Towards Managing Visual Impacts on Public Spaces: A Quantitative Approach to Studying Visual Complexity and Enclosure Using Visual Bowl and Fractal Dimension

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Abstract: Diverging opinions on the visual impact of high-rise developments on public spaces and the lack of measurements to justify these impacts drive our inquiry for this paper. To address this, we propose a workflow by 1) conceptualising and modelling a visual bowl's volume, 2) quantifying sky and height-width ratio, sightline distance and, 3) estimating the fractal dimension of geometry using a voxelization process and box-counting method. Using this workflow, we report a negative correlation between enclosure and visual complexity indicators when assessing the visual impacts of future high-rise developments in Central Melbourne. The computation of a volumetric visual bowl and its fractal dimension potentially offer a new approach to study these impacts.

Keywords: Visual impact, skyline, complexity, enclosure, fractal dimension, voxel

1 Introduction

The Melbourne Planning Scheme sets out objectives that aim to produce a high-quality public realm. These include a policy to control the environmental impacts of future developments on Melbourne's character, attractiveness and visual quality (City of Melbourne, 2017). Clause 22.02, *Sunlight to Public Spaces,* identifies several 'Key Public Spaces' across the Central Business District (CBD) to control the environmental impacts of high-rise buildings. Although the policy aims to minimize overshadowing impacts, there is little assessment of how new developments impact the visual amenity of public spaces by way of changes to the spatial form that surrounds them. This paper attempts to fill this gap by testing new methods of assessment.

The second 'gold rush' by residential towers within the CBD has altered its visual character and resulted in a departure from the height-controlled skyline policies introduced in the 1980s (ADAMS & DOVEY 2018). The abundance of high-rise buildings may result in poor environmental quality as it replaces human-scaled environments in various parts of the city (GEHL 2018). While towers increase vibrancy and efficiency by maximizing mixed-use programmes and density, they can have considerable impacts on the quality of public spaces. Admittedly, Melbourne's current *Floor Area Ratio* and *Floor Area Uplift* regulations may put the city at risk of losing its amenity and character if they continue to tip this balance. While urban design strategies attempt to weigh out this concern by developing street-level features to compensate for the loss of human-scale built form, they ignore the issues caused by residential towers that rise to 300 meters with the promise of solving the housing unaffordability. These changes not only affect city users, but can also impact residents of the surrounding suburbs by skyline intrusions. Consequently, they may considerably transform the existing character of Melbourne's unique streetscapes and skyline unfavourably. Despite the introduction of these

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high-rise developments, we need to respect the character of existing places and plan for future growth by balancing continuity and change of such developments (ADAMS & DOVEY 2018).

This issue is not unique to Melbourne. Evidenced through an increasing number of costly court proceedings in Queensland to voice opposition to new development, the public's reaction to increasing building heights within the city remains mainly negative (TARA 2017). In addition, a public survey on controlling building heights in Hobart, the most populous city of the Australian state of Tasmania, revealed that 86% of respondents supported absolute height-limit controls (CITY OF HOBART 2018). Contrary opinions about the justification of building heights continue to exist between experts and the general public and there is no one approach to rationalise this process. The nature of visual impacts and sense of overdevelopment associated with high-rise buildings are still vague and unknown terms in the planning policy.

To date, there is no indicator, measurement, thresholds or methodology in place to control visual impacts of high-rise buildings on public spaces. On the other hand, reviews of development applications are largely based on best practices that tend to rely on conventional bird's-eye views, cross-sections and photomontages. These approaches are considered limited in tackling visual concerns within complex urban settings. Therefore, we intend to pursue these issues by developing new techniques and quantifiable indicators to arm designers and monitor changes in urban environments.

The sense of enclosure, human scale and *visual complexity* are considered important urban design qualities which have direct effects on the perception of public spaces (EWING & HANDY 2009). Vertical elements define and shape the outdoor spaces that limit the viewer's sightlines and create a sense of enclosure. The ratio between the height of vertical elements and the width of space can create a room-like quality that has a direct effect on the sense of enclosure and 'human-scaled' space. Extreme levels of enclosure can evoke claustrophobia and low levels of enclosure can create discomfort due to lack of 'psychological shelter' (ALKHRESHEH 2007). Similarly, long sightlines and out-of-proportion building heights can detract from the perception of human scale (EWING & HANDY 2009).

