The plan is an inadequate tool for planning: Enhancing the urban design process through the use of 3D+ digital tools directed towards sustainability.

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1 Abstract:

The term *town planning* implies a planar – two dimensional – method of analysis and design. For most of the 20th Century, two dimensional analysis was seen as adequate as it could deal with the planning issues of the time. With increasing density and populations; more complex land uses, a desire to improve public spaces as well as growing environmental concerns, it has become apparent that two dimensional planning methods are no longer adequate. "*3D+*" tools must be adopted that utilise a combination of three dimensional (3D), three dimensional plus time (4D), and parametric modelling for urban analysis and design.

This paper focuses on the development of a suite of 3D+ digital tools geared towards sustainable urban design. The tools have been developed either through customization (scripting) or through taking advantage of under-utilized parametric features within industry standard CAD and animation software. This has been done with the intention of beginning to address planning issues which are difficult to address using conventional 2D planning techniques. The toolkit also avoids the great expense of additional specialised software, additional hardware or the appointment of additional consultants.

The tools are currently being developed and tested on urban design case studies within an award winning architectural practice in Melbourne, Australia. The tools discussed in this paper are: wheelchair access gradient analysis; agent-based pedestrian connectivity analysis, overshadowing envelope design, radiance-based daylight analysis, visual impact analysis and urban form generation. The tools are proving to be taken up and used quickly and concurrently 'in house', early in the urban design process. This suits both the limited fees and the compressed time frame of sketch design and design development within architectural practice.

With careful research and reassessment of the way we use existing software for analysis and design, this paper highlights an opportunity for architects to not only address planning issues that have hitherto been beyond their reach, but also increase the contribution architects can make in the generation and advocacy of sustainable planning policy.

2 Keywords:

Customisation, Urban-analysis, Agents, Connectivity, Daylight-hours, Parametric, Scripting, Plug-in

3 Introduction: Adequacy of plans – 'modelling' in two dimensions

A *model* is defined as a 'simplified version of reality, built in order to demonstrate certain of the properties of reality', (Haggett, 1965)[1]. *Urban Planning* can be taken to be 'the process of deciding how land in a particular area will be used and designing *plans* for it'[2] and a *plan* a 'representation of a thing drawn on a plane, as a map or diagram'[3]. By its very name, the term planning implies a planar – two dimensional – method of analysis and design. *Urban Planning* using *plans* is essentially a kind of model that simplifies the infinitely complex reality of urbanism to a two dimensional abstraction in order to analyse and design key elements. (Antoni 2002) [4].

For my argument, the term *inadequate* is taken to mean 'insufficient for a purpose, unable to deal with a situation'[5]. Adequacy can be subjective and perceived by the observer, and this perception may change over time. For a *model* to be adequate, it must simplify reality sufficiently for the model to be practical, whilst retaining a sufficient level of reality to test the key elements in question at the time successfully. As I discuss in this paper, the questions of our time have changed, meaning that the level of abstraction in our modelling needs to change. Planning in two dimensions is no longer adequate for today's society in the light of the increased complexities to be accommodated along with the extended range of opportunities digital technology afford.

Throughout the history of urban design the level of abstraction in the city modelling for analysis and design has varied greatly. Pre Renaissance cities generally either grew organically in 'the pack donkey's way' (Le Corbusier 1924)[6] or were derived from a two dimensional grid model.

> *The pack-donkey meanders along, mediates a little in his scatter-brained and distracted fashion, he zigzags in order to avoid larger stones, or ease the climb, or gain a little shade; he takes the line of least resistance.* [7]

Le Corbusier's concept of civilised humans planning cities with a 2D orthogonal grid in contrast to the unplanned-organic echoed the thoughts of Haverfield (1913) [8] who suggested the orthogonal grid distinguished the civilized from the *moral inconsistency* of the barbarian who were incapable of producing plans (Kostof 1991)[9]. The difference between the medieval city and the grided city was that the medieval city was modelled at 1:1 in real materials, pulled down and altered gradually as necessary, where as the grided city was generally modelled in 2D before construction.

Through the late medieval period pseudo perspective – 'bird's eye view' drawings of cities (somewhere between 2D and 3D) allowed for an overview of the relationships of key buildings. The discovery and understanding of perspective lead to application of the perspective drawing technique as an urban design tool through the Renaissance, Baroque and Picturesque. Urban designers began to compose perspective images or 'scenes' that were projected back to 2D plans for construction.

With the rise of commerce, such noble aesthetic pursuits gave way to the reversion to 2D grid plans due the ease with which this method allowed real-estate to be divided up and sold. Real-estate generally being sold by square metres (2D) which is calculated with Length by Width equals Area, not by how beautiful a blocks shape is, nor by computer measured volume - cubic metres. Consequently, the 2D orthogonal grid method of planning has been adopted all over the world and is seen as the norm. It is sometimes applied over areas regardless of topography resulting in areas of Street grid that are too steep even for a car to drive directly up. Notable examples are San Francisco California, (the home of the movie car chase) and Wellington New Zealand which was designed in England using 2D site plans with no topographical information and the designer never having visited the site.

During the 80s and 90s the effectiveness of the plan as the tool for urban design was questioned. Changes in the kind of industry, manufacturing, concerns for heritage, and the way in which people worked and lived had changed making 2D zoning plans seem out of step with peoples needs. Attempts were made to overcome the inadequacy 2D modelling of cites with a movement towards doing away with plans all together, and replacing them with descriptive text. Performance statements were used to describe what a city ought to be like, though this has since proven to be unsuccessful for various reasons (Neuman 1998)[10].

This paper focuses on the development of a suite of 3D+ digital tools geared towards sustainable urban design. *3D+* is a term refers to modelling not restricted to 2d. It is modelling that includes 2d, 3D, 3D with time (4D), 4D with options or changeable parameters (parametric modelling), natural elements such as daylight and so on. The tools have been developed either through customization (scripting) or through taking advantage of under-utilized parametric features within industry standard CAD and animation software. This has been done with the intention of beginning to address planning issues which are difficult to solve using conventional 2D planning techniques. The toolkit also avoids the great expense of additional specialised software, additional hardware or the appointment of additional consultants.

The tools are currently being developed and tested on urban design case studies within an architectural practice in Melbourne, Australia. The tools discussed in this paper are: wheelchair access gradient analysis, agent-based pedestrian connectivity analysis, overshadowing envelope design, radiance-based daylight analysis, visual impact analysis and urban form generation.

4 The contemporary problem:

4.1 Environmental Awareness > Increased Density > Diminished Amenity

Over the past decade an increased cultural awareness of environmental issues has forced governments to re-assess planning policies with regard to increased density of inner suburbs. This is often in direct opposition to local residents’ desire to maintain amenity by retaining lower density. This may be partly due to density having an historical stigma to overcome. High density has been problematic even in pre industrial cities, where increased density of people led to famine and high levels of disease. The problem worsened as cities became industrialized with the addition of smog etc. Attempts to address the issue of public health with planning have been investigated in various forms. Most notably Haussmann's Paris[11](1850's) and the Garden City Movement (Howard 1898) both used 2D planning methods to address this problem of amenity, either with great boulevards or land use zoning.

In the 1900's the initial uptake of the car led to the lateral spread of the city – *suburban sprawl*, which meant that residential, could be located far away from industrial areas. Initially this would have had a positive effect on health, but as numbers grew, roads became more and more congested (Davison, Yelland 2004)[12] . The effect of pollution from cars is now seen as a major contributor to global warming, a phenomenon even the greatest sceptics such as the current President of USA and Prime Minister of Australia are beginning to recognize (Darby 2006)[13]. This has led to the desire by governments in Australia to adopt a *smart growth* policy, attempting to contain the sprawl by placing development boundaries around cities and encouraging higher density development in *transport hubs* near existing public transport to lessen reliance on cars. On the surface, this policy seems logical. It draws on the existing rail coverage which, whilst not in the same league as a city like Tokyo, is far more extensive than most US cities. However by encouraging higher population densities, the old fears of public health, access to daylight, fresh airs etc. once again move to the fore. In 2002 the Victorian State Government released the planning document 'Melbourne 2030 Planning for sustainable growth', with nine objectives to promote urban consolidation and the containment of suburban sprawl.

Figure 1 Melbourne 2030 – Planning for sustainable growth -- Key aspirations / objectives.

