been addressed by Hunter et al. (2021) stating that AR enables civic participation in the city transformation process by creating a dialogue between citizens and councils for co-design in cities.

Challenges related to urban planning communication are addressed through the emergence of digital-tangible interfaces like mobile AR (Ben-Joseph et al., 2001b). Incorporating offline functionality can reduce the battery drain, and memory constraints of devices as well as address the digital divide when using AR for planning (Silva et al., 2023). Furthermore, mobile AR has the potential to incorporate contemporary techniques such as gamification, crowdsourcing, real-time visualization, and evaluation to enhance community engagement (Imottesjo & Kain, 2018a ; Resek et al., 2024).

## 4.3 To What Extent Does the CityBuildAR App Bridge the Gap between Professionals and the General Public in Designing Public Spaces?

The CityBuildAR application enables the public to create and visualize public areas via their mobile devices, similar to a professional, substantially improving their capacity to engage in designing public spaces. The contradiction between community wishes and favoured public engagement strategies has resulted in insufficient public involvement in urban planning using traditional methods (Caldeira & Holston, 2015; Al-Kodmany, 2001).

Moreover, real-time visualization prompts users to reimagine spatial designs despite constraints in time and skill, since actual visualizations are more impactful than abstract representations, particularly in engaging a non-specialist audience such as the general public (Al-Kodmany, 2001). AR models may encourage individuals to engage in the planning process and provide prompt feedback using AR technology (Othengrafen et al., 2023; Yigitcanlar,2010). The CityBuildAR app facilitates designing public spaces by allowing users with little technical skills and experience to use advanced tools, hence increasing public involvement in the process. Consequently, using augmented reality for designing public spaces might effectively connect planning professionals with the general populace regarding design and visualization. The use of technologically sophisticated apps (AR, VR) assist experts in developing an inclusive and accessible participatory planning technique for all people, including students (Hunter et al., 2022; Sabah et al., 2023).

The CityBuildAR application promotes participatory planning and improves stakeholder interaction, therefore streamlining the planning process for authorities. The application should be included in community-oriented urban planning and regeneration initiatives, enabling residents to create and visualize their preferences in real-time while offering prompt input to the authorities. For example, in Vienna, Austria, AR has been used in two urban planning projects to evaluate its efficacy in participatory planning, with findings demonstrating that AR enhances communication between stakeholders and planners (Reinwald et al., 2014). Accordingly, the study highlights that AR has the potential to enhance community engagement in designing public spaces. Furthermore, the AR app facilitates dialogue, a two-way communication between the community's needs and the planning expertise of professionals, as addressed in the third research question.

Nonetheless, despite its benefits, the application exposes a significant deficiency in the design process, namely the justification for designs. During the application presentation, the professionals evaluated the current configuration of the university cafeteria. They incorporated features into the existing layout without discarding it or neglecting the current configuration, since they emphasized utility and practicality based on their expertise, leading to more pragmatic designs. Conversely, university students were innovative and disruptive, disregarding the current environment in implementing their ideas. The findings indicate that undergraduates are often urged to engage in creative thinking, and based on their feedback, university students exhibited more familiarity with AR technologies and a willingness to explore without limitations. The overall public used the software to envision current patterns and spatial configurations with few prerequisites, indicating that using CityBuildAR for design has been entirely experimental for them. It suggests that knowledge and skill directly influence the design while using CityBuildAR. Moreover, it underscores the application's adaptability to meet the diverse demands of various societal strata in articulating their design ideas.

The CityBuildAR application enables professionals and the general public to participate in designing public spaces, facilitating improved visualization and conceptualization. Nonetheless, the application enables users to conceptualize their needs and preferences via design. At times, critical factors such as walkability, accessibility, comfort, and activity density may be overlooked, as shown in the image analysis (Figures 3.17 – 3.19). The ideas and visualizations created by the university students include a comprehensive transformation that necessitates the substitution of the current materials (concrete pavements). However, to bridge the gap between professionals and the general public in designing public spaces, as addressed in the third research question, it is essential to update the app to the latest versions, integrate new technologies such as AI, and ensure continuous debugging.

The general public only focused on their basic requirements, such as seating and shading, while the professional designers were more focused on keeping the same layout by adding a few elements. Therefore, the necessity of incorporating the knowledge of placemaking to the app using other alternatives such as incorporating gamified can be emphasized.

## 4.4 Can M-AR Tools Like CityBuildAR Replace Traditional Participatory Planning Tools?

A major concern of this study, as mentioned in the first research question, is to determine whether M-AR can completely replace existing traditional participatory planning tools. CityBuildAR application enhances sociability by providing an immersive, real-time, interactive experience for altering public places and facilitating collaborative decision-making. In contrast to conventional techniques that depend on drawings, 3D renderings necessitating specialized knowledge, or public hearings with restricted engagement with the actual environment, the CityBuildAR app allows users to visualize designs and position and modify virtual objects within a real-world context, providing a concrete link between designs and the physical surroundings.

