Large Scale 3D Scanning as an Interactive Teaching Approach in Built Environment Disciplines

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Abstract: Virtual Site Visits (VSV) are used to approximate site visits where in-person visits are infeasible. Typical VSV rely on photography, videos and 360-degree images. With these methods, the creator must choose what to capture and from where to capture it, reducing the independence of subsequent analysis. 3D scanning methods, often used to create highly detailed replicas of small objects, can also create large scale scans of sites, eliminating the need for predetermined signposting or choice of shot. We describe a large-scale 3D scanning method to capture informal settlement areas in Bandung, Indonesia. Outputs from this capture method were surprising, revealing cultural and physical details not initially evident. Students can inhabit the 3D scanned space as they explore, from wide shots where slope and scale are evident, to narrow and close spaces where the lived experience can be felt. This can create an immersive study experience for built environment students.

Keywords: 3D Scanning, built environment, large scale, virtual site visits

1 Introduction

Virtual site visits (VSV) have emerged as valuable pedagogical tools across various educational contexts (TREGLOAN et al. 2023, KLIPPEL et al. 2019). Educators have employed them to provide students with access to environments that would otherwise be difficult or impossible to visit in person, places such as dangerous construction zones (EIRIS et al. 2021) or protected heritage locations (KOSMAS et al. 2020). They have also been designed to offer students flexible, on-demand access to site-specific information within its spatial context (WALLS 2021).

Much of this work is focused on captured reality approaches, which often include high-resolution 360-degree panoramic views alongside standard photographs taken on site, and recorded videos of experts explaining various processes and material components of site (QUINN et al. 2019). The strength of captured reality technology lies in its use of authentic site imagery and footage, however, because the content is already captured and has been organised by the creator, students have limited freedom to explore independently. This results in a more passive learning experience (PHAM et al. 2018).

Established spatial data capture has been explored most through high resolution scans of small objects for archiving purposes (LI et al. 2023, PIRAS et al. 2024). Mobile-based 3D scanning apps are increasingly common in undergraduate architecture education, enabling students progressing from traditional drafting to hands on digital data collection on site (ÁLVAREZ et al. 2025). It also allows students to quickly test design proposals in 3D environments starting from sketch physical models. Similarly, 3D scanning is used to produce models of cultural heritage artifacts allowing students the opportunity to spend time with artifacts that they may not be able to access in real life (REMONDINO 2011). The strength in

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these models is in the detail of the scan, including scale, colour and materiality (BARSZCC et al. 2023) and how closely they simulate specific objects.

In contrast spatial data capture at large scale is an emerging field. While tested earlier, it was limited by lower resolution and technology constraints (HAALA et al. 2008). Recent advances have made this approach more viable and applicable, largely because the technology to combine scans from different systems is only recently becoming well understood, access to the correct equipment is only just now becoming affordable and the people with the skills to undertake this work are rare. However, spatial data capture methods represent a potentially more immersive experience for students because the scan is made of the space or area wholistically and potentially seamlessly, meaning that the creator does not necessarily need to choose, frame or highlight specifics angles (BARSZCZ et al. 2023, FANG et al. 2025).

Although research has established the efficacy of virtual learning environments across disciplines such as medicine and engineering (TREGLOAN et al. 2024), their application within built environment education remains underexplored, but the development of digital site recording and spatial data capture methods has the potential to transform design methods and teaching for the built environment, particularly when recording physical and environmental characteristics of space in urban environments (GREENE & WALLS 2023, LANGENHEIM & WHITE 2022).

This paper presents a case study of 3D scanning output of an informal settlement, captured using drone-based photogrammetry and terrestrial LiDAR scanners to recreate spaces in Bandung, Indonesia. Informal settlements, commonly known as *kampungs* in Indonesia, represent a significant and enduring feature of the country's urban landscape, housing a substantial portion of the urban population (KENT et al. 2022). The focus on the Tamansari sub-district. Tamansari is located in Bandung Wetan sub-district, approximately 3.3 km from Central Bandung. Tamansari also has the largest sub-district population, with 22,553 inhabitants.

Understanding informal settlements like Indonesia's *kampungs* is essential for developing cultural competence, place-based learning, and global perspective (JONES 2019). Informal settlements house nearly one billion people worldwide and represent the reality of how the majority of future urban growth will occur (SHIRLEYANA 2022). Built environment students must be given the resources to move beyond sanitised case studies to engage with the lived experiences, adaptive strategies, and community resilience embedded in these environments. Of particular note for our case study is that the informal settlements captured do not have street view options in Google Maps or other global satellite capture maps, and thus no other virtual opportunity exists to interrogate them at this level of detail.

