Utilising the Virtual World for Urban Planning and Development

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Key words: 3D Visualisations, city models, K2Vi, urban modelling

SUMMARY

The twenty-first Century has seen the Asia Pacific region undergo rapid growth in its urban environments, and this shows no signs of slowing. Cities in the region are developing with whole district renewal, mega structures, mass transport corridors and significant population increases … often with only rudimentary spatial data upon which to manage the development. This dearth of traditional spatial data has opened the way for utilisation of the Virtual World to plan, visualise, analyse and better manage the planned developments. The Virtual World involves a realistic 3D GIS, which supports master panning scenarios with ePlanning workflows and storytelling The objective of this paper is to describe how virtual urban citymodels are assisting those in the planning process to better understand the development and then communicate outcomes to the various stakeholders. This paper will discuss the process from user needs assessment, data acquisition, visualisation, proposal dissemination and stakeholder input. The pros and cons of the various options at each of these steps will be presented.

Case studies will demonstrate how the Virtual World can assist in many of the specific topics of FIG's Spatial Information Management and Spatial Planning and Development Commissions, including Urban and Landuse Planning, Managing Urbanisation, Spatial Data Infrastructure, 3D/4D Models and Web and Mobile GIS. Recent Case Studies will show how the Virtual World can effectively bring government and society together, by spatially enabling the planning and approval process.

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1. INTRODUCTION

In this Age of Information, the general public is a lot more aware and more demanding of public authorities and their planning role. Planning Authorities must involve a wider range of stakeholders in the consultation phase of a project. Many a meritorious proposal has foundered because the stakeholders have not been able to absorb and appreciate the wealth of information utilised in its formulation. Other proposals have failed because an aesthetic development was not suitably presented and stakeholders not experienced in comprehending 3D data were distracted by the presentation instead of focusing on the merits of the proposal. Even those experienced in the spatial sciences are having difficulty absorbing the diverse range of spatial and textual data existing over complex landforms, particularly when the power of such data is magnified by combining different datasets. Visualising transport corridors with population densities, or combining the current cityscape with planning envelopes provides far more understanding than any one of these datasets alone.

These drivers have lead Planers to adopt a Virtual World in the urban planning and management process. The technology exists to recreate an urban environment to a high degree of accuracy and photorealism which allows all stakeholders to recognise the location and appreciate the proposed visual impact. The visualisations exist to incorporate and present disparate datasets such as planning schemes, population densities or transport corridors over the current landscape. The functionality exists to allow novices to modify building position, orientation, height or even design, and receive instant feedback on the visual impact, shadow effects, line of sight and view shed.

In this paper, a Virtual World is defined as a digital representation of reality. Virtual Worlds are implemented in a variety of complex environments such as cityscapes, mine sites or industrial plants; this paper concentrates on urban cityscapes in the context of Planning and Urban Management.

2. VIRTUAL URBAN CITYMODEL PROCESS

There are a number of critical items which need to be considered before embarking on the creation of an urban citymodel. These include:

- User Needs Assessment: determine, clarify, understand and plan for the requirements of those who will utilize the citymodel;
- data quality: review the User Needs and establish criteria for the data quality to meet those needs;

- data acquisition: assess various data sources against the data quality criteria;
- visualization: decide the required capabilities required to visualize the citymodel
- functionality: decide what the Users need to do with the data;
- maintenance establish processes to maintain the investment in the citymodel and provide ongoing confidence in the uses made of the model;
- proposal dissemination: consider who needs to review proposed developments.

2.1 User Needs Assessment

Urban citymodels serve a wide range of users, so it is important to identify the users and specific needs which a pending project has to satisfy. The User Needs Assessment involves identifying all of the potential users of the citymodel, and understanding their needs and intended functionality. One way of eliciting this information from potential citymodel users is to ask them to describe their potential User Stories: "I am a [user definition] and would like to be able to …"

Once the range of functionality and breath of user profiles is known, it is important to prioritise these needs as it is often unrealistic to design (and afford) an urban citymodel which meets everyone's requirements (and their wishes). This is particularly the case if the urban model is to serve a range of users inside a diverse organization. A useful technique is to rate each requirement as a "Must Have", "Should Have", "Could Have" and "Wont have".

