SmartCity AR: Re-imagining Cape Town's Foreshore Freeway

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ABSTRACT

Urban planning requires a comprehensive understanding of infrastructure, transportation, and sustainability. Traditional tools like static maps lack interactivity, limiting effective decision-making. This report introduces SmartCity AR, an Augmented Reality-based urban planning viewer designed to enhance visualization and analysis. Focused on Cape Town's Foreshore Freeway Precinct, the tool addresses traffic congestion and inefficient land use by enabling users to compare sustainable vs. unsustainable planning scenarios, explore transport hubs, and visualize pedestrian-friendly routes. The report outlines the system's design, user requirements, methodology, and implementation strategies.

1 INTRODUCTION

With rapid urbanization and increasing population density, cities face growing challenges in managing infrastructure, transportation, and land use. Effective urban planning is essential for optimizing space, improving mobility, and ensuring sustainable growth. However, traditional planning tools—such as paper maps, 2D blueprints, and static models—often lack interactivity and fail to accurately convey the complexities of infrastructure networks.

The Foreshore Freeway Precinct in Cape Town exemplifies a poorly optimized urban space, suffering from traffic congestion, underutilized land, and inadequate pedestrian infrastructure. Existing redevelopment proposals have highlighted the need for improved transport integration, mixed-use developments, and pedestrian-friendly spaces, but communicating these ideas to stakeholders remains challenging due to the limitations of static planning tools [1].

To address this, the project proposes an Augmented Reality (AR)-based educational tool that enables urban planners, architects, and stakeholders to visualize and interact with different infrastructure designs in an immersive environment. By overlaying proposed enhancements onto the real-world precinct, users can better understand how strategic planning decisions—such as improved public transport integration, MyCiTi bus expansion, and optimized land use—can enhance connectivity and sustainability.

2 LITERATURE REVIEW

Augmented Reality (AR) has emerged as a powerful tool for urban planning, allowing users to overlay digital models onto real-world environments. Previous studies have demonstrated the potential of AR in infrastructure design, transportation planning, and public engagement. CityBuildAR's mobile app demonstrated that AR can engage the public in placemaking, enabling users with limited design knowledge to actively contribute to urban planning and express preferences, such as favoring more green spaces in public areas [2]. AR's effectiveness in participatory urban planning has also been evaluated in studies that show varying preferences for levels of detail (LOD) in 3D models, with higher LODs offering more clarity but introducing challenges like visual clutter and scaling issues [3]. In architecture and urban planning, AR has been used to visualize both simple and complex design elements, with techniques like GPS-based and marker-based AR offering dynamic ways to enhance user interaction and spatial understanding in both professional and public settings [4]. While these studies highlight AR's effectiveness, few implementations specifically target sustainable urban planning. This project hypothesizes that such an AR tool will improve user comprehension and support better-informed planning choices compared to traditional 2D methods.

3 PROJECT PROPOSAL

Urban planning requires a clear understanding of how infrastructure and transport networks interact within a city. Traditional tools—such as static maps (e.g., paper maps or 2D blueprints) and static diagrams (e.g., fixed architectural renderings or zoning diagrams)—often fail to provide an intuitive and interactive way to visualize these complex relationships. Static maps are limited in their ability to demonstrate dynamic features like traffic flow, pedestrian movement, and real-time infrastructure changes, while static diagrams can be overly technical and difficult for non-experts to interpret. This makes it challenging for urban planners, architects, and the public to assess potential improvements in city infrastructure and urban development effectively.

In Cape Town's Foreshore Freeway Precinct, traffic congestion, limited pedestrian access, and inefficient transport integration remain significant challenges [1]. Additionally, the precinct's potential for mixed-use developments and underutilized spaces beneath the freeway has not been fully explored. While various redevelopment ideas have been proposed, there is a clear need for an accessible visualization tool that demonstrates how different urban design choices—such as public transport expansion, improved MyCiTi bus integration, pedestrian-friendly infrastructure, and optimized road networks—can improve mobility, connectivity, and the overall urban environment. This project will develop an AR-based educational tool that allows users to do the following.

Visualize proposed enhancements to the Foreshore Freeway Precinct, including better pedestrian walkways, public transport integration, optimized land use beneath the freeway, and mixed-use developments.