Direction 1: A more compact city Direction 2: Better management of metropolitan growth Direction 3: Networks with the regional cities Direction 4: A more prosperous city Direction 5: A great place to be Direction 6: A fairer city Direction 7: A greener city Direction 8: Better transport links Direction 9: Better planning decisions, careful management

Local councils are responding to the *Melbourne 2030* report in the form of 'Urban Design Frameworks' and 'Structure Plan' documents, which set up the planning rules within which new construction must abide. These documents are produced by planners, stake holders, user groups, traffic engineers, landscape architects and architects. They set out zoning plans for future development allocating programs eg. 'Retail Zone' or 'Entertainment Precinct', suggest preferred visual character, suggested urban interventions, set height limits for different areas with the intention of addressing each of the nine objectives of *Melbourne 2030*, achieving both an increased density and retaining amenity despite generally being limited to written instructions or that which can be drawn in 2D plans or sections.

4.2 Do we have the tools?

4.2.1 Existing tools / Available tools

The general aims of *Melbourne 2030* have been widely accepted, even by the Leader of the State Opposition of Victoria[14], though the implementation has been widely criticized. Resident groups complain that the report does not protect ‘local character’ from ‘inappropriate development’. They believe height limits should be in line with the Residential Code of Victoria - *ResCode* (Kirby 2003)[15]. They also have problems with the ‘selection *techniques* for determining which are the best areas to direct higher density development’[16]. An independent study produced by Monash University on *Melbourne 2030* concluded that there are ‘too few tools to ensure that the strategy is implemented’ *(Birrell 2005)[17]*. In the context of this report, the tools to which they are referring are not limited to the modelling techniques of urban designers; they are also talking generally about the many problems with the communication between the different many tears of government, of consultation with the community and so on.

In focus group discussions held with various municipal planning departments of Melbourne, a more specific opinion was put forward with regard to the lack of design and analysis modelling tools, ‘neither architects, nor planners currently posses the tools to deal adequately with the *2030* directives within the time and fee constraints’[18].

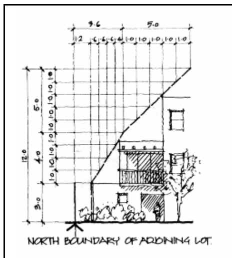


Figure 2
ResCode - Residential setbacks - ‘Setback from boundary for building height at any point - more than 3·6m but not more than 6·9m must be: 1m plus an additional distance calculated at the rate of .3m for every metre of height over 3·6m.’[19]

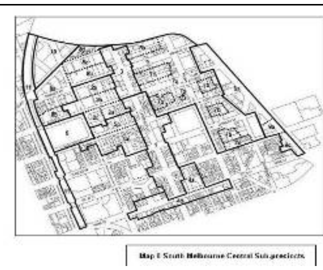


Figure 3
Planning zones illustrated in 2D plan for South Melbourne Central Urban Design Framework (Port Phillip 2005) relating to use and height limits.

This lack of design and analysis tools relates to what the industry has at their disposal, and the way in which it uses the software. The architecture industry predominantly uses Autodesk’s AutoCAD™ software. Some architects are slowly including Building Information Modelling (BIM) software in addition to AutoCAD (such as Revit™, or ArchiCAD™). And an increasing number of enlightened councils are moving to GIS (Geographic Information System) systems (Yigitcanlar 2005)[20]. GIS software is very strong on data/statistical analysis but has traditionally been 2D, and relatively weak on 3D. Even with the extended packages offered by software developers ESRI and MapInfo™ that allow 3D modelling there is resistance to the uptake of the 3D capabilities (Pietsch 2005)[21]. Despite the efforts by ESRI to produce the *all-in-one out-of-the-box* planning program, they are have opened the program up to 3rd party 'add-ons'. Google's Sketchup™ has recently released a plug-in for ESRI - GIS which theoretically allows information transfer between the two programs. This is an acknowledgement that both programs individually are insufficient to deal with planning issues - ESRI's 3D modeller is 'too clunky', and Sketchup's 'user friendly' polygon meshes don't store the required attribute information, but the two programs combined move closer to what is needed by planners. This synergy of software seems to have many advantages; if the planners/architects already posses the GIS software, the very cheap Sketchup can be added on with minimal cost and training. Unfortunately the majority of planners in Victoria do not use the ESRI software, opting for the slightly cheaper Map Info (Yigitcanlar 2005)[22], for which no plug-in for information transfer with Sketchup currently exists. In the case of architects any form of GIS is extremely rare, (see table 1).

Table 1 : Primary CAD system survey of architects (2004)[23]

Product	Percent
Architectural Desktop	14.1%
ArchiCAD	1.0%
AutoCAD	54.3%
AutoCAD LT	1.8%
AutoCAD Map	1.2%
Inventor	2.1%
Mechanical Desktop	2.1%
MicroStation	4.2%
Land Development Desktop	9.1%
Solid Edge	1.2%
SolidWorks	3.3%
All Other (ESRI, Revit, Map Info etc)	5.6%

4.3 What is needed?

4.3.1 Customisable software - building upon industry standard software (old dogs really can learn new tricks)

It is essential for any software used by planners and architects to be customisable (Burry 1997)[24], and for the digital information to be transferable to a range of other programs. It is inevitable that any software package will be good for some discipline-specific tasks, but poor at other tasks, illustrated in the ESRI GIS and Sketchup example. This should not be considered a bad thing; with this combination of software the best of both worlds begins to be possible. If the *all-in-one out-of-the-box* planning program is recognised as an unachievable aim, energy can be put into development of innovative 3rd party add-ons and on transferability between programs.

Like most architectural offices, the office in which this research has been conducted does not possess GIS software. It does however posses the usual AutoCAD, 3D Studio Max, (normally used for rendering presentation models), and a copy of Revit (BIM). None of these programs by themselves are adequate, but AutoCAD and Max are open to customisation with basic 'user programming' (Autolisp or scripting), meaning there is the opportunity to improve the programs and produce tools which fill the gaps identified above.

4.3.2 Increase speed of analysis and reduce work done in isolation.

There is great cost associated with the engagement of additional specialist consultants to do 3D and 4D analysis for lighting, wind, pedestrian connectivity analysis etc. as well as the time lost as information is sent out, with feedback coming days and sometimes weeks later, (McGauran 2006)[25]. This limits the number of design iterations possible, but also means the analysis happens in isolation – the person carrying out solar access doesn't see the results of traffic studies. Or, just as problematic, the traffic analysis has to be done first with no chance to revisit decisions made. In this sequential scenario, the traffic consultant does traffic flow analysis and proposes road layout, which is then 'locked in', the next consultant does their analysis and then the next. This is problematic for a number of reasons, not least of which is that it produces 'a system that, relentlessly condemning all artistic traditions, has restricted itself exclusively to questions of traffic', (Sitte 1889)[26]. Whilst there might be some artistic traffic engineers out there somewhere, traffic engineers are also less likely to consider pedestrian movement (Desyllas et al. 2003)[27], just as lighting engineers are unlikely to be concerned with traffic flow, and – dare I say it – architects could be accused of considering aesthetics of designs and not much else. The suite of add-on tools being developed enable the architect to take on some of this work currently done in isolation by others, by reducing the level of abstraction in the modelling, without sacrificing speed or flexibility. As the one consultant can manipulate the model and instantly see perspective views for visual assessment as well as pedestrian, solar access etc. concurrently, a more synergistic planning response can be made.

5 The Digital Tools:

5.1 'The Gradiator' - Access for all

5.1.1 The planning aspiration

Improving wheel chair access [28] and catering for a rapidly aging demographic (Murray 2006)[29] have both been stated within the objectives of *Melbourne 2030*. In the case of residential developments catering for the elderly, it is desirable that these projects be located close to public transport and for topography be considered during initial siting. Topography is also important when considering upgrading transport facilities – the introduction of wheelchair friendly train & bus stops etc.

5.1.2 Existing method and their shortcomings

Within traditional drafting packages, 2D sections of contour drawings can be produced and used to analyse gradients along the section cut line. However, this traditional manual 2D section is time consuming and only allows assessment of that which is actually cut by the section plane.

There is a plug-in available for the 3D add-on for ESRI GIS, which allows contours lines with height attributes to be used for gradient analysis. McNeil's Rhinoceros 3D program has change of gradient analysis capability with the *Draft Angle* command which can be used on topographic 3D meshes, although Rhino itself does not have terrain mesh creation capabilities. Landscape architecture programs such as the ‘vertical application’ (discipline specific add-on package) Land-CAD (add-on for AutoCAD) can be added to with the purchase of ‘Eagle Point’.