Complexity refers to the higher-order phenomena created by interconnected subcomponents of a system and describes its dynamic and structure (BOEING 2017). In urban environments, the varying size, height, materials, colours, architectural style, and articulation of buildings can contribute to the perception of complexity. An optimum balance between complexity and variety, order, and disorder to avoid chaos and dullness is encouraged in urban design literature (BOEING 2017).

Beyond qualitative interpretations of complexity and enclosure, measurable quantitative approaches are useful to formalise these indistinct senses within complex systems (BOEING 2017). The visual performance and evolving state of Melbourne's physical urban spaces can be studied through a measurable lens to describe and understand its formal configuration and adaptive capacity. New approaches to the application of digital technology can enable us to quantify these attributes and gain new insights into visual impacts of high-rise developments which can be perceived on the street level.

Hence, this research is focused on quantitative measurements of the visual effects of future high-rise buildings upon the existing environment as perceived on-the-ground. The approach we developed consists of a series of systematic observations, measurements, experiments and the formulation, testing, and modification of a hypothesis that is aligned with a scientific method of understanding the visible space. To achieve this, we proposed a workflow expressed through a geographical information system (GIS) platform and consequently, a 3D computer-aided design platform supported by a visual programming language environment (Rhinoceros and Grasshopper).

In discussing this method, we first introduce the modelling of a visual bowl as a volume and discuss this as a step beyond standard visibility analysis to achieve a deeper understanding of visual attributes and relationships (Erwin and Steinitz, 2003). This concept provides an opportunity to study the change of visible space by plotting the skyline to calculate the human scale and sky ratio as a measure of the visual enclosure. The resulting 3D visual bowl appears as a complex volume in high-density areas due to the varied arrangement of buildings. The variations of this volume are further studied by estimating a fractal dimension using a box-counting method. The calculation of sky ratio, height to width ratio and fractal dimension provide indicators of visual space to compare, study the change and interpret the results. The contribution of this paper is in demonstrating the calculation of visual bowl and estimating the fractal dimension of this volume are novel approaches and contribute to the field of urban design and study of the visual impact of high-rise buildings on public spaces.

2 Crystallizing the Complexity

2.1 Tailoring a Geo-model

Many cities have developed ‘city models’ that abstract spatial representations of physical public and private assets at varying levels of detail (LoD). These city models represent the built environment that would typically include built and landform but exclude vegetation and other physical assets not relevant at the desired LoD. However, high-LoD city models developed by municipalities that are based on aerial LiDAR, photogrammetry, and mobile laser scanning provide opportunities to estimate the fractal dimension of a visual bowl at both micro and macro levels (Figure 1a). This paper will focus on the macro level by considering the city-scale application of such datasets and hopes to consider the micro level in the future.

The City of Melbourne 3D ‘Development Activity Model’ (3D DAM), provides a representation of major development activity in the Melbourne Local Government Area, is used as the main data source for this research. This platform presents the existing environment and future developments that are under construction, approved and applied for developments (Figure 1b). This model is openly published at a LoD that does not include details such as architectural materials, fenestrations, and vegetation. As such, it is suitable to model the visual environment defined by bulk, height, and spatial relationships of built form in Melbourne’s CBD and estimate the complexity by fractal dimension (FD). Another dataset including cadastral boundaries, public roads and contours were sourced to develop the model.

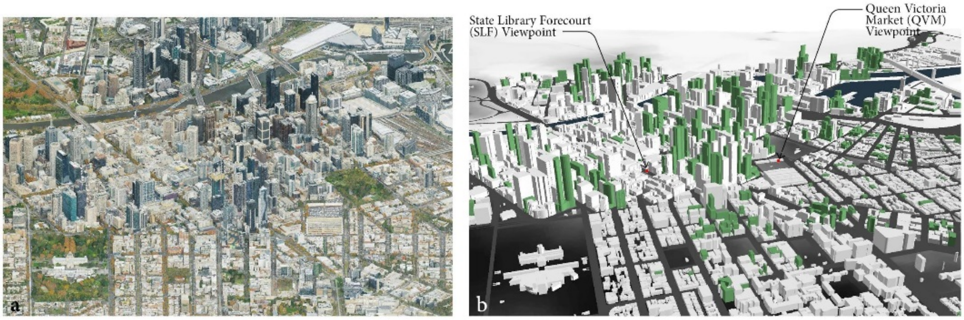

Fig. 1: a) City of Melbourne 3D Point Cloud at 7.5cm ground sample distance (2018); b) Tailored builtform model of Melbourne CBD and selected public spaces (white blocks: existing, green blocks: future developments)