Furthermore, it improves spatial perception by allowing users to amalgamate visual and cultural components inside public areas and examine the influence of design features on the overall character and identity of the place, so augmenting its imageability. The application's capabilities, including real-time visualization, an interactive platform, and accessibility, remove the obstacles linked to traditional approaches such as discussions, public hearings, and stakeholder meetings, allowing it to serve as a modern tool for designing public spaces.

Unlike the 34 applications examined in the literature study, CityBuildAR circumvents location-based mistakes and GPS inaccuracies (Pombo & Marques,2020; Santana et al., 2017) as it does not need location retrieval for design purposes. The CityBuildAR application utilizes marker-less augmented reality technology, using real-time spatial recognition and surface tracking via the device's camera, with virtual items positioned concerning the identified plane. This technique enables users to swiftly position things. This, however, constrains the capacity to alter or replicate the same design with great accuracy, since it is stored as a picture in the cloud. The geographic coordinates and design settings are stored in the cloud for future retrieval. Consequently, the City-BuildAR application allows anybody globally to generate a design and thereafter save the image in a cloud database managed by the relevant local authorities. This software mitigates additional restrictions, such as technological complexity and elevated costs associated with other AR applications, by requiring just a smartphone for installation, design execution, and cloud storage. The CityBuildAR application has several inherent constraints, including the need for a suitable smartphone to operate the AR application, fundamental technical knowledge for installation and use, and an internet connection to link the program to the cloud for design storage. Moreover, the AR applications identified in the assessment do not provide direct public interaction within the planning context. Although 6 applications pertain to urban planning, only the Smart AR mini application (Sanaeipoor & Emami, 2020) and the ChangeExplorer app (Wilson et al., 2017) provide real-time public interaction in a real-world setting. Other applications, such as City View AR and Wikitude, provide just visualization capabilities. Conversely, other applications mentioned in the literature are not immediately pertinent to urban planning; nonetheless, they facilitate community involvement in other domains, such as construction.

However, the CityBuildAR application does not possess the potential to entirely replace traditional participatory techniques. This application enables individuals to create distinctive designs, so augmenting their participation and comprehension in placemaking. However, the image analysis (Table 3.2) indicates that significant factors such as physical context, sociability, and imageability in placemaking were not emphasized in the designs generated by the program. However, the CityBuildAR facilitated the design of public spaces for all users. The limited time and area available for design, together with the characteristics of the environment (cement pavements, existing table, and bench arrangement), have impacted the professional's designs. The comment underscores the need for cooperation between planning practitioners and the community using augmented reality for successful placemaking.

Decisions may be formed by integrating the public's knowledge into the decision-making process, as stated in (Pissourios, 2014). The local population has awareness of crimes or traffic issues in certain areas, and this insight may be integrated by planners via participatory planning (Gordon et al., 2013). The integration of traditional elements and augmented reality applications effectively conveys placemaking information to participants. The CityBuildAR application, as shown, presents challenges in comprehension and navigation for users. Additionally, it facilitates only solo experiences, resulting in a deficiency of discourse and collaborative spatial design.

Consequently, mobile AR apps such as CityBuildAR should be regarded as supplementary instruments rather than substitutes for traditional tools. This AR application shines in visualization and improving accessibility to the design process; nonetheless, it should be used with expert interpretation before real deployment. The research indicates that CityBuildAR may improve community involvement. However, while contemplating placemaking, it is essential to integrate professional ideas into the designs of the general public. It may prevent the oversight of critical elements such as inclusion, spatial considerations, activity density, and variety.

## 4.5 Scope and Limitations

Initially, this research scope was focused on broader aspects of urban planning, with an emphasis on enhancing community engagement in the planning process. However, following a comprehensive literature review, the study refined its focus to explore the use of M-AR, particularly aimed at engaging youth in planning and designing public spaces. The research examined how M-AR applications can strengthen community involvement and bridge communication gaps between the general public and planning professionals.

The AR applications reviewed in this study were selected based on the papers identified through the systematic literature review. As a result, the review may not have captured all existing AR applications used for participatory planning, potentially limiting the comprehensiveness and generalizability of the study's findings.

The CityBuildAR application exhibits technological constraints, including a restricted selection of features, the need for prior familiarity for effective design, and insufficient dissemination of data within the app. The continuous introduction of new versions and tools to the applications, together with acknowledging each contribution and maintaining ongoing responsiveness, is essential for encouraging user enthusiasm in utilizing these tools and applications for urban planning (Yigitcanlar, 2006). The application lacks any advice for users prior to the design process, an issue that must be addressed before its official launch.

The AR application is still in the development stage and exhibits several technological flaws and limitations that impact its functionality.