These methods are far more useful than a simple section, but require a topographic mesh to be created from 3D contour lines using one program, then imported, converted into an appropriate format and then analysed, which takes time. Also, once the surface is analysed, changes to the topography must come from the original source, re-imported, re-converted then re-analysed.

5.1.3 Constraints

The speed of analysis is seen to be a key constraint in this process. The 3D terrain creation and manipulation as well as slope analysis must be fast enough to analyse existing topography, but in the case of new developments also be quick to test alternate topographic manipulations.

5.1.4 The digital tool

The ‘Gradiator’ tool can be applied on any size topography, even large scale areas as big as whole cities and done in seconds. There are two steps to this process for using the Gradiator, firstly 3D contours lines are turned into a surface using 3D Studio Max’s inbuilt ‘Terrain’ ‘compound object’ command. This is followed by running the Gradiator script, which assesses each polygon’s *normal* in relation to the Z axis and applies a material colour (fall off map) according to the user-defined key. The key by default is set to show equal access areas (relatively flat areas accessible by an unassisted wheelchair) as blue, fading from blue to red as the gradient gets steeper.

5.1.5 Case studies

The two case studies shown here illustrate the use of the Gradiator to help the decision making process in urban scale designs. The first project analyses two entire suburbs for wheelchair access which enables the Architectural practice to propose where elderly/respite housing and similar should and shouldn’t occur to ensure maximum mobility and limit isolation. (Figure 4)

The second case study was an extremely rapid collaboration with a landscape architect - Nano Langenheim, involved in the master planning of a residential subdivision in rural Victoria. A 3d topographical model was emailed; the Gradiator was applied to the surface and the file was emailed back to the landscape architect within 45minutes. This gradient analysis of the large subdivision was then used to help locate new housing to minimise the cost of site *cut and fill*, in an attempt to keep the housing affordable. (Figure 5)

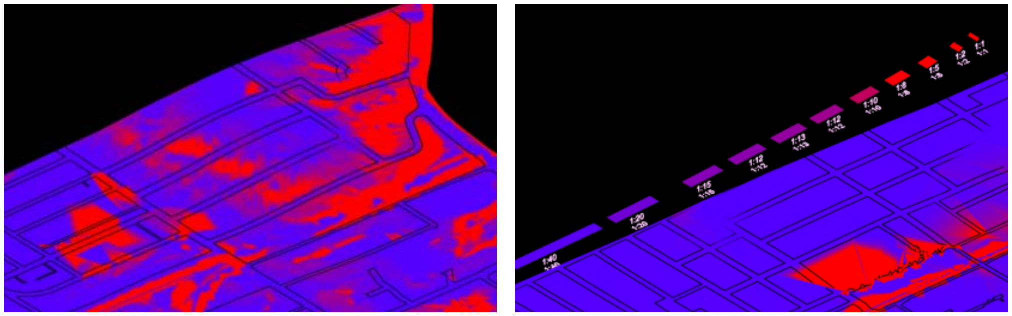


Figure 4 Gradiator applied to an area in Prahran / South Yarra in Melbourne. Analysis of non-accessible areas of suburb made in 140 seconds.

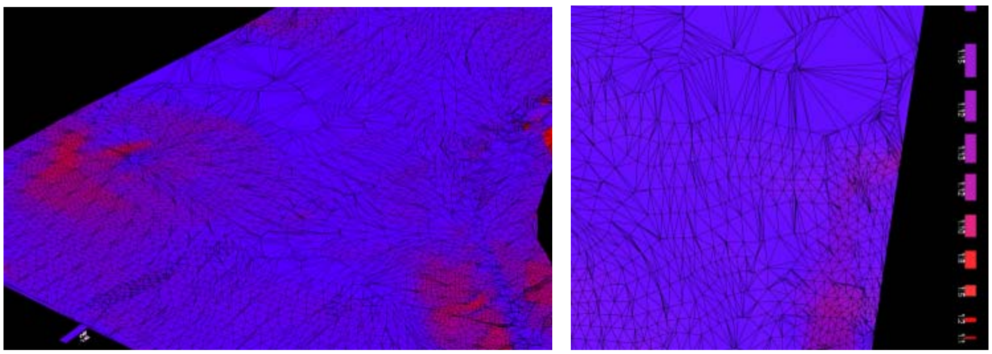


Figure 5 Gradiator applied the town of Hamilton in rural Victoria for Oculus Landscape Architects.

5.1.6 Results – speed, accuracy, level of abstraction

The Gradiator can be applied to a terrain mesh in seconds. The level of accuracy is as high as the topographic information put into the terrain model. The model can be progressively refined as more data is gathered and these updates are reflected in the analysis.

This tool allows an architect to know where a retirement village should (or shouldn't) be located and where special wheelchair friendly bus or tram stops may be ineffective due to surrounding topography. It can also be used in conjunction with pedestrian catchment analysis in cases which may be greatly influenced by steep terrain. One unforseen use for the tool pointed out by the landscape architect Nano Langeheim, was for the analysis of surface gradients with respect to turf planting. Due to the dry climate in Australia, grass will not grow on angles that are more than 1:6 (to 1:3 depending on soil type) without the need for excessive watering and additional soil stabilisation.

5.2 'Ped Catch' - Pedestrian connectivity

5.2.1 The planning aspiration

An over arching theme of *Melbourne 2030* is urban consolidation through improved access to public transport. It is believed this can be achieved by increasing density within existing transport node catchments (walking distance from railway stations etc).

5.2.2 Existing methods and their shortcomings

This idea of catchment has been considered important by planners since the 1930's and particularly after the housing shortage at the end of the Second World War (Barnett, Burt, Heath 1944)[30]. The technique for establishing this catchment has remained unchanged.

The Circular catchment method: The analysis technique adopted for assessing transport catchments uses a 2D plan and simplifies pedestrian movement from a central node (eg a railway station) to an 'as the crow flies' radial catchment, (see Figure 7). Radii commonly used are 400m and 800m, which represent five and ten minutes walking distance at average walking speed of 1.33 meters per second, the amounts of time people are willing to walk to shops and transport respectively (Pushkarev 1975) [31].

Shortcomings: This modelling technique is very quick but has very low accuracy. It fails to allow for discrepancies in street grid layout, busy roads and crossings, as well as ignoring 'aspects of the physical environment that may influence walking distances, such as gradient, perceptions of safety, destination type and climate'[32] (Pikora 2001). This is a 2D abstraction of what is essentially a 4D problem. Consequentially the technique is only accurate when the topography is flat, the street grid is radial and no time is spent waiting at lights.

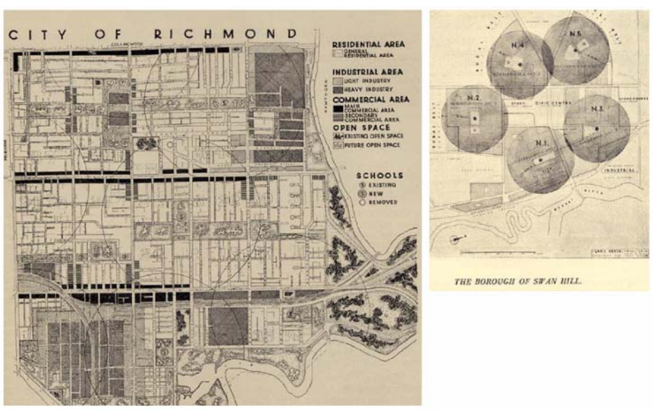


Figure 6 Diagram from We Must Go On (1944) showing five minutes walking distance catchment measured from centre of transport interchanges.

Figure 7,

Diagram from Melbourne 2030 (2003) showing five minutes walking distance catchment measured from centre of transport interchanges.

Pedestrian Route Directness: Research by Dr Jennifer Dill at Portland State University, into other GIS based methods of measuring pedestrian connectivity compared methods such as Block length Ratio, Block Density, Street density, Pedestrian Route Directness (PRD) and Link Node Ratio concluded that by far the most effective method of measurement is PRD. (Dill, 2004) [33]. PRD measures the distance between two nodes and expresses this as the 'ratio of route distance to straight-line distance for two selected points', eg. the distance between railway station and a supermarket are measured both 'as the crow flies' and also by navigating through the block layout and these distances are expressed as a ratio.

Shortcomings: Although accurate, PRD is the most difficult to calculate and most time consuming method, and its computational complexity renders it difficult to use for policy making and consequently it is rarely employed by planners. (Dill, 2004) [34]. Also, PRD doesn't consider aspects of 3 and 4 dimensional environment, such as topography, busy roads, and daylight.