Two of the 'Key Open Spaces' in Melbourne – the State Library Forecourt (SLF) and Queen Victoria Market (QVM) – were selected as case studies for this research. Based on our initial review, the selected sites will experience a considerable change in their visual character given future development. Therefore, two viewpoints in the centre of these public spaces were selected for the visual bowl analysis. The SLF is located along Swanston Street and hosts the highest recorded counts of pedestrian traffic throughout the CBD. QVM is an iconic public space which is located on the edge of CBD (ADAMS & DOVEY 2018). The visual experience from these two locations will be considerably changed by future developments. While there are unlimited public locations in Melbourne to use in this study, they were selected as sample sites to estimate the fractal dimension of the visual bowl by quantifying the existing and future visual environment. Figure 2 displays the existing photos and abstracted visual context defined by surrounding buildings that can be experienced from these locations.

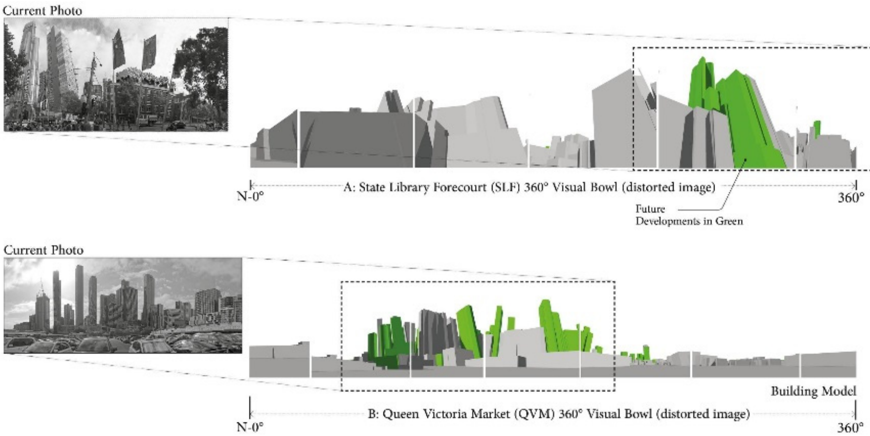

Fig. 2: 360° unwrapped view of the built environment from selected viewpoints

2.2 Calculation of the Visual Bowl

A visual bowl is defined as the hollow three-dimensional volume around a defined observer point (TARA et al. 2018). It also referred to as 3D isovist or viewshed and view sphere (LIN et al. 2015, MORELLO & RATTI 2009, TELLER 2003, FISHER-GEWIRTZMAN et al. 2003). The conventional 2D viewshed techniques available in GIS platforms are inadequate to visualise this space in the complex context of CBD. We considered the resultant 'hollowed space' as changes and impacts that are predominantly disregarded in existing design and planning controls which could be visualised and studied using the method proposed.