Toggle infrastructure layers to explore how different elements—such as roads, public spaces, transport hubs, and mixed-use buildings—interact within the precinct.

Compare sustainable and unsustainable planning approaches, highlighting how targeted, strategic design choices can significantly enhance connectivity, reduce congestion, and foster sustainable urban growth.

By providing an interactive and localized visualization, this tool will help urban planners, students, and the public better understand how urban improvements, such as public transport expansion, MyCiTi bus integration, and pedestrian-friendly infrastructure, can make the Foreshore Freeway Precinct more efficient, accessible, and sustainable.

4 USER REQUIREMENTS

4.1 About the Project

4.1.1 Purpose. Urban planning is a complex process that requires effective visualization and simulation of different city infrastructure scenarios [5]. Traditionally, planners have relied on static maps and blueprints to represent their ideas, but these tools do not provide the interactivity needed to truly understand the dynamic nature of urban systems. This project aims to develop an Augmented Reality (AR)-based educational tool that helps urban planners, architects, and civil engineers visualize city layouts and proposed infrastructure changes in real-time. The tool will specifically focus on the Foreshore Freeway Precinct in Cape Town, which suffers from issues like traffic congestion, inefficient land use, and poor pedestrian access. The goal is to provide an immersive AR experience where users can visualize and interact with sustainable and unsustainable planning scenarios, facilitating better decision-making in urban development.

4.1.2 Agile Development Approach. This project follows an Agile iterative development cycle, with weekly milestones to incrementally test and refine core features.

4.2 User View of the Project

The primary users of this project are urban planners, architects, civil engineers, and students of urban studies. These users need a tool that allows them to visualize proposed changes to city infrastructure interactively. SmartCity AR will allow them to see how different planning scenarios—such as better pedestrian pathways, public transport integration, and optimized land use—will affect the urban environment. The user can manipulate the city layout, toggle between data layers, and explore the impact of various sustainable versus unsustainable planning strategies. This tool will aid them in creating more efficient, connected, and sustainable urban spaces by providing an accurate representation of how changes in infrastructure will influence traffic flow, pedestrian movement, and overall city functionality.

4.3 Problem Domain

The problem domain of this project involves urban planning, city infrastructure, and the visualization of proposed developments in an easily interpretable manner. Urban planners often work with complex datasets, static models, and maps to make informed decisions, but these tools fail to effectively show the real-world implications of their planning decisions [5]. To address this gap, the project utilizes Augmented Reality (AR) to bring the planning process into an interactive, visual, and immersive space. Users must be familiar with urban planning concepts such as land use, transportation networks, pedestrian infrastructure, and sustainability metrics. Additionally, the tool needs to integrate with 3D models, data layers (such as traffic flow), and real-time interactions to enhance the user experience.

4.4 Expectations

SmartCity AR is expected to serve as a comprehensive tool that enables urban planners and other users.

4.4.1 Visualize Proposed Developments. The tool should allow users to interact with and visualize city layouts, proposed changes, and urban designs in a 3D AR environment.

4.4.2 Scenario Simulation. The tool must allow users to simulate various urban planning scenarios (e.g., adding new transport hubs, modifying pedestrian routes, and redesigning public spaces).

4.4.3 Sustainability Comparison. Users should be able to compare the effects of sustainable and unsustainable planning approaches in terms of traffic flow, pedestrian access, and environmental impact [5].

4.4.4 Interactive Features. The viewer should support intuitive user interactions, such as zooming, rotating, and toggling between different data layers (e.g., traffic data, pedestrian data).

4.4.5 Ease of Use. The tool should provide a simple and accessible interface for users, prioritizing usability and functionality. The UI should be easy for both technical and non-technical users to navigate.

4.4.6 Educational Value. The tool should serve as an educational tool, helping users understand urban planning concepts, the impacts of different planning decisions, and how to design cities more sustainably and efficiently.

The primary objective of the SmartCity AR is to help urban planners make informed, data-driven decisions that lead to more sustainable, efficient, and well-connected urban spaces. It should enhance the planning process by providing a deeper understanding of how infrastructure interacts within the urban environment, making it easier to identify potential problems and solutions before they are implemented in the real world.

4.5 Out of Scope

The following items are considered out of scope for the current version of the project.