Visual Graph Analysis (VGA): The Space Syntax method of analysis developed at UCL can be used for pedestrian connectivity using Visual Graph Analysis (VGA) . This method has shown to have a direct link to pedestrian movement (Hillier 1996)[35] in studies conducted in London. The work of Dr. Jake Desyllas from Intelligent Space London also uses VGA as well as many other factors such as footpath width, along with empirical studies of an area, with the use of multi regression analysis (MRA).

Shortcomings: Whilst the VGA method has been shown to be a successful method of analysis in London (Desyllas etal)[36], London is a very particular form of urban fabric. For those people having walked around Brasilia, (a city with very high levels of VGA), few would argue that the city has high levels of pedestrian connectivity. There are many other factors that must come into account such as street program (retail, blank carpark walls etc), shade etc. These factors are taken into account with the MRA method, but the method requires a great deal of data collection, and, to have the analysis performed, one must appoint Intelligent Space (London based spatial consultants).

Agent based analysis: The use of Artificial Intelligence (AI) for an agent-based pedestrian analysis technique utilises advancements in crowd animation (examples include Peter Jackson's Lord of the Rings and any advertisement with a crowd). These use large numbers of 'agents' that are capable of being programmed to make basic decisions, move at human walking speeds[37], be attracted or repelled by other elements with in a 3D model, slow down as they travel uphill etc.

Shortcomings: The main pitfalls of Agent based analysis are the prohibitive cost and the fact that the programs used are specialised and require training to use. Though originally designed for crowds escaping from burning buildings, Agent based evacuation software such as Legion and Ped-Sim could be reconfigured and used to determine pedestrian catchment, but these programs are quite specialist and expensive and require the translation of all data into another program.

5.2.3 What is needed

A tool is needed which allows analysis of a single destination – such as a railway station – and all destinations within ten minutes walking distance. A 4D analysis should use CAD with a 3D animation software package commonly used within architectural practice to not only compare agent's walking distances versus the 'as the crow flies' distance, but also allow the comparisons of various proposed urban interventions whilst still managing to meet the architectural office's deadlines.

5.2.4 The digital tool

A simplified version of the Artificial Intelligence (AI) in the form of *Crowds* and *Particle Flow* has been built into relatively cheap animation programs such as 3D Studio and Maya, with 3D Studio being the most commonly used in architectural practices (Hobbs 2006) [38].

These new software capabilities can be used to simulate crowds of pedestrians capable of 'seeking' goal destinations such as libraries or railway stations and being 'repelled' by destinations/objects, eg. move as far as that can away from a particular building and avoid bumping into each other. To calculate transport interchange catchments, we run the agent process in reverse, with agents which begin at the transport node (railway station) and are programmed to move as far away from the node as possible in ten minutes, negotiating streets and intersections as they go.

5.2.5 Case study

The Ped-Catch technique was used for analysing the 'Mega-Mile', an area between two Melbourne suburbs - Mitcham and Nunawading focusing particularly on the pedestrian catchment of the Nunawading railway station. The Ped-Catch was run over the existing street layout to test the current catchment area. This test illustrated that though the catchment was reasonably good to the south of the railway station, due to the poor connectivity to the north of the station, the over all pedestrian catchment was comparatively small.

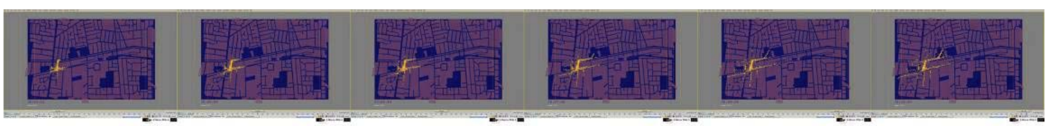


Figure 8. Frames from Ped-Catch pedestrian animation for 10 minutes walking distance - existing street layout for the Nunawading railway station precinct.

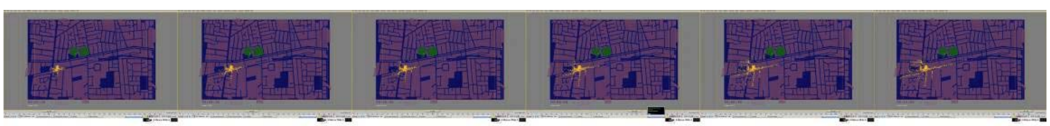


Figure 9 Frames from Ped-Catch pedestrian animation for 10 minutes walking distance - proposed street layout for the Nunawading railway station precinct.

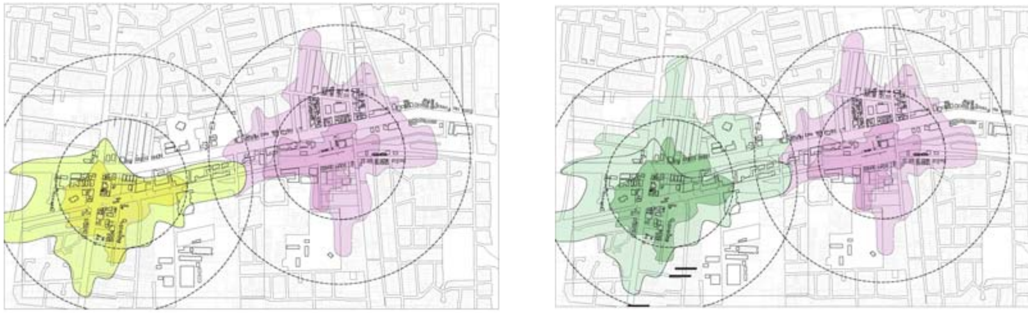


Figure 10 LHS, Catchment shape for 10 minutes walking distance existing street layout - RHS Catchment shape for 10 minutes walking distance proposed street layout (5&10 minutes walking distance illustrated by 400&800 m radius circles

The tool was then used to assess the merits of acquiring two vacant commercial blocks to the north of the station with the intended use of a pedestrian connection. The model was altered to reflect this pedestrian connection and the Ped-Catch tool reapplied. The resulting catchment was greatly improved. This proposal is currently undergoing design development and has the support of the majority of the councillors.

5.2.6 Results – speed, accuracy, level of abstraction

In application of Ped-Catch, the speed failed to match existing 2D method of analysis. To draw the 800m radius in plan takes approximately seven seconds compared with Ped-Catch method, which takes approximately seven hours although this includes modelling of the site.

According to validation studies, the Circular Catchment method of analysis is less than 50% accurate and there is no mechanism for comparison studies – 'what if' scenarios which look at different street configurations, something Ped-Catch allows. The accuracy of this method is currently being tested through empirical researcg – running observation trials with actual student pedestrians in a method similar to Daamen, W, & Hoogendoorn (2003) [39]. Based on this research the accuracy of Ped-Catch is substantially higher (more than 80%) than that of the Circle Catchment method.

This method also visually illustrates the catchments more clearly than the circle technique. Ped-Catch analysis presented to community focus groups as animations have proved to be a powerful advocacy tool, (Figure 8 & Figure 9) with the proposed changes to street layout in the Mega-mile case study gained support by stakeholders and community representatives in the suburb.

Ped-Catch allows designers to make educated decisions on where density should be increased with regard to access – higher density within five minutes walking distance, tapering down to lower density at ten minutes walking distance.

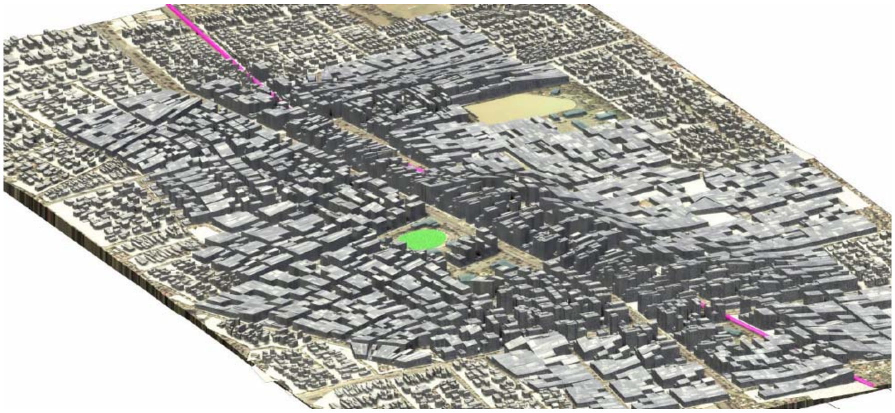


Figure 11 Pedestrian Catchment for 10 minutes represented as logarithmic density

5.3 'P-Radiance' –Quick Solar Access Assessment

5.3.1 The planning aspiration

Equally important is the need to protect solar amenity. Increased density should not be at the expense of access to daylight and fresh air. This sentiment is reflected in the *2030* objectives of 'a better place to be'. In response to these issues, investigation into urban form simulation as well as solar access has been conducted.