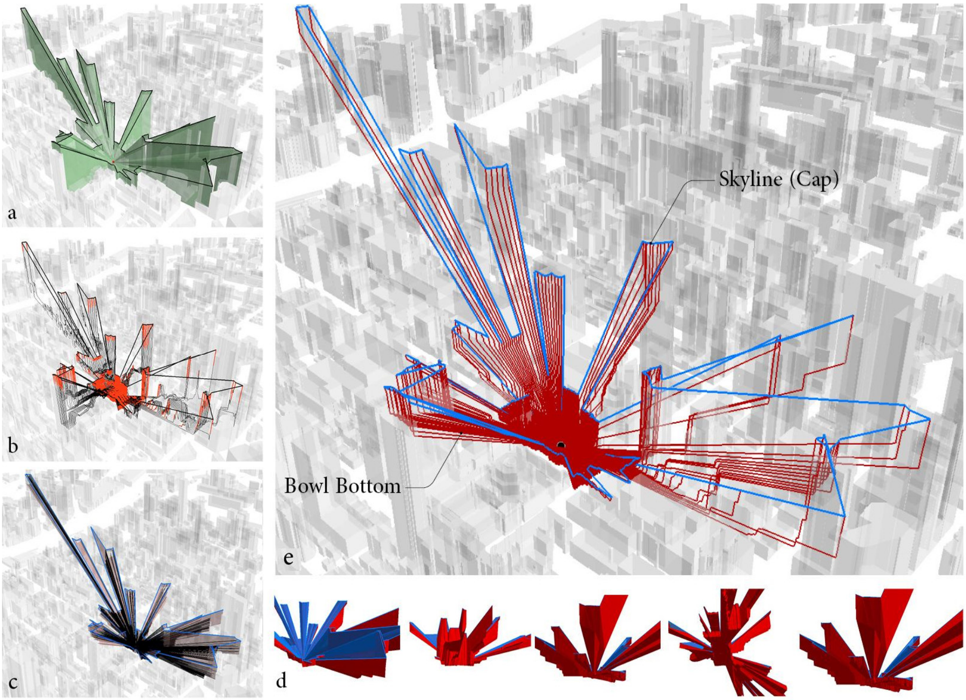

Fig. 3: Modelling steps in the calculation of visual bowl in ArcGIS, namely a) The modelled skyline and Skyline Barrier; b) Visible and invisible parts of the bowl; c) Sightlines from the origin to visible surfaces; d) The modelled visual bowl formed by multi-patches (different 3D views of a single geometry); e) The wireframe visual bowl defined by surrounding buildings

The extraction of a skyline in Geographic Information Systems (GIS) using geo-models or digital surface models (DSM) was our preferred approach to model the visual bowl and understand the form of this space. A GIS workflow was developed in ArcGIS Model Builder to visualise the bowl. The workflow begins by defining the limits of the visible space through the collection of sightlines from the standpoint of the observer to the visible 360° skylines (Figure 3a to 3c). This forms a surface or barrier which defines the upper limit of the visual bowl. The lower limit and ends of the visual bowl are then defined by the form and setbacks of the surrounding buildings that include both horizontal and vertical surfaces. These limits create a 3D form of the hollow visibility space for each selected viewpoint (Figure 3d and 3e). This provides a basis to analyse the visual changes by the future developments as any visible additions to the existing context would affect the skyline threshold by altering its cap or bottom.

Multiple other variables that characterise the visual experience from a given viewpoint can be calculated from the modelled visual bowl (Figure 4):

1) *Sky ratio factor as the proportion of visible sky* provides a measure of the enclosure.
2) *Human scale* is measured by calculating the elevation angle *(θ)* which represents the height ratio.
3) *Height ratio* is the relationship between the height and the 2D dimensional distance to the objects calculated in degrees.
4) *Distance from the viewpoint to skyline is* measured as the 3D distance which is another parameter of visual experience in the landscape.

In the urban setting, high rise development can dramatically change the form of the visual bowl by intruding into the skyline and changing the shape of the bowl or 3D distance to the skyline. These measurements *(θ, 2Dd, 3Dd & h)* can be calculated in 360° and plotted by 2D unwrapped skyline diagrams to visualise the changes of view can be viewed from the bowl's origin (TARA et al. 2018). Further to these variables, as the second outcome of this research, visual complexity of the visual bowl volume is estimated by fractal dimension as a new approach in analysing complexity in urban environments.

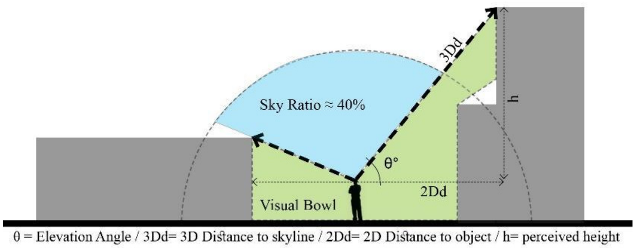

Fig. 4: Measurable variables of visual bowl

2.3 Fractal Dimension of Volumes

The crystal form of the visual bowl defined by surrounding constraints goes beyond the description of Euclidean geometry – the visual bowl in high-density urban centres can be considered as a 'fractal feature'. Fractal geometries, as defined by MANDELBROT (1977), are complex and cannot be characterised by an integral dimension (LOPES & BETROUNI 2009). The resulting 'fractal dimension' is a measure of geometric order created from self-similarity which is a particular type of complexity (PERRY 2012). Estimation of the 'fractal dimension' is expressed as the potential for analysing different types of landscapes and can be applied to the visual bowl where the complexity and self-similarity of this volume measure the visual experience as seen from the bowl's origin.