2 Methodology

2.1 Site Selection

The Bandung *kampung* was selected as a location that fulfilled key criteria as an area for built environment learning. An initial workshop with informal settlement experts from Institute Technology Bandung (ITB), the University of Melbourne, and Hong Kong University was led by our research team and identified areas of opportunity and challenge in the urban environment, specifically the Tamansari Urban Village region. Based on the workshop discussions, critical themes for on-site visual capture were identified, with focus areas including housing, public spaces, commercial areas, transport and infrastructure.

2.2 Equipment and Pre-field Planning

A Leica BLK360 terrestrial LiDAR scanner was selected for its compact form and portability, prioritising mobility over range and ultra-high precision. The scanner was mounted on a compact tripod at a constant height (~1.5 m) to simplify registration and maintain vertical consistency across scans.

Pre-field planning additionally considered the integration of complementary datasets, including 360-degree imagery and video-derived photogrammetry, and aerial drone capture, to address known limitations of terrestrial LiDAR in capturing roofs, upper facades, dynamic street conditions and broader environmental extents beyond ground-level line of sight.

2.3 Scanning Strategy and Data Capture

Scanning was conducted across a range of urban typologies, including narrow, open laneways (5–6 scans per segment), high street frontages (approximately 4 scans per elevation) and small, enclosed spaces (1–2 scans per space).

A high-overlap strategy (>40–50%) was maintained between adjacent scans to ensure robust registration and minimise drift. Short station spacing (5–8 m) was applied in constrained areas. To reduce occlusion, the scanner was offset laterally in a zigzag alignment rather than positioned along the centreline and was rotated around corners to maintain line-of-sight continuity.

The high degree of geometric and visual overlap, through features such as doors, poles, and facade corners eliminated the need for external registration targets.

2.4 Data Processing and Registration

Raw scan data was processed using Leica Cyclone REGISTER 360. Cloud-to-cloud registration based on point proximity was employed to align individual setups, resulting in minimal cumulative drift and vertical error. The consistent scanner height and high overlap contributed to stable registration across the dataset.

Following registration, the point cloud was cleaned and exported to CloudCompare for meshing and visualisation. A point-to-mesh workflow generated textured 3D models for enhanced interpretability and surface realism. The resulting 3D scenes were integrated into the Pedestal 3D platform to support object-based learning, visual analysis, and self-guided site exploration.

2.5 Multi-modal Data Combination

Terrestrial LiDAR data were combined with 360° imagery video-derived photogrammetry (processed in RealityScan), and drone photogrammetry. While LiDAR data acted as a primary geometric reference framework, image-derived datasets improved colour information and extended spatial coverage beyond scan extents, such as facade detail, roofs and upper levels and broader extent of the street inaccessible from ground-based scanning.

Together, these modes established a multi-scale continuous street-scale model and capture strategy combining metric accuracy, visual continuity and contextual completeness. These datasets were co-registered using iterative closest point (ICP) alignment and manual tie-point verification, resulting in a comprehensive unified model of the *kampung* environment suitable for subsequent analysis and pedagogical use.

3 Results and Discussion

3.1 Technical Challenges

Conducting laser scans in informal settlements presented multiple interconnected challenges. Initially, obtaining access required working with a local guide who had existing relationships with community leaders and residents. Without this crucial connection, researchers risked being perceived as outsiders or potential threats, which could have restricted access to the sites entirely.

The alleyways for the street transect scans are notably narrow yet serve multiple critical functions. They act simultaneously as transportation corridors, commercial zones, and residential spaces. This multifunctional nature meant constant pedestrian activity throughout the day. It was difficult to spend a lot of time capturing spatial information. To minimize disruptions, researchers strategically scheduled scans during early morning hours, before the sites became congested with daily activities. However, even during these quieter periods, the constrained spaces and ongoing foot traffic frequently interrupted the scanning process. As a result, it was necessary to rescan the same locations multiple times to capture complete and accurate data.

Data capture was conducted under mixed daylight conditions, with intermittent sunlight and variable pedestrian activity. Despite uneven and sloping terrain, the lightweight scanner facilitated stable positioning and re-levelling between setups. Some occlusion remained unavoidable within the densest portions of the settlement due to restricted access and obstructed sightlines.

3.2 Captured Data Outputs

Our intention was to use interactive 3D models to simulate an in-person field trip to expose students to local contexts. Through interactive 3D models, students were able to examine how residents navigate their local environment and daily challenges such as inadequate infrastructure and limited services.