5.3.2 Existing method and their shortcomings

Though it is relatively straight forward to produce shadow studies of a building using 2D plans and sections using solar tables tracing Azimuth and Altitude, complex building forms or large areas involving many buildings can be time consuming and if on undulating topography can be almost impossible. Fortunately over the last ten years or so, 3D modelling packages have gained the ability to raytrace shadows, with a light rotated to match Azimuth and Altitude in the solar table. In some programs, *Solar Systems* have been included so the user can choose the location and the time of day and the system moves the light to the correct angle to cast accurate shadows. This alone is a very powerful ally for urban designers and better still; in some programs the system is parametric and animatable.

5.3.3 The digital tool

With some scripting, multiple sun positions and shadow positions can be shown simultaneously. This, combined with *P-Radiance* render setting, can be used to analyse the amount of daylight hitting each surface over the course of a full day and over different days of the year. This gives almost real-time feedback on different urban design proposals. (Figure 12). 'What is the difference between two levels and four levels in an area with regard to footpath over-shadowing?'.

5.3.4 Case study

The P-Radiance tool has been used on a master plan proposal for the 'Office Of Housing' in Prahran, Melbourne. The tool was used to test 18 different options of slab block / tower configurations for daylight impact within the site as well as neighbouring sites.

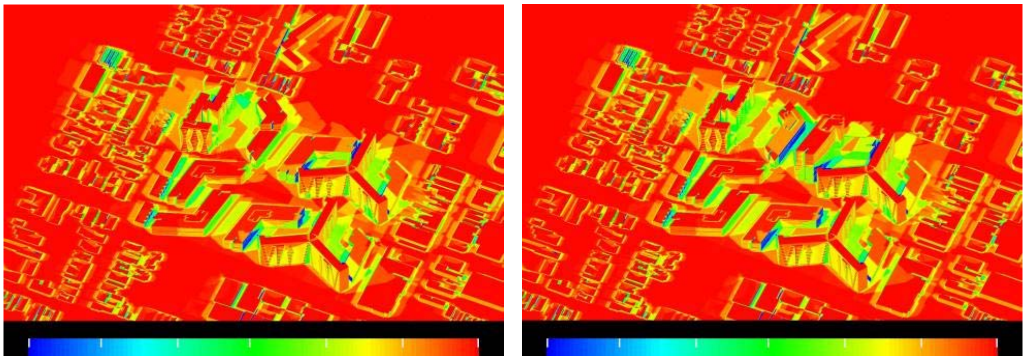


Figure 12

Case study for Prahran Office of Housing – Urban Design Framework for City of Stonington using P-Radiance

5.3.5 Results – speed, accuracy, level of abstraction

Speed with which comparison solar studies can be made is greatly improved. What would normally take a day can be done in a minute. The level of accuracy is also greater than existing solar table methods. Whilst a solar study might previously have taken into account two or three different time/sun positions for the year, P-Radiance can take into account 20-60 solar positions. Whilst not as accurate as a full radiance/daylight hours calculation analysis performed by specialist lighting engineers, speed is maintained and accuracy is improved to a level in which a comparative in-house form studies are possible. This technique enhances the urban designer's ability to assess cause and effect, where a design can be proposed and the effects can be seen quickly allowing for comparison and more informed decision making.

5.4 'Subtracto Sun' – solid negative shadow subtraction tool

5.4.1 The planning aspiration

Where a clearly defined outcome is given – for example 'This plaza must not be in shadow between these hours' – a kind of reverse solar modelling is required. For the St Vincent's Hospital in Melbourne, part of the master plan brief dictated that a particular plaza should remain unaffected by shadows during 9.30 am and 3.30 pm between March and September.

5.4.2 Existing method and their shortcomings

Other than an extremely time-consuming process of trial and error, there was no existing method to perform this task within the available software.

5.4.3 The digital tool

This problem lead to the development of a technique called *Subtracto- Sun*, a scripted tool which utilises parametric solar systems, real-time parametric Boolean operations, and Wired (linked) parameters. (Figure 13) The script creates a permissible building envelope by subtracting a solid negative 'shadow' object derived from angles of the sun during the given period. This results in a development envelope within which any building can be built without casting a shadow onto the plaza within the designated times.

5.4.4 Case study

This technique has since been used on other urban design projects to minimise effects of overshadowing on footpaths, plazas and existing buildings (public library).

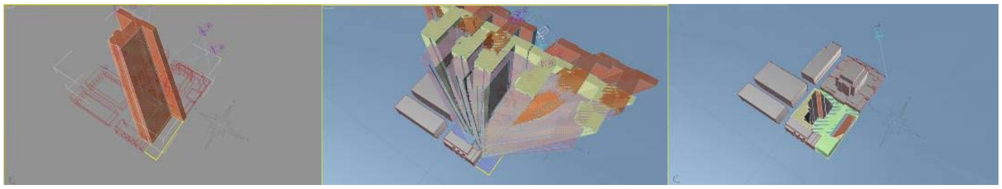


Figure 13

St Vincent's Hospital master plan using 'Subtracto-Sun' to project plaza shape as a subtractive solid of different times of day and removed from surrounding potential built form.

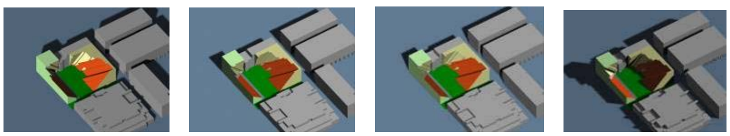


Figure 14

Permissible building volume created with Subtracto-Sun tested with raytraced solar shadows based on Melbourne Solar tables.

5.4.5 Results – speed, accuracy, level of abstraction

In the case of Subtracto-Sun, the level of accuracy can be as high as the amount of detail in the model. This technique was both developed and used within the time allocated for the job, and so met with the client's deadlines. Subtracto-Sun has since been used on other projects where similar desires have been expressed. It has been used to provide height limits on the opposite side of a café strip footpath requires direct sunlight at lunch times throughout the year. It has also been used for a development site directly adjacent an existing high school library to ensure no overshadowing of the reading room during school hours.

5.5 Visual Impact – Rapid Urban form simulation and visualisation tools

5.5.1 The planning aspiration

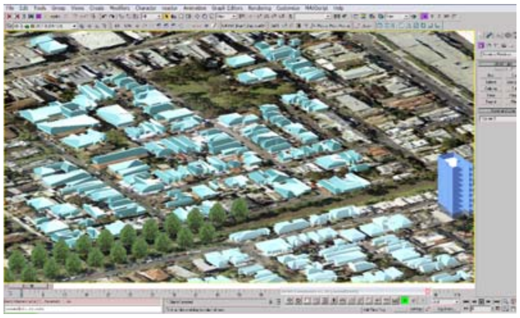
When density is increased, there is a need to protect heritage, community identity and consider the visual impact of development. There is generally a desire to keep buildings low, to 'hide' upper floors of buildings or 'reduce visual bulk'. This can be a very subjective discussion, as what is bulky to one may be elegant to another.

5.5.2 Existing method and their shortcomings

Planning departments generally stipulate that plans, sections and elevations be submitted to council as part of the planning application process. These 2D drawings are then compared with the 2D legislation drawings for compliance. (see Figure 15). Perspective images are sometimes submitted, but are rarely a requirement.

5.5.3 The digital tool

With the adoption of 3D Studio Max™ as the program used for modelling, the recently built-in *walk-through* command can be used to test eye height perspective views. Once again scripted tools have been created to enhance the speed of creating building envelopes (Quick-House, Quick-Tower and Quick Medium Density). These envelopes can be adjusted parametrically, with changes registering in perspective views in real time.



5.5.4 Case study

The City of Port Phillip council's planning code legislates a desire 'not to see' upper levels of buildings. This is legislated by way of a 2D sectional diagram alongside a description (Figure 15). When this is modelled in 3D and 'walked through' it quickly becomes apparent that though the upper level is in fact not visible in sectional viewing position, the upper levels may be clearly seen from many other viewpoints. This exposes a flaw in the legislation and highlights the need to test planning policies three and four dimensionally, by actually moving around the virtual 3D model of the proposed urban form.