4.5.1 iOS Support. The app will not support iOS devices in the current version. The focus will be on Android devices, and features such as iOS-specific AR capabilities (ARKit) are excluded.

4.5.2 Real-time Data Integration. The initial release will not include real-time traffic or environmental data, although this feature may be considered in future iterations of the application.

4.5.3 Advanced AI Simulation. The app will not include advanced artificial intelligence (AI) features for traffic or pedestrian movement prediction. The current focus will be on basic simulations and visualizations.

4.5.4 Multiplayer/Collaborative Features. The application will not feature multiplayer or collaborative capabilities in the current version.

4.6 Use Case Diagram

The use case diagram in Figure 1 for SmartCity AR outlines the key interactions between the system and its users.

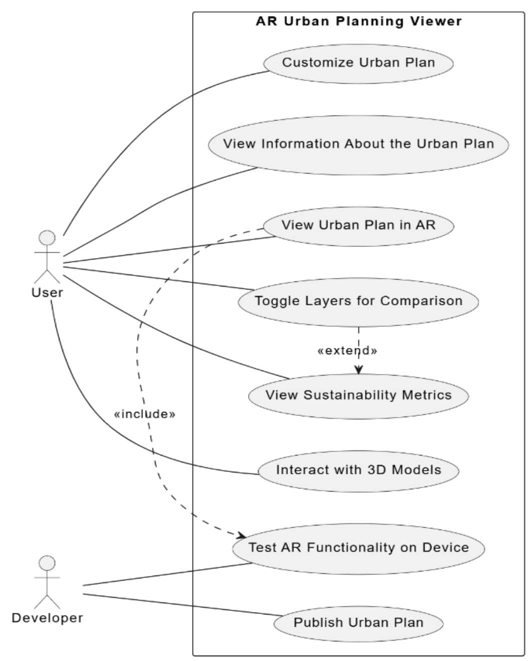

Figure 1: Use case diagram for SmartCity AR showcasing user interactions, system functionalities, and relationships between key actions.

5 REQUIREMENTS ANALYSIS

5.1 Current System

SmartCity AR is being developed on a Windows 11 platform using the Unity game engine for creating the 3D AR models, and AR Foundation for cross-platform AR support. The tool will also utilize Visual Studio for development, and GitHub for version control and collaboration. The system requires Android Studio for testing AR functionality on mobile devices. For users, the tool can be run on devices such as Android smartphones supporting ARCore. The development environment also includes the following prerequisites.

5.1.1 Unity 6. The latest version of the Unity engine is used to build and render the AR environment.

5.1.2 AR Foundation 5.0. This framework enables cross-platform AR development, supporting both Android and iOS.

5.1.3 Visual Studio 2022 with Unity integration. This integrated development environment provides tools for coding, debugging, and managing the project.

5.1.4 Git 2.7.4. A version control system is used to manage source code, track changes, and facilitate team collaboration.

5.1.5 Android Studio. This IDE is essential for testing AR functionality on mobile devices, ensuring compatibility with Android-based ARCore.

5.1.6 Blender. A 3D modelling software is used to create and optimize assets for the AR environment.

5.1.7 Itch.io. Once the development is complete, the tool will be published as an APK for Android and shared on platforms such as Itch.io.

All tools used in this project are free and open-source or available through free academic licenses, making the project cost-effective and accessible. Testing is conducted using Android devices that support ARCore, with on-campus access to mobile testing equipment where needed.

5.2 Functional Requirements

5.2.1 Basic City Layout Visualization. The app must allow the user to view a predefined 3D city model, which will include streets, buildings, roads, and other relevant urban infrastructure. Users should be able to interact with this city layout to simulate and compare different planning scenarios.

5.2.2 Building Manipulation. Users should be able to move, add, or remove buildings in the AR environment, allowing for flexible city planning and experimentation with urban design.

5.2.3 User Interactivity. The app will include intuitive touch-based interactions for navigation, such as zooming in/out, rotating the city layout, and switching between different views of the model.

5.2.4 Scenario Simulation. The AR viewer will enable users to visualize various urban planning scenarios (e.g., pedestrian-friendly spaces, public transport integration, green corridors) and analyse their impact on traffic flow and accessibility.

5.2.5 Data Layer Toggle. The application will support toggling between different data layers, such as traffic data, pedestrian movement, and infrastructure utilization, to help users better understand the dynamics of urban spaces.