The captured data outputs varied in scale and size and comprised large scale scans of street transects varying in length from 30m to 80m and up to heights of 10m (Figures 1–7).

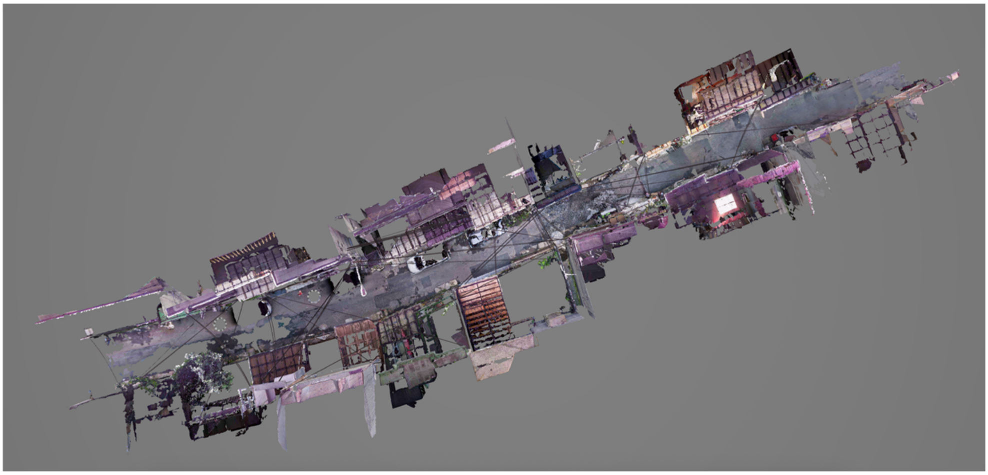

Fig. 1: Alley transect 1 – A top-down view including some rooftop detail and runs of power lines crisscrossing the street

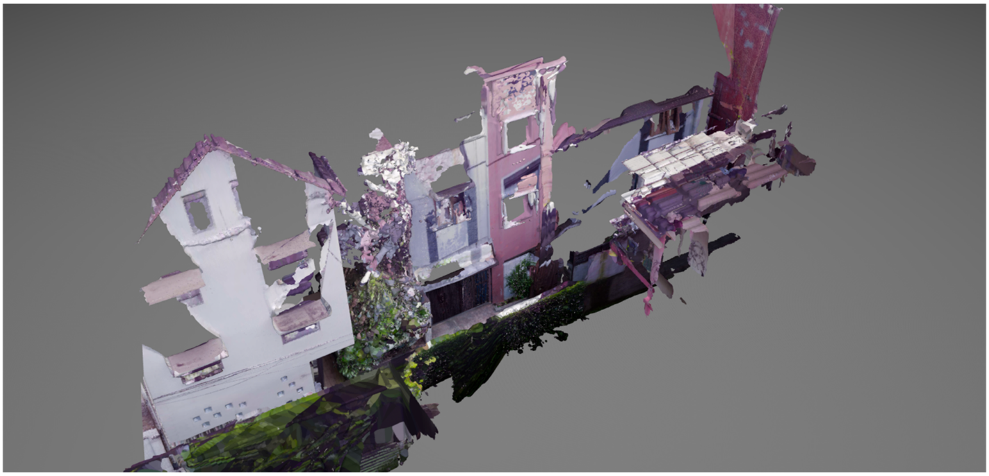

Fig. 2: Alley transect 2 – The highest point of the white building is 13m. From this view, with both sides of the alley built up, the alley itself is obscured.

3.3 Refining the Definition of Interactive 3D Models

KLIPPEL et al. (2019) identifies three distinct types of VSV. At the basic level, virtual environments mirror actual physical spaces, with users experiencing the same spatial limitations they would encounter during an in-person visit. The intermediate 'plus' level extends beyond physical constraints by offering viewpoints and comparisons unavailable in reality such as aerial perspectives or simultaneous views of buildings located far apart, while still maintaining representations grounded in physical space.

The Interactive 3D model method created in our examples aligns closely to the intermediate approach described above, but the model provides an experiential quality of depth and perspective change, giving the feel of a less manufactured environment than other methods (Figure 3 and Figure 4).