Related works in various disciplines including geography, landscape architecture, urban planning and architecture have investigated the links between fractal geometries and the built environment in macro and micro scales (LIANG et al. 2013). Fractal analysis of the built environment is one of the most widely used methods for the quantification of visual properties (VAUGHAN & OSTWALD 2013) and it has been widely applied in preference studies to understand the trends in aesthetic judgments (CHALUP et al. 2009). These studies demonstrate the fractal dimension as an important visual property to differentiate landscapes through their built or natural elements (KELLER et al. 1987, STAMPS 2002, HAGERHALL et al. 2004). The fractal dimension of urban skylines has also attracted several researchers to pursue its contributions to their work (STAMPS, 2002, CHALUP et al. 2009). In these studies, the silhouette is extracted from 2D images which ignores the variation of depth in the visible space and skyline. Despite the potential and wide usage of the fractal dimension to quantify complexity within urban environments, we stress that, there is no correlation between what may be considered as 'good design' and the fractal dimension (TUCKER 2004). However, it can be used as a comparative measure of visual complexity to understand the change (TUCKER & OSTWALD 2007).

The fractal dimension using box-counting can be used as a comparative measure of visual complexity to quantify the change. Since the 1990s, architectural researchers have reportedly been using the 'box-counting method' using photographs (OSTWALD 2013). The fractal dimension *(FD)* is estimated by counting the number of boxes *N(d)* at different magnifications and scale invariances *(d)* (HAGERHALL et al. 2004). If the plot of the logarithm of *N(d)* versus the logarithm of *d* follow a straight line, the geometry has a fractal property. The slope of the regression line is the estimated *FD*. Recently, this method has been repurposed to operate on 2.5D or 3D models using the 'cube-counting method' in combination with voxels as expanded in this paper to calculate the fractal dimension. This is demonstrated through the work of JIMENEZ et al. (2014) by estimating the fractal dimension of the brain lobe using MRI data by voxelization of 2D original MR images. This study, when contextualised to the visual bowl, holds potential in the estimation of fractal dimension for the modelled geometry.

To achieve this, a box counting algorithm was developed in Grasshopper to estimate the fractal dimension by performing a voxelization process at different cube sizes. To do so, the visual bowl geometry was exported to Rhino for voxelization. The geometry was then voxelized based on two grids aligned with the geometry and the number of voxels was calculated for each voxel size. The slope of regression line resulted from the *log/log* plot of measurements estimated the fractal dimension of the geometry which was estimated at 2.8773 for the sample geometry (Figure 5).

The voxelization process was applied to the geometry created from the skyline surface (upper part of the bowl) and does not include the bottom of the bowl. This limitation considerably reduces the level of details from the modelled geometry and estimated fractal dimensions. However, this was identified as potential for further development of the voxelization algorithm to include the details of the bottom of the bowl.

The estimated fractal dimension represents a measure of the complexity of the bowl and another descriptor of visible space. FD can be monitored alongside other variables of the visual bowl to study the change resulted from the future high-rise development visible in the context. The presented methods for modelling of the visual bowl and fractal dimension were applied to the selected study sites to compare and quantify the future change.

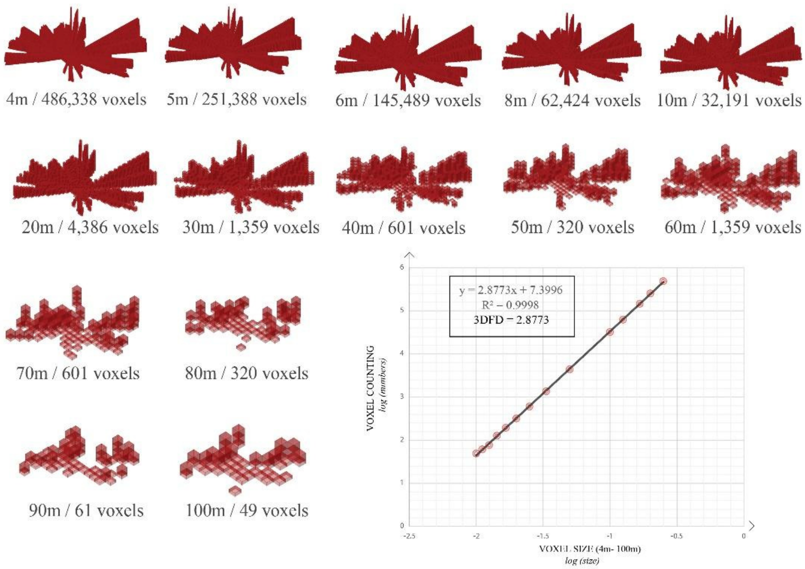

Fig. 5: Sample voxelization of the visual bowl and estimating 3D Fractal Dimension

3 Quantifying Change

Visual bowl modelling was conducted for the selected two public spaces (SLF & QVM) in Melbourne CBD to quantify the change in visual character caused by future developments. Two variations of the visual bowl that included existing and future conditions were calculated for each site (Figure 6a & 6b). These measurements provided a basis to compare two locations with each other, as well as to understand the magnitude of change resulted by the future developments on the existing condition.