***5.2.6 Sustainable vs. Unsustainable Comparison*.** The app must allow users to toggle between sustainable and unsustainable urban planning scenarios to analyse the effects of different planning strategies on the environment and public mobility.

5.3 Non-Functional Requirements

The non-functional requirements for the Urban Planning AR Viewer are as follows.

5.3.1 Performance. The application must perform efficiently, with quick loading times and minimal latency in rendering AR models. It should provide a smooth and responsive user experience, even when manipulating complex urban layouts.

5.3.2 Compatibility. The app will be developed for Android devices and must support a wide range of devices with varying hardware configurations, including mid-range smartphones with AR capabilities.

5.3.3 Usability. The application must have an intuitive user interface (UI) that simplifies navigation and interaction. The user experience should prioritize ease of use, with clearly labelled controls and a straightforward interface design.

5.3.4 Scalability. While the initial version will focus on basic urban layouts, the app should be scalable to allow for future expansions, such as integration with real-time traffic data, user-generated content, or the inclusion of additional cities and regions.

5.3.5 Maintainability. The app's codebase should be structured to facilitate easy maintenance and updates, enabling developers to add new features or fix bugs efficiently. It should also be compatible with future versions of Unity and ARCore.

5.3.6 Security. While the app does not handle sensitive user data, it should ensure that all user interactions are secure, and any data transmitted between the app and external servers (e.g., for data layer integration) should be encrypted.

5.4 UML Class Diagram

The UML Class Diagram in Figure 2 for SmartCity AR outlines the system's key components and their interactions. It shows how the ARSceneManager handles infrastructure layers and info overlays, the ScenarioManager loads planning scenarios, and the UIManager processes user input. The InfrastructureLayer manages visibility, while the InfoOverlay displays relevant data, ensuring smooth information flow within the AR system.

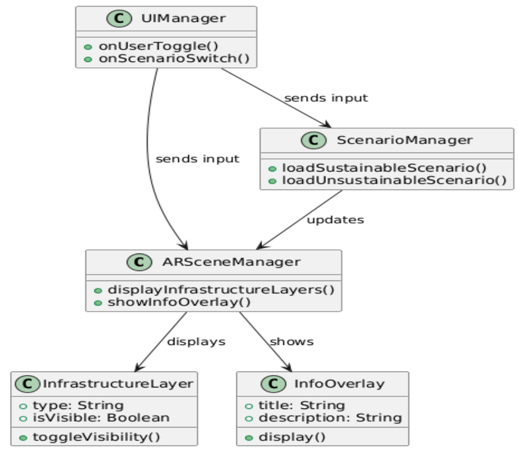

Figure 2: UML Class Diagram represents the core classes, their attributes, methods, and relationships in the system.

6 CONCLUSION

The development of an Augmented Reality Urban Planning Viewer presents a transformative approach to city planning, addressing the limitations of traditional static tools. By enabling interactive visualization of sustainable and unsustainable urban planning scenarios, this tool enhances decision-making for urban planners, architects, and civil engineers. Focusing on Cape Town's Foreshore Freeway Precinct, the SmartCity AR facilitates the exploration of transport hubs, pedestrian infrastructure, and mixed-use developments in an immersive environment. Ultimately, this AR-based solution has the potential to redefine how urban planning is conceptualized, communicated, and implemented, fostering smarter and more sustainable city development.