- Plane-detection problems: The application requires plane identification to be completed before item placement, since it cannot identify more planes after objects are positioned.
- Restricted design elements: Participants were provided with a restricted selection of things for spatial design, perhaps limiting their inventiveness and design options.
- Scaling limitations: Users cannot resize items, constraining design flexibility.
- Deletion errors: Certain elements encounter errors when deletion, leading to challenges in modifying the design.

Despite these limitations, the application operates as a prototype for participatory placemaking using augmented reality. Insights obtained from the testing sessions will guide future improvements, addressing these issues and enhancing its usability and features.

## 4.6 Recommendations for future studies

### 4.6.1 Practical Implications

This study indicates that M-AR applications like CityBuildAR can be incorporated into the planning processes carried out by agencies like UDA in the Sri Lankan context. During community consultation phases, these tools provide a more participatory platform for residents to visualize proposed designs, offer improvements, and communicate their views more effectively. Similarly, this approach can strengthen transparency and promote two-way communication and collaboration with citizens, stakeholders, and the professionals in placemaking.

In addition to that, other local planning agencies, including Municipal Councils, Urban Councils and Pradeshiya Sabhas, can also implement M-AR-based tools like CityBuildAR to make placemaking more accessible and appealing for everyone, especially encouraging youth to get involved in the process. Utilizing technology that facilitates active community engagement with proposed designs enables authorities to obtain more meaningful feedback, promote increased engagement, and enhance the overall quality and acceptance of planning decisions. Moreover, practical integration via engagement with authorities and stakeholders is essential to mitigate existing restrictions and assess the app's long-term effects.

### 4.6.2 Technical Constraints

The CityBuildAR application enables anyone with no design expertise to imagine and construct spatial designs, creating a feeling of ownership and agency in modifying their environments. Integrating the advantages of conventional participatory approaches with the novel functionalities of AR provides a more inclusive and successful placemaking strategy. Nonetheless, the application's technological deficiencies, including inaccuracies in plane identification, restricted design features, and irregular crashes, resulted in less comprehensive feedback and limited the capacity to develop participants' ideas.

Future studies should investigate methods to provide an interactive login feature inside the application, enabling several users to collaboratively build places. The CityBuildAR will be developed to improve collaborative placemaking by including ratings, enabling comments on others' ideas, and integrating gamified aspects such as scoring and leaderboards. Additionally, to prevent server failures, it is advisable to have a guest option, allowing users to log in and design once without retaining their login credentials on the server, while just the drawings, accompanied by geographical coordinates, are preserved.

Improving application stability and including features like gamified aspects is essential to prevent restricted participant engagement and to maximize application performance (Yigitcanlar, 2006; Gonsalves et al., 2021; Kankanamge et al., 2022). Future revisions must improve technology to ensure app stability and promote a user-centric design by assessing user engagement and the efficacy of CityBuildAR in practical placemaking contexts. Moreover, the opinion study revealed that technological limitations hinder the capacity to generate distinctive design concepts for each person, and experienced experts exhibited a degree of resistance to technology as a result of this challenge. Consequently, future research must emphasize the need to elicit unique and distinctive designs and ideas from people by using technological tools.

### 4.6.3 Recommendations for future researchers

Future researchers are encouraged to extend user testing of M-AR apps like CityBuildAR to involve a wider and more varied range of participants. Testing must include a diverse range of age groups, professional backgrounds, and socio-economic sectors, rather than being restricted to university students or academics, to ensure that the applications address the requirements of a wider society. This method would provide a comprehensive understanding of the interactions among diverse user groups using M-AR technologies and identify particular modifications required to enhance accessibility and usefulness.

Moreover, future research should investigate the integration of emerging technologies, including Artificial Intelligence (AI), Internet of Things (IoT), and 5G networks, with M-AR applications. These technologies could enhance real-time responsiveness, customize user experiences, and enable more intelligent, data-driven placemaking approaches. Furthermore, researchers should investigate methods for adapting M-AR approaches for rural and limited-resource contexts, where obstacles such as slow or unavailability of internet connection, inadequate digital literacy, and device cost could hinder participation. A special focus must be given on developing portable, offline-capable, and user-friendly applications for such situations. Another crucial aspect for future study is to examine the long-term effectiveness of M-AR tools in continuing the community engagement beyond the preliminary stages of the planning process. Researchers should investigate how M-AR tools facilitate ongoing dialogue, feedback collection, and project monitoring.

By using the transformational capabilities of M-AR, urban areas consist of more inclusive, dynamic, and resilient communities. This technology enables people from many backgrounds to engage in the creation of urban places, ensuring that progress aligns with the needs, goals, and identities of all citizens. Integrating M-AR into urban planning and design enables cities to foster collaborative, transparent, and innovative decision-making processes, eventually resulting in more people-centered plans.

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