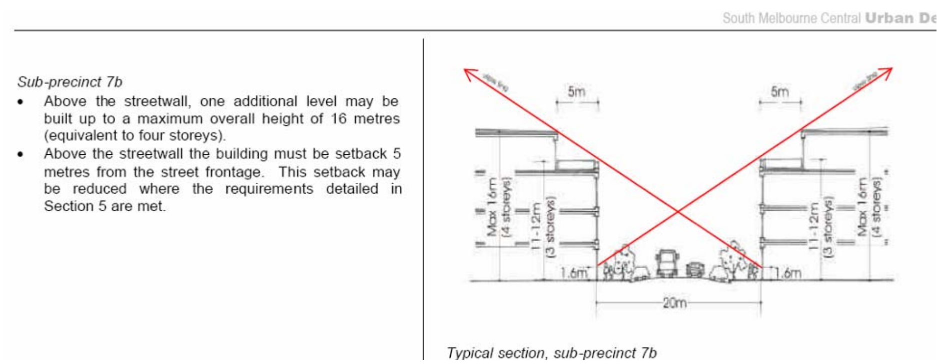


Figure 15 - 2D section of legislated height limits aiming to obscure upper level of building. (South Melbourne Central – Urban Design Framework for city of Port Phillip, by David Lock Associates (Nov 2005) PDF exhibition version)

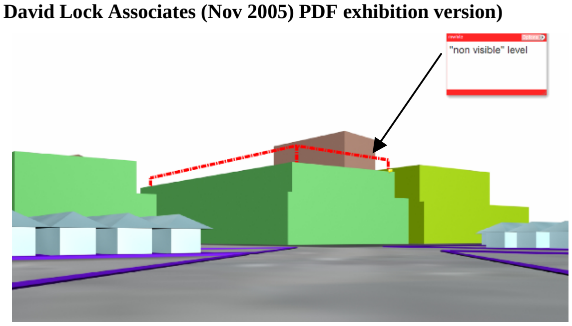


Figure 16 - 3D model of permissible form exposing the inadequacies of the legislated 2D section, as the upper level is clearly visible when viewed from numerous perspectives at eye level

5.5.5 Results – speed, accuracy, level of abstraction

These tools improve statutory planner's ability to generate maximum building envelopes etc that closer represent the planners' aspirations.

Real-time building envelope manipulation provides the opportunity to better ensure envelopes do what they are intended to do. There is also a possibility to revisit forgotten ideas from the Renaissance such as perspectival composition of urban form and the Picturesque which I will discuss later.

5.6 'Solid Silhouette' – Historic silhouette preservation

5.6.1 The planning aspiration

There is long history of city silhouettes, or skylines being important to cities identify. Until the 20th century, there has been an understanding that key civic buildings would announce themselves upon the skyline, be it is the gothic church spire or the dome of the town library. In recent times, this concept has fallen by the wayside with commercial towers eroding the skyline. In Melbourne, relatively unsuccessful attempts have been made to restrict building heights within the CBD to 40 metres. There are however two key legislative regulations that have made an impact on the Melbourne skyline with respect to historic vistas/silhouettes – The Shrine of remembrance – war memorial, and the St Paul's Cathedral.

The Shrine of Remembrance was built between July 1928 and November 1934 in remembrance of the men and women of Victoria who served and died in the Great War of 1914-18. The Shrine has been protected since the passing of the *Shrine of Remembrance Act* in 1978, and various master plans for the area over the years all protecting the historic silhouette looking down St Kilda road to the South.

Figure 17 Photo of the Shrine in the 1930s (LHS), and photo taken in 2006 (RHS). Note no buildings in background.

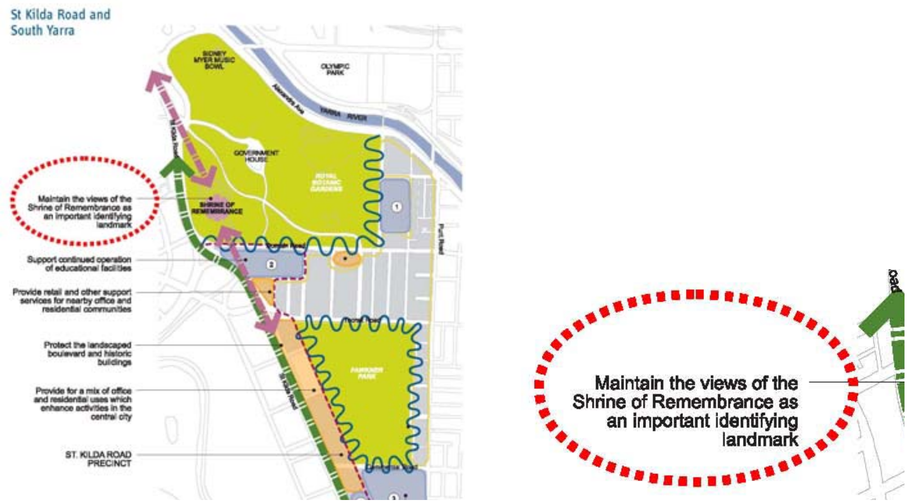


Figure 18 Plan from the St Kilda Road Master plan.

The other important protection of historic vistas in Melbourne has been the highly publicised St Paul's Cathedral/ Federation Square Shard controversy. In 2000 the Victorian state government commissioned a report on the effects of the proposed new Federation Square development, concluding with a recommendation that "the heritage vista of St Paul's Cathedral southern facade and complete silhouette should be preserved and protected in perpetuity."[40] This led to a redesign of the building to not interrupt the view or the silhouette of the Church.

5.6.2 Existing method and their shortcomings

Both of the examples sited above have been difficult to communicate and enforce and consequently have been surrounded in controversy, particularly the example of Federation Square. It is not enough for the city council to describe in text that a view should be preserved, or show an area in plan that is 'under a heritage vista overlay', volumetric envelopes must be described using plans and sections. To create these envelopes has been shown to be a timely and costly exercise.

5.6.3 The digital tool

The technique I have developed uses built in 3d perspective view camera creation. Camera position (XY) as well as height (Z) can be altered along with the direction and lens aperture of the virtual camera. A 3D digital model of the historic building in question is made and the camera can be matched to a designated viewing point. 'PFlow', (a built in particle system used to simulate explosions and the like) is used to generate particle rays that move through they eye (camera) position and then through each of the corners (vertices) of the historic building. The particle rays then intersect with an extrusion of the neighbouring property boundaries marking the intersection with a point. These marks can then be used to sculpt the permissible envelope, within which, anything can be built without impacting on the historic silhouette.

5.6.4 Case study – Melbourne High School

As part of the *Chapel Vision* structure plan for the Melbourne suburbs of South Yarra and Prahran, an analysis of potential future development adjacent the historic was undertaken. According to the heritage report produced by Bryce Raworth Pty Ltd Conservation, recommended that the view of the school from the corner of Yarra Street and Alexander avenue should be retained unimpeded by development – ‘the castel hill view’. Due to the form and castled parapet the building’s silhouette was considered important enough to be maintained. Any development to the East of the school must therefore be restricted in height. To work out the permissible heights, the solid subtractive silhouette technique was employed. The resulting envelope maximised the potential yield of adjacent cites whilst ensuring the heritage silhouette is protected.

Figure 19 LHS - image of historic school building, Middle – photo from designated historic view point (photo MW 2006), RHS digital model perspective matched to photo

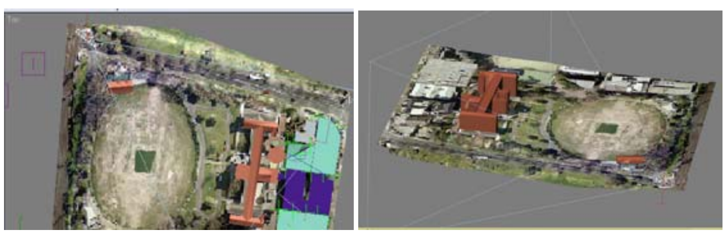


Figure 20 Images showing positioning of camera

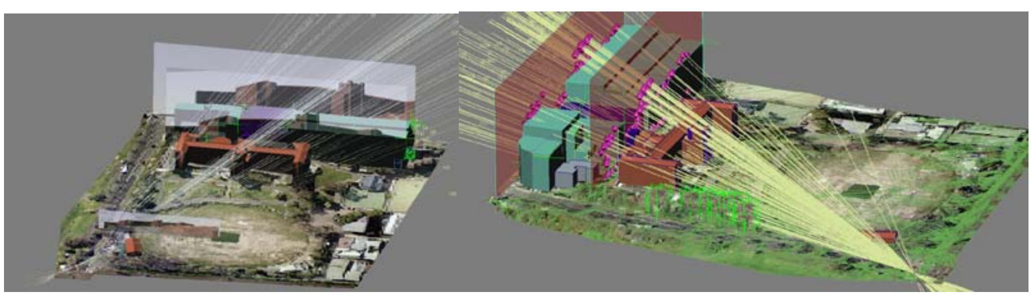


Figure 21 Particle rays projected from camera intersecting with site boundary planes, leaving intersection marks.