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APPENDICES

APPENDIX A
Project Timeline

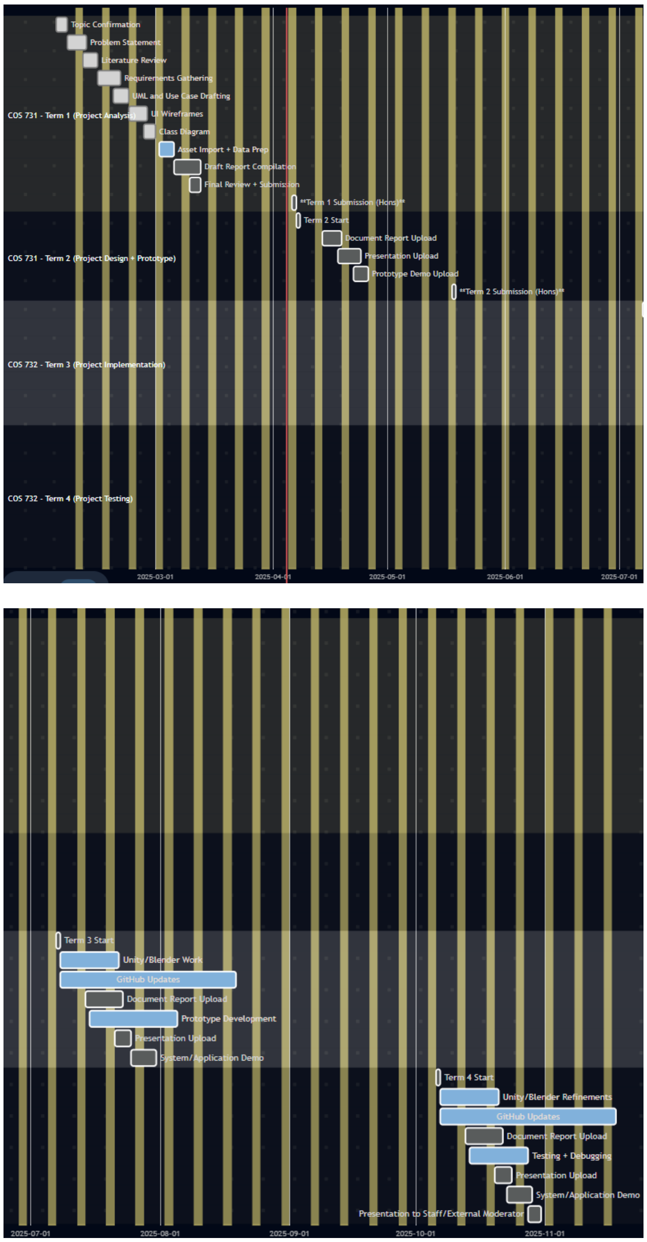

Figure A: The projected timeline of the project.

APPENDIX B
Project Budget Distribution

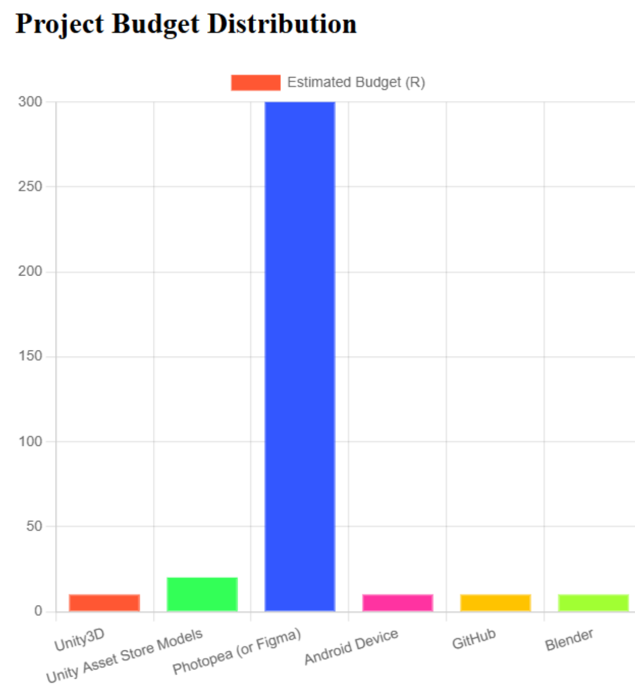

Figure B: Illustrates the budget distribution for the project.

APPENDIX C
Foreshore Freeway Precinct

Figure C: Illustrates the unfinished highway in the foreshore freeway area.

APPENDIX D

Proposed Solutions

Figure D: CITYLIFT (a proposed master plan for Cape Town) proposes a dense, vibrant, green new city district at the harbour's edge.

Figure E: Illustrates another proposed solution. This proposal is focused on creating affordable housing units and making the city centre accessible and open to everyone. It aims to take the urban wastelands which runs rife in the city centre and turn them into dignified streets.

APPENDIX E

GitHub Repository

Link:
https://github.com/mohamedasad10/SmartCity-AR

APPENDIX F

Google Sites Website

Link:
https://sites.google.com/view/cos731mohamed-asad-bandarkar/home