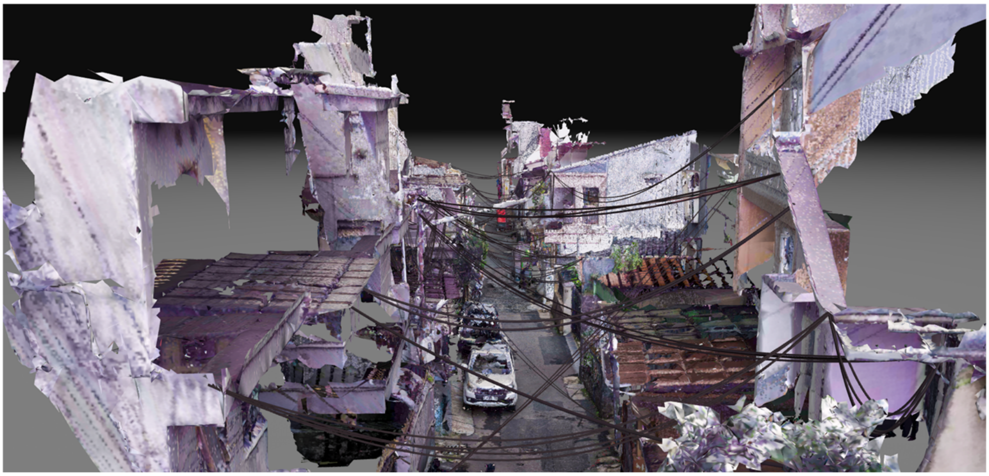

Fig. 3: Main Road transect – View down the main road with cars for scale showing how narrow the street is, as well as detail of powerlines and construction details of buildings

In addition, in our other paper (WALLS et al. 2025) we argue that void areas and occlusions offer insights into spatial variance and influence how a human subject might interpret the space, the gaps that illustrate areas that could not be seen and holes that show areas that are behind allowing a kind of digital extension of human perception that is made available through the artifact of the digital scan (ALVEAR 2020, IVANKOVIC-WATERS 2024).

This is evident in the scans made in Kampung. By working with the local conditions, particularly the small spaces of the streets and the fact that the alleyways are multifunctional in nature, and thus always busy, we have generated interactive 3D models that are less than perfect, reflecting the motion that exists. This quality becomes a texture of the space and reflects the way the space is lived in.

Further, as a result of the nature of the lidar capture and the conditions of capture, there exist elements of surprise as you examine the model. An example of this can be seen in the volleyball court scan (Figure 4), which at face value seems a typical space for exercise. However, by panning and moving through the space, students can discover small shops and a hidden seating area (Figure 5) with people watching the volleyball court from behind a netting.

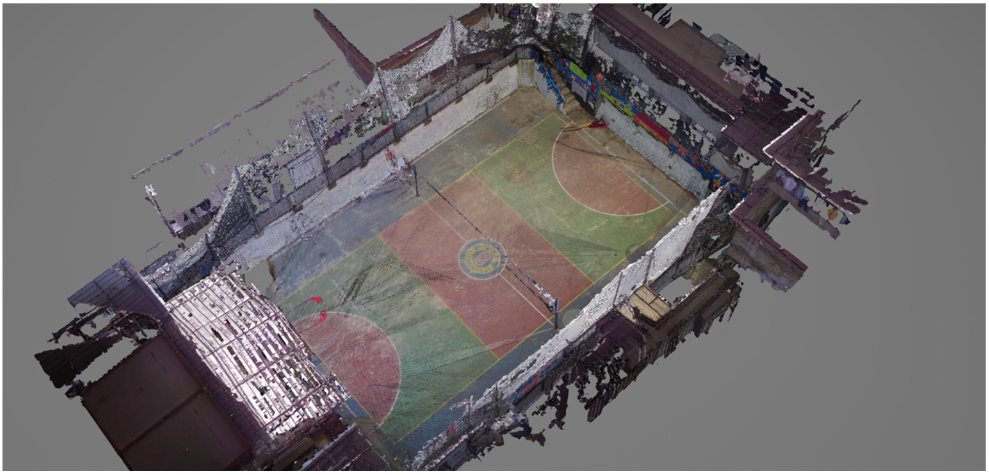

Fig. 4: Community volleyball court aerial view – Closer examination reveals details not visible here such as a hidden seating area (Figure 5)

Fig. 5: Community volleyball court seating area, including people and a small shop

The fragmented nature of the seating area scan presents an interesting opportunity for discovery through the output of the LiDAR scanning method. Although the seating space was not intentionally captured, it appears in the dataset, nonetheless. This differs from earlier technologies that required instructors to manually construct 3D models with predetermined scopes and intentions. The earlier approach often constrained students' exploration (MAGHOOL et al. 2018). The level of detail in such instructor-created models was typically dictated by specific learning objectives and the intended content of the virtual visit (LUCAS 2018, MAGHOOL et al. 2018). In contrast, the passive recording enabled by LiDAR scanning minimises subjective decisions about framing or composition in VSVs, allowing for a more objective spatial record. This objectivity gives subsequent viewers the freedom to interpret and construct their own narratives within the captured environment. Consequently, the seating area and other partially rendered figures and objects become sites of discovery that enhance students' agency as they navigate the space.