The User Needs Assessment and prioritization / classification of the various User Stories needs to be signed off by the major stakeholders and project sponsors as this will form the definition of a successful urban citymodel project.

2.2 Data Quality

Once agreement has been reached on the required level of functionality, the spatial professional needs to reviewthe options and define the spatial data required to meet those needs. This definition should cover the following characteristics of "Data Quality":

- **Accuracy** – positional quality in absolute terms (important for assessing planning schemes, broadacre viewsheds, interaction with external datasets, etc.);
- **Precision** – positional quality relative to nearby objects (important for localised viewshed analysis, localised shadow analysis, assessment of vehicle clearances etc.);
- **Reliability** – overall quality of source material (important for legal challenges, critical and tight design decisions etc.);
- **Currency** – measure of how well the Virtual World has kept up to date with the ever-changing real world;
- **Completeness** – percentage of model which has been built and textured (often noting

whether all sides of the building are well defined);

- **Reality** – level of photo realism.

Of these six components of Data Quality, the two critical ones are: ***Accuracy*** and ***Reality***. These are the two potentially high cost items, which greatly affect the reliability and functionality of the urban citymodel. These components are generally *additive*: meaning that one spends money on getting the models spatially correct, and then spends more money getting them looking realistic.

Compiling and assessing the User Stories identified during the User Needs Assessment will generally identify the level of spatial accuracy required of the urban dataset.

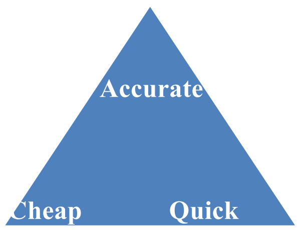
Everybody *wants* higher degrees of Reality, but some users *need* higher degrees of Accuracy.

User Stories dominate with references to court hearings, legal planning decisions, measurement functionality, references to other datasets and other applications where "***it has to be right***".

User Stories dominate with references to visual appeal, aesthetics, public consultation, visual amenity, and other applications where "***it has to look right***".

In the author's experience, projects which require a high degree of accuracy ***and*** a high degree of reality rarely get funded !

The Spatial Professional needs to discuss the six components of Data Quality with the project decision-makersin terms of the triumvirate of cost, quality and time (shown right). Humannature dictates that stakeholders always want their data "quickly, cheaply and accurately". These three components work against each other so the Spatial Professional has to guide the project team to achieve a realistic balance of these three key project aspects.



It is important to receive signoff from major stakeholders and project sponsors for the time-cost-quality balance because that will guide the thresholds of Data Quality.

It is worth noting that most Urban Modelling projects are dynamic and living entities, which may require utilizing existing data and possible updates from disparate sources during themaintenance phases. It is often unlikely that setting a global level of Data Quality will be possible (or desirable) for the life of the urban model, so an overarching Data Quality Policy should be agreed.

2.3 Data Acquisition

2.3.1 Data Sources

The possible data sources for urban citymodels are numerous and growing. The more common sources include:

Pros	**Cons**
Satellite Imagery	
Pros: − Little (or no) site access required − Significant archives available − Often cost efficient − Cloudy areas can be captured without paying standby aircraft charges	**Cons**: − Low resolution (0.5m at best) − poor resolution for capturing façades − archive imagery may be out of date
Aerial Photography	
Pros: − very high resolution available − archives may be available − versatility with bespoke capture − rapid and efficient capture once on site	**Cons:** − ATC & possibly military permits reqd − poor geometry for capturing façades − archive imagery may be out of date − higher startup costs
Oblique Aerial Photography	
Pros: − simultaneous nadir & oblique imagery − defines façade texturesandgeometry − supports crisp vector definition − good definition of upper building parts − access to all sides of every building − rapid and efficient capture once on site	**Cons:** − ATC & possibly military permits − many flightlines for densedefinition − poor definition of lower building parts − higher startup costs
Airborne LiDAR	
Pros: − simultaneous LiDAR and imagery − good definition of upper building parts − access to all sides of every building − rapid and efficient capture once on site	**Cons:** − geometry inferred from point data − building lines confused by data noise − crisp building lines need highdensity − poor definition of lowerbuilding parts − higher startup costs