Two 2D unwrapped skyline graphs were provided to illustrate the elevation angle *(θ)* and the distance between viewpoint to the skyline *(3Dd)*. These two graphs were produced to visualise the spatial form of built volume from the given location. The graph of *Elevation Angle* displays that SLF (average 35°) has a considerably higher height ratio compared to QVM viewpoint (average 15°) (Figure 6b). The sightline angles are converted to height-width ratio as it offers a more familiar reading of an urban design indicator. This reading reveals that *future developments will result in higher height ratios on both viewpoints peaking up to 1.7:1 ratio in SLF*. The graph of 3D distance confirms that sightline distances from both locations extend up to 1.3 km to the skyline defined by high-rise developments, which are visible in the bowl. As informed by the 3D DAM, future developments will increase this distance to 1.5km in both locations (Figure 6c).

These measurements reveal that the SLF site is more contained compared to QVM, as reflected by the differences in elevation angle and 3D distance. The combination of these two factors defines the volumetric bowl which can be seen from these locations. Further, the proportion of visible sky calculated for SLF site is calculated 48.37 % which is considerably lower than the QVM site with 80 % sky ratio (31.63 % difference). Future development will reduce the sky ratio by to 46.23 % and 74.67 % respectively (Figure 6d).

The fractal dimensions of existing and future visual bowls were also calculated for both sites (Figure 6e). Currently, the QVM site holds more fractal dimensions and greater complexity as compared to the SLF. While these two sites present highly different spatial form in terms of size and volume, the difference in calculated fractal dimensions for QVM site (2.8773) and SLF site (2.8658) is negligible. This highlights the fact that – similar to previous studies – the fractal dimension differentiates between the type of landscapes and that these two sites present similar urban context.

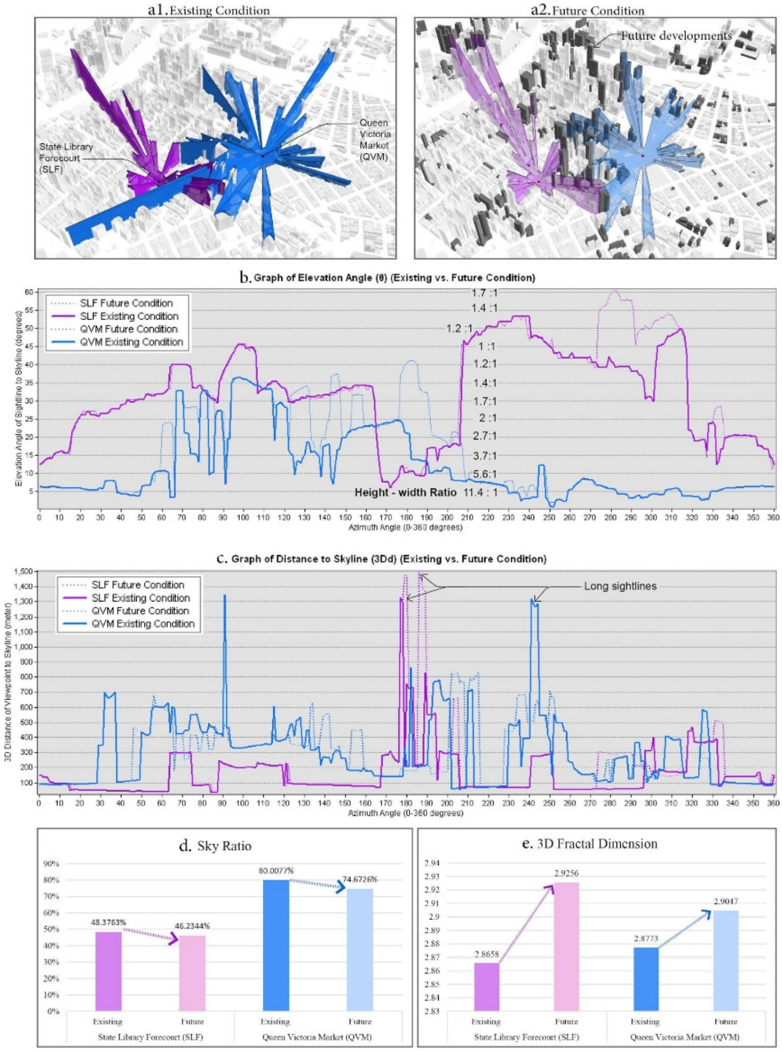

Fig. 6: Calculated variables from the visual bowl; a.1 & 2) Modelled visual bowl for two sites-existing and future conditions; b) 2D Skyline graph of elevation angle; c) 2D Skyline graph of 3D distance to skyline; d) Calculated sky ratio; e) Estimated Fractal Dimension based on Voxels