Lastly, it has been shown that Virtual landscapes (VL) make accurate depth and slope perception difficult – by a figure of about 20% (CH'NG et al. 2016). Another advantage of these large-scale interactive 3D models is that they allow users to 'step out' of the landscape. For example, in the constricted space shown in Figure 6, where the low roof and lack of visibility around corner make it difficult to estimate distance, viewers can zoom out of the model and view it from a transect perspective (Figure 7) to better understand slope and profile. This is useful for understanding terrain, and something not possible in a VR environment or using photographs and 360 photographs.

Fig. 6: Inside view of Alley transect 4. The constricted space makes it hard to get a sense of depth and scale, equally it demonstrates the sense of enclosure residents would experience as they walked through there. For reference, this shot is taken from the green end of the transect in Figure 7.

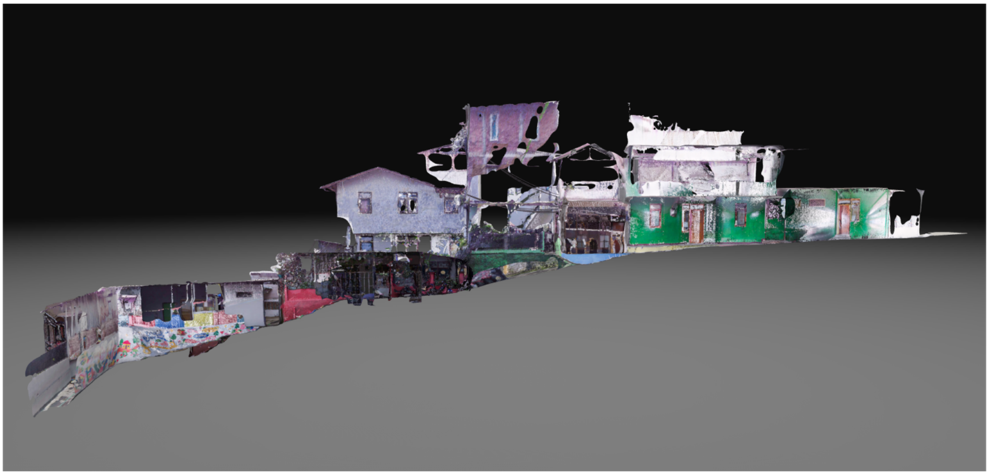

Fig. 7: Alley transect 4 – Providing a sense of the length of the space, but critically the slope of the alley from right to left as it bends to the left at the bottom, the user can investigate the space from many perspectives

This multi-scalar capability is valuable for developing critical urban analysis skills. Students can seamlessly zoom out to examine the broader neighbourhood fabric. The immersive nature of 3D visualization helps students who have never physically visited these communities to develop spatial empathy and contextual awareness.

Our experiential approach bridges the gap between abstract landscape theory (LEGACY 2017, JONES 2019) and the reality of how people inhabit these spaces. It encourages students to think critically about conventional planning methods that often overlook local knowledge and instead embrace community-centred approaches that lead to more resilient and contextually appropriate solutions.

4 Conclusion and Outlook

These 3D models function as part of a comprehensive suite of resources. The VSV additionally comprises an interactive map and include 360-degree videos that allow students to navigate through the alleyways and experience the spatial character of the settlement, interview content with community leaders, academics, and policymakers to gather detailed, place-based knowledge about key thematic issues and 3D laser-scanned models that provide detailed, explorable views of particular spots of interest. This combination enables students to both move through the broader environment and examine specific locations in depth.

Students' informal in class responses suggested that the 3D models promoted engagement, critical thinking, and self-led learning. Beyond simply observing narrow alleys and improvised structures, many students reflected on how residents creatively adapt limited spaces for multiple uses.

Technically, there is scope to refine the multi-method workflow. Improved drone coverage and overlap with scan areas and denser photogrammetric reconstructions could reduce occlusions to strengthen higher-level geometry. By combining multiple capture modalities within a single spatial framework, this research advances a model of VSV that privileges spatial agency and self-directed exploration over pre-determined framing.

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