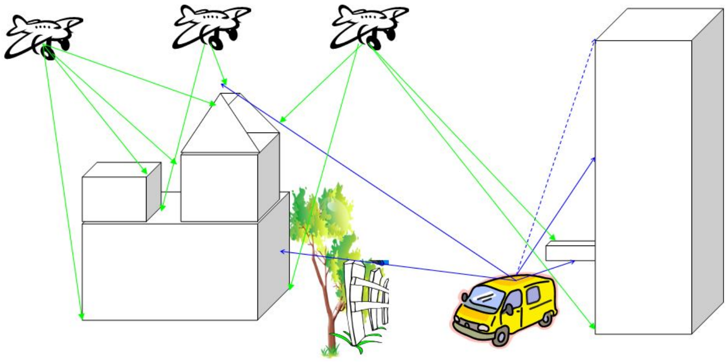
Terrestrial LiDAR **Pros:** − simultaneous LiDAR and imagery − efficient mobile (vehicle) capture − good definition of lowerbuilding parts − high point density available − lower startup costs	**Cons:** − lessaccess to rear side of buildings − may require entering private property − lower accuracy in urban canyons − poor definition of upper building parts − buildings obscured by fences or trees − facades obscured by traffic
Terrestrial Imagery **Pros:** − inexpensive GPS/attitude cameras − skilled labor not required − can access buildings by foot or vehicle − lower startup costs	**Cons:** − provides poor building geometry − less access to rear side of buildings − may require entering private property − buildings obscured by fences or trees
Existing Building footprints **Pros:** − no site access required − low cost − ensure consistency with other data layers	**Cons:** − footprints may have variable accuracy − no shape in the building upper stories − building height required from elsewhere − building texture required from elsewhere
As built Plans **Pros:** − no site access required (for this project) − lower cost	**Cons:** − rarely complete dataset available − often inaccurate building location − building texture required from elsewhere
Design Plans **Pros:** − no site access required − allows proposals to be assessed − good for maintaining existing citymodels	**Cons:** − doesn’t support building existing cities
UAVs **Pros:** − small areas can be updated inexpensively	**Cons:** − Public safety concerns of UAVs in cities − Can become expensive over larger areas

2.3.2 Aerial Versus Terrestrial Cityscape Capture

One of the fundamental issues in designing a data capture program involves striking the balance between airborne and terrestrial data capture. The aerial perspective allows definition of every building, with roof-top elements captured to further increase the realism and precision of the city model. The high resolution images can then be used to texture the ground surface and every building façade to add to the high degree of photorealism. The aerial oblique images provide a high degree of realism, as they reflect what the human eye sees of the city, including sun/shadows, window reflections, advertising hoardings and all of the other visual components which make up a complex cityscape.

While providing a great richness in defining a cityscape, a limitation of aerial capture (imagery or LiDAR) is that the geometry and photorealism of the lower extents of tall buildings may be affected by shadows, building awnings or street vegetation. This can be overcome by capturing and applying street-level imagery and adding photorealism to streetscapes. This process is illustrated below, where the building geometry and shadowed façade constructed from aerial imagery on the left is updated on the right with street-level imagery to further increase the level of overall realism.

Aerial imagery provides the most efficient means of defining the geometry and photo-realistic facades of a cityscape, as it is able to define all sides of the buildings and rooflines. This provides a distinct advantage over street-level capture, as the latter approach is limited to the capture of faces accessible by vehicle or foot. The aerial perspective also supports multiple capture of buildings from many positions, maximising the opportunities for clear sight of the various facades. This is illustrated in the following diagram, including how street level capture can also be limited by verandas, fences, steep observation angles and vegetation.