When we consider future developments, there is a negative correlation between sky ratio and fractal dimension. Future developments in both sites result in an increase in complexity and fractal dimension by 2 % and 1 % in SLF and QVM sites respectively. Drawing more conclusions from the fractal dimension requires further work to include the details of the bottom of bowl and test on more locations in different urban settings to interpret the measurements and changes.

4 Discussion

The visual bowl was calculated here by using a novel approach implemented with off-the-shelf functionalities in ArcGIS. It resulted in the crystallization of a new volume to shape the skyline and all the surrounding objects and surfaces that define this space. Compared to previous research (LIN et al. 2015 MORELLO & RATTI, 2009, TELLER 2003, FISHER-GEWIRTZMAN et al. 2003), this study provided a clear representation of visual bowl using open-source city models. Its volume provides a means to study the variation of the volumetric visible space of existing public spaces that monitors the changes caused by future developments.

However, the limitations presented in this paper in visual bowl modelling is that it only includes built form heights and does not consider vegetation or street furniture elements that can change the form of the visual bowl considerably, for example by blocking the views to buildings. Incorporating such elements in future research could include micro-level details through the use of terrestrial laser scanning to increase the precision of modelling the visual bowl.

Extraction of the hollowed space and the calculation of its volume within the visual bowl provided an opportunity for further study of visual environments through the fractal dimension. As a novel approach in landscape and urban studies, the fractal dimension was estimated for the conceptualised volume of visual bowl by using voxels. This is a new approach in analysing urban scenes compared to previous studies (STAMPS 2002, HAGERHALL et al. 2004, CHALUP et al. 2009). This contributed to rendering an indicator to read and encode the visual space. Estimation of fractal dimension using voxels is a new approach to study the complexity in a variation of public spaces. However, the developed method has limited the inclusion of the upper limit of the bowl and does not include the lower part of the bowl, which holds a high number of details in the foreground.

The contribution of this research is multi-faceted. The presented techniques are applicable to most landscape settings that requires us to define building height thresholds in response to visual concerns. Furthermore, calculated variables including sky and height-width ratios, sightline distance, and fractal dimension provide opportunities for further research to study indistinct senses of overdevelopment, pleasure, comfort or safety in urban environments by comparing it to perceptual responses. This research contributes to decision making by defining appropriate future building heights, and guide densification of future urban settlements considering public concerns and place values.

5 Conclusion and Outlook

This research does not criticize high-rise developments in Melbourne CBD. However, it addressed the challenges derived from contrary public and expert opinions as an opportunity to study and quantify the visual effects of high-rise buildings on public spaces. This research contributes new methods to quantify the visual impacts of high-rises by calculating fractal dimensions in 3D alongside other metrics derived from the visual bowl. Incorporating human perception surveys and justifying the applicability of these measurements are future directions for this research. This would aid in deliberative design and decision-making processes that are based on scientific findings in developing building heights controls, reviewing development proposals, and a better understanding of their visual effects.

References

ADAMS, R. & DOVEY, K. (2018), The Marios Talks. In: DOVEY, K., ADAMS, R. & JONES, R. (Eds.), Urban Choreography. Melbourne University Press, Melbourne.

ALKHRESHEH, M. (2007), Enclosure as a Function of Height-To-Width Ratio and Scale: Its Influence on User's Sense of Comfort and Safety in Urban Street Space. PhD, University of Florida.

BOEING, G. (2018), Measuring the Complexity of Urban Form and Design. Journal of Urban Design International.

CHALUP, S. K., HENDERSON, N., OSTWALD, M. J. & WIKLENDT, L. (2009), A Computational Approach to Fractal Analysis of a Cityscape's Skyline. Architectural Science Review, 52, 126-134.

CITY OF MELBOURNE (2017), Melbourne Planning Scheme, Sunlight to Public Spaces.