5.6.5 Results – speed, accuracy, level of abstraction

The proposed envelope has been presented to the council and has been approved in principle, and is awaiting the results of public consultation. The technique has proven to be a accurate as the digital model and can be tested by checking with independent 3D cameras. The speed with which the particle rays can be applied take just a few minutes, however there is some manual tracing of the shape marked intersections in order to remove the tops of the extruded forms. Future development of the tool would require the automation of this part of the procedure. This technique proves to be useful not only when dealing with sensitive historic design responses, but also offers a great deal of potential for non historical urban gestures, new public buildings, silhouette having a direct relationship with the surrounding urban form.

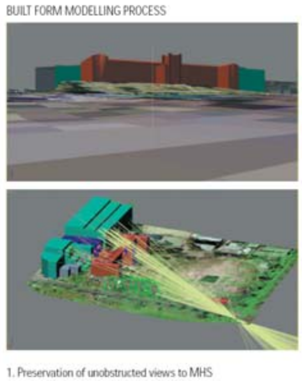


Figure 22 Images included in Chapel Vision Structure Plan report.

5.7 *'Parametric-Picturesque' – Perspectival composition planning*

5.7.1 The planning aspiration

According to the Brundtland Commission (1983), Sustainable Development is: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.[41] This definition is usually accompanied by a Venn-diagram showing *economic, environmental* and *social* sustainability though in reality one of these bubbles ends up being a great deal larger than the others, and the smallest bubble tends to be *social*. Assuming that *cultural* fits within a subset of *social*, it is my opinion that this should be at least as big as the other two if not larger, for culturally baron development leads to demolition and redevelopment, a process that has great financial cost as well as environmental cost. There are endless examples Sullivan's 'form follows function' manifesto being miss read, not understanding that part of the function of a design is and aesthetic and cultural function.

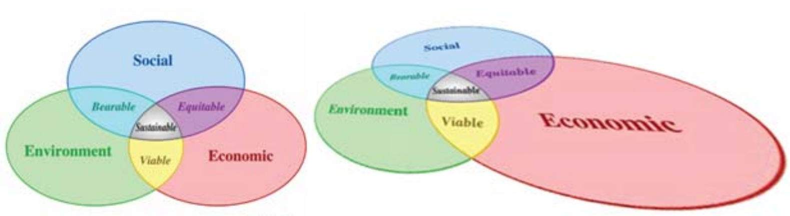


Figure 23, LHS - Commonly used diagram illustrating sustainability (Johann Dreo 2007), RHS distorted version of diagram illustrating what happens in practice.

For a building or urban design to function it must consider aesthetics, and not just in a nostalgic application of period decoration and inclusion of Italian style plazas as suggested by the New-Urbanists, but in a holistic composition. Designs should be rich with contemporary ideas and aesthetics, reflecting society's aspirations and technological advancements 3 dimensionally. This was the case in the 16th century with the technological advancements in understanding perspective which in turn helped shape cities.

> *"in the second half of the 16th century, the urban setting became a collective concern… ….perspective city views in which a great deal of information was combined in a realistic rendering…*
> *…Perspective, the tool used to create these images was subsequently and continuously employed for the rectification of urban settings. The new rectilinear avenues became more frequent and longer, and better emphasised the view of the vanishing point"* (Benevelo 1995)[42]

A prime example of urban design taking into account a city's aspirations and technological achievements is Michelangelo's Campidoglio (1546) which remodelled the Capitoline to reflect Pope Paul III's idea of the new Rome, turning away from the Roman Forum towards the civic centre, the St Peter's Basilica. Here Michelangelo produced one of the earliest examples of anamorphic projection, the paving pattern appearing as a pure ellipse shape whilst viewed in perspective is actually more of a eg shape in plan.

Perspectival composition continued episodically into the Baroque period and then in the late 1700s Picturesque with the likes of Capability Brown and Uvedale Price, who used the perspective view as a compositional tool, which in turn informed there landscape plans. Key moments along a path were chosen as viewing points where one would dismount (from horse) and view the estate.

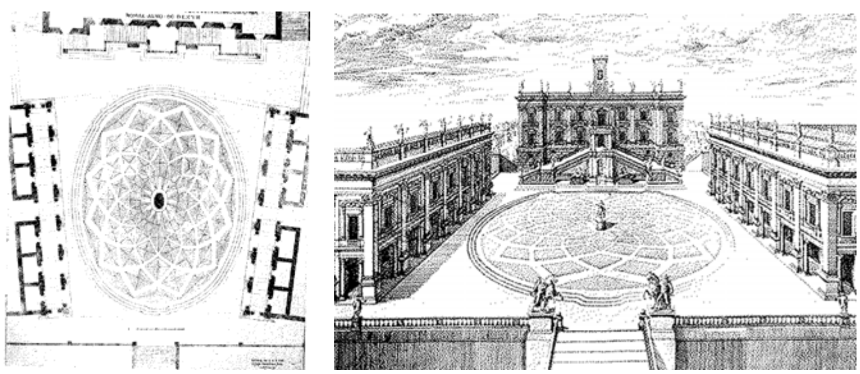


Figure 24 (LHS) Michelangelo plan for the Capitoline Hill (Piazza del Campidoglio) (1567). RHS perspective view showing corrected perspective.

5.7.2 Existing method and their shortcomings

It is likely that there are many reasons that perspective composition in urban design is uncommon today. In addition to not being currently fashionable, vehicular traffic movement is seen as more important, numbers of car parks provided are seen as more important, net letable areas (real-estate yield) are seen as more important. Perspective planning composition was also quite difficult and time consuming to draw by hand. It required drawing perspectives, but then in addition, reversing the

drawing process, where one would normally use the plans projected to the horizon back to the picture plane, the perspective *image* was composed and projected back to the plan; a process that requires a high level of skill and time.
With the increased availability of 3D CAD programs it has become much faster to produce 3D perspective views of buildings, but only in the last 10 years or so have computers had enough power to handle modelling cities. To model cities is still seen as a major undertaking requiring many staff modelling on many computers and a great deal of time. The normal procedure involves a designer coming up with the plans and the modelling team producing the digital model to take perspective views to 'sell' the design, Once the model is built, it is often very slow to change and so the perspective view usually ends up as purely a representation of the plan with additional height data.

5.7.3 The digital tool

The parametric picturesque modelling technique simply involves the utilisation of existing perspective and parametric capabilities of a commonly used animation package 3D Studio Max ™, (or 3D Max). Like most 3D modelling programs it allows multiple view ports so the user can look at the top, side, and perspective 'camera view', but unlike many programs the user is able to alter parameters of the model and see the perspective view update instantaneously – real time. For example the height of a tower can be changed by pulling the hight parameter 'spinner' up and town seeing the tower height update instantly in the view port, or in the Michelangelo's Campidoglio example, the elliptical paving pattern can be stretched at one end until the perfect ellipse is visible in the perspective view port. The program also has associative geometry capabilities where parameters can be shared. Eg. All tower heights are the same, when one height is changed; all the tower heights are changed. Mathematical formulas / functions can also be applied to the parameter relationships, eg the first tower height is the hight of the second tower height squared etc.

5.7.4 Case study

In December 2005 the Melbourne City Council commissioned a study of the Melbourne South Bank to look at development opportunities in the area. Unfortunately the council did not posses a 3D digital model, so an 'existing conditions' model needed to be produced using a cadastral base and surveyed spot levels. The study was also limited to a one week time frame, so the digital model was made, a design and feasibility areas was produced, design feasibility areas were refined, and presentation images produced with in this time. Time constraints dictated that the one digital model needed to be able to fulfil all these roles – feasibility, presentation, co-ordination. Key perspective views were set up within the model, and the buildings within the views were sculpted by adjusting object parameters for those particular views – much like the picturesque. (Price 1810)[43] The added advantage of producing the scheme in this way was that the floor areas of the buildings were also measured as parameters, linked to a table meaning the building massing could be 'sculpted' whilst maintaining site yield.

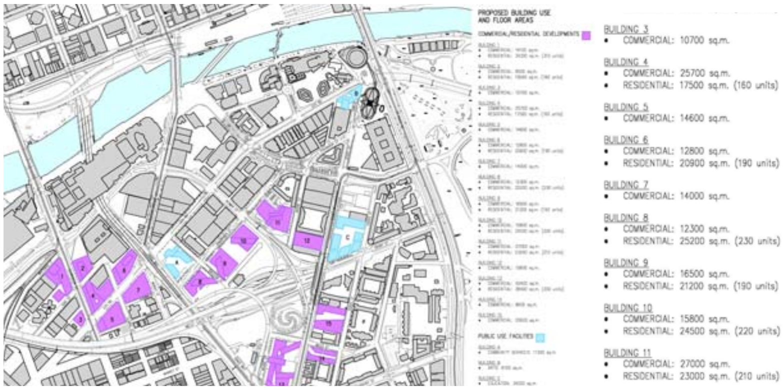


Figure 25 Plan view from digital model showing proposed new buildings and area and residential units and commercial yields.

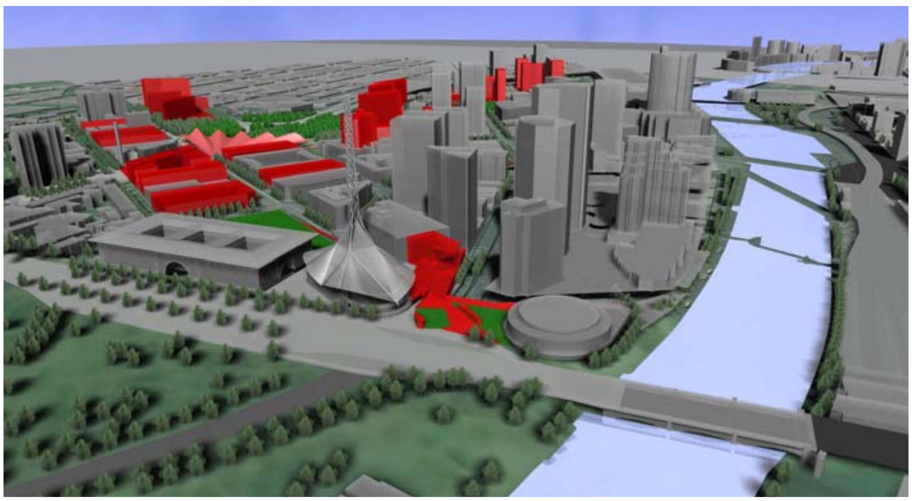


Figure 26 Aerial view of 3D digital model of South-bank Melbourne

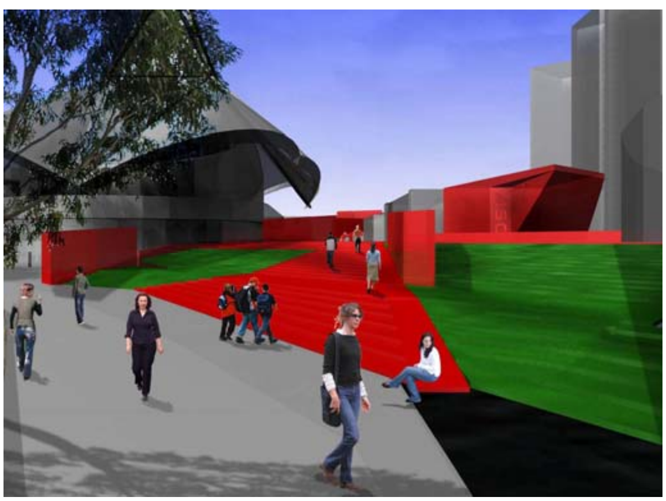


Figure 27. Key composed view employing the 'parametric picturesque' design technique.

5.7.5 Results – speed, accuracy, level of abstraction

The parametric picturesque technique allows the designer to 'sculpt' space with a level of tactility and fluidity that has previously not been possible. Though the discussion on defining beauty is beyond the scope of this paper, and that visual appreciation of composition is extremely subjective and can vary enormously from person to person, it could be said with some certainty that this parametric technique gives any designer regardless of their particular view on urban beauty, a better chance of realising their particular urban aesthetic.

The speed in which one can move around the model can be quite fast and the perspective is as accurate as that of a photo taken with a digital camera. The level of detail in the model is definitely a factor in both speed of model making but also of model viewing, where the higher the level of detail, the more powerful the computer required to view it.

6 Conclusion

This research has been conducted within an architectural office, so has had to work within the day to day constraints of practice. By building upon existing software with user customisation, the tools are not expensive, work within tight time frames, and build upon existing practice knowledge. The tools surpass the level of accuracy of 2D modelling for analysis and design without sacrificing speed and efficiency by finding a balanced level of modelling abstraction. The level of abstraction of a model is adjusted to match the question; there is no point modelling the door knobs on a model testing a city skyline, and there is no point modelling the entire city if you are testing the aesthetics of a door knob. For some of the tools a compromise was made between levels of accuracy and the speed in which the tool could be used. For example the Ped-Catch tool uses programmable 'events' which allow the agents to make decisions like turning left and right, or stoping for traffic lights etc. The level of detailed programmed into these agents is theoretically endless; agents could be programmed to prefer concrete footpaths to asphalt, or prefer to walk on streets with low fences than on streets with high fences, but the amount of time taken to input all of this artificial intelligence, and the computational power required to run the simulation would put the technique outside of the realm of the architect or planner thus making the tool ineffective. Another example is the Subtracto-Sun tool; whilst it is theoretically possible to do a subtraction of each and every second of the day, the time taken to do such an analysis would make the tool unworkable in practice. That level of detail in the model would result in 100% accuracy compared to around 95% of the current settings, a level that some may already see as overkill. So how much detail do we need to put into our models? For architects, the amount of detail needs to be high enough to highlight problem areas and allow comparative studies to be conducted, but low enough to not increase the time and cost dramatically.

These tools are in no way definitive. They illustrate an approach to of how architects might overcome limitations of working in 2D to address contemporary planning issues. Each of the tools can contribute in a small way to decision making with the overall aim of designing sustainable communities. The

Gradiator can help a community decide where to house its aging population in locations that minimise isolation and reliance on cars, Ped-Catch can help make transport, schools, and groceries more accessible by pedestrians. The solar analysis tools can improve daylight access to streets or buildings reducing the need for artificial lighting and making public spaces more comfortable, and the visual compositional tools can help designers provide places that respect the heritage of a community but can also offer new dynamic spaces that have both artistic merit as well as providing for commercial aspects of development. The tools used together can offer more synergistic design solutions those the might occur by out sourcing to specialists.

There are many other tools which should be developed and other valid platforms from which to begin. Future research could include simulating the effects of noise pollution using particle flow on buildings with sound reflective and absorption properties, allowing designers to consider traffic noise and noise from music venues. Particle flows could be used for a simplified computational fluid dynamics to analyse wind speeds and pressures for comparative urban design scenarios. There are many opportunities to further expand the skill set and tools of architects and urban designers, and the industry should be increasing their understanding of what is now possible an pushing the software development in the right direction.

Is the plan an inadequate tool for planning? As my comparisons of the current 2D methods of analysis with 3D and 4D methods has shown, the existing methods are unable to satisfy many of the contemporary planning aspirations. Plans alone are unable to deal with issues of increasing density and population, more complex land uses, environmental consciousness and amenity awareness. The plan is still a useful tool but additional tools are needed which work in four dimensions to create a holistic approach to planning.

> *The pack-donkey meanders along, mediates a little in his scatter-brained and distracted fashion, he zigzags in order to avoid larger stones, or ease the climb, or gain a little shade; he takes the line of least resistance.* [44]

Le Corbusier’s pack-donkey considered space in 3D, assessing topography and obstacles and also considered 4D factors such as solar locations and wind. These desires are not dissimilar to those of *Smart Growth Policies* and *Melbourne 2030*. Le Corbusier dismissed the pack-donkey, thinking that order – the architect’s graphic – was of primary importance. I believe that both Le Corbusier’s and the pack-donkey method of urban design have merit, and it is now possible – and desirable – to have a combination of both techniques. The tools described in this paper begin to provide a 4D-digital-pack-donkey to help compose cities in an artful yet rigorous way, which is socially, economically and environmentally sustainable.

7 Acknowledgement

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