CITY OF HOBART (2018), Building Height Standards Review. https://www.hobartcity.com.au/Projects/Current-projects/Building-Height-Standards-Review (18.11.2018).

COOPER, J. (2003), Fractal Assessment of Street-level Skylines: A Possible Means of Assessing and Comparing Character. Urban Morphology, 7, 73-82.

ERVIN, S. & STEINITZ, C. (2003), Landscape Visibility Computation: Necessary, but Not Sufficient. Environment and Planning B: Planning and Design, 30, 757-766.

EWING, R. & HANDY, S. (2009), Measuring the Unmeasurable: Urban Design Qualities Related to Walkability. Journal of Urban Design, 14, 65-84.

FISHER-GEWIRTZMAN, D., BURT, M. & TZAMIR, Y. (2003), A 3-D Visual Method for Comparative Evaluation of Dense Built-up Environments. Environment and Planning B: Planning and Design, 30, 575-587.

GEHL, J. (2018), Move to Melbourne. In: DOVEY, K., ADAMS, R. & JONES, R. (Eds.), Urban Choreography. Melbourne: Melbourne University Press.

HAGERHALL, C. M., PURCELL, T. & TAYLOR, R. (2004), Fractal dimension of landscape silhouette outlines as a predictor of landscape preference. Journal of Environmental Psychology, 24, 247-255.

JIMÉNEZ, J., LÓPEZ, A. M., CRUZ, J., ESTEBAN, F. J., NAVAS, J., VILLOSLADA, P. & RUIZ DE MIRAS, J. (2014), A Web platform for the interactive visualization and analysis of the 3D fractal dimension of MRI data. Journal of Biomedical Informatics, 51, 176-190.

KELLER, J. M., CROWNOVER, R. M. & CHEN, R. Y. (1987), Characteristics of Natural Scenes Related to the Fractal Dimension. IEEE Transactions on Pattern Analysis and Machine Intelligence, PAMI-9, 621-627.

LIANG, J., HU, Y. & SUN, H. (2013), The Design Evaluation of the Green Space Layout of Urban Squares Based on Fractal Theory. Nexus Network Journal, 15, 33-49.

LIN, T., LIN, H. & HU, M. (2015), Three-dimensional visibility analysis and visual quality computation for urban open spaces aided by Google SketchUp and WebGIS. Environment and Planning B: Urban Analytics and City Science, 44, 618-646.

LOPES, R. & BETROUNI, N. (2009), Fractal and multifractal analysis: A review. Medical Image Analysis, 13, 634-649.

MANDELBROT, B. (1977), Fractals: Form, chance, and dimension, W. H. Freedman and Co.

MORELLO, E. & RATTI, C. (2009), A Digital Image of the City: 3D Isovists in Lynch's Urban Analysis. Environment and Planning B: Planning and Design, 36, 837-853.

OSTWALD, M. J. (2013), The Fractal Analysis of Architecture: Calibrating the Box-Counting Method Using Scaling Coefficient and Grid Disposition Variables. Environment and Planning B: Planning and Design, 40, 644-663.

OSTWALD, M. J. & VAUGHAN, J. (2013), Representing architecture for fractal analysis: a framework for identifying significant lines. Architectural Science Review, 56, 242-251.

PERRY, S. (2012), The Unfinished Landscape – Fractal Geometry and the Aesthetic of Ecological Design. Traditional Queensland University of Technology.

STAMPS, A. E. (2002), Entropy, visual diversity, and preference. The Journal of General Psychology, 129, 300-20.

STAMPS, A. E. (2002), Fractals, skylines, nature and beauty. Landscape and Urban Planning, 60, 163-184.

TARA, A. (2017), Measuring visual attributes for assessing visual conflicts in urban environments. Ph. D., Queensland University of Technology.

TARA, A., NINSALAM, Y. & ANDERSON, C. (2018), Interrogating Urban Renewal Scenarios Using Skyline Analysis in Fishermans Bend, Melbourne. Digital Landscape Architecture, 3.

TELLER, J. (2003), A Spherical Metric for the Field-Oriented Analysis of Complex Urban Open Spaces. Environment and Planning B: Planning and Design, 30, 339-356.

TUCKER, C. (2004), Developing Computational Image Segmentation Techniques for the Analysis of the Visual Properties of Dwelling Facades within a Streetscape. Traditional, University of Newcastle.

TUCKER, C. & OSTWALD, M. J. (2007), Using algorithms to analyse the visual properties of a building's style.