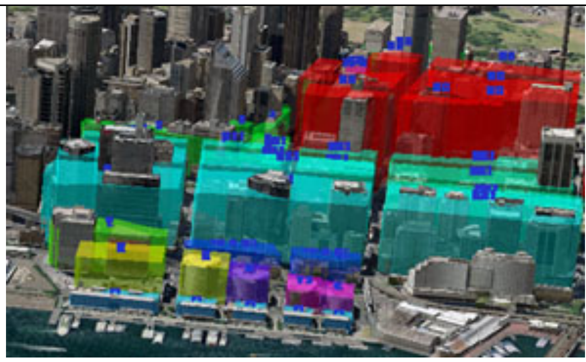
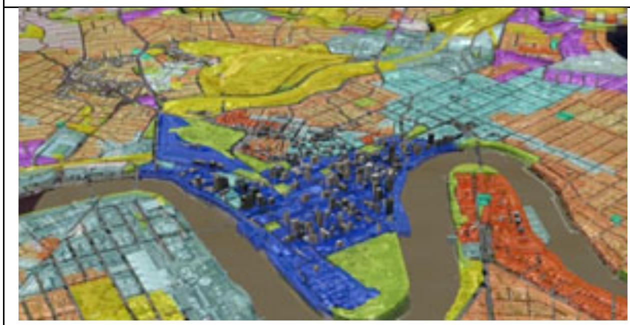
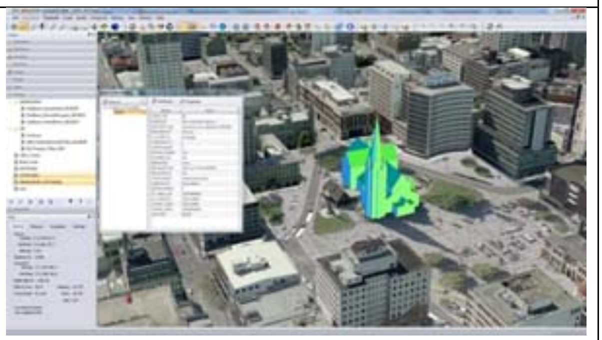
A cityscape is therefore almost always more realistic and complete when captured and textured with an aerial approach (in terms of both geometry and photo-realism), and supplemented with street-level imagery as required. This approach is also supported by commercial considerations of the project … it is more efficient to define the entire city in one aerial survey (which generally has greater startup but lower incremental costs), and then supplemented with street level capture where required (as this generally has lower startup times and costs). Many projects plan to texture the city from the air en masse, and then add streetlevel textures and geometry on a localised basis as and when required.

2.4 Visualisation

One of the key drivers for urban citymodels is to allow stakeholders to visualize a complex environment such as a cityscape. Visualisation often involves adding additional information to the landscape, such as proposed buildings, textual attributes, or conceptual surfaces like planning zones or the cadaster. Modern packages allow these complex items to be visualized and comprehended by spatial professionals, professionals not used to interpreting 3D information, and those from the general public.

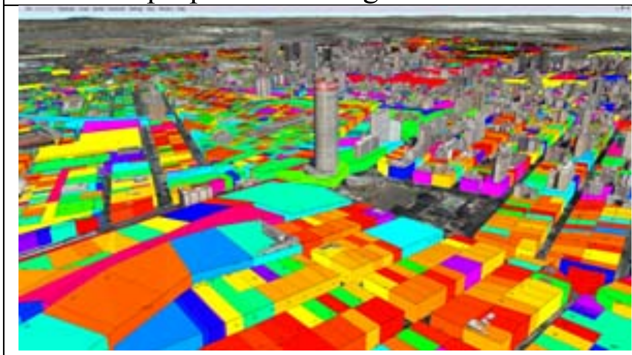
There are numerous packages available, each with their own strengths and weaknesses. The following review of visualisation features utilizes K2Vi software, as that is the one with which the author is most familiar.

The virtual world can be visualized for urban planning and development in the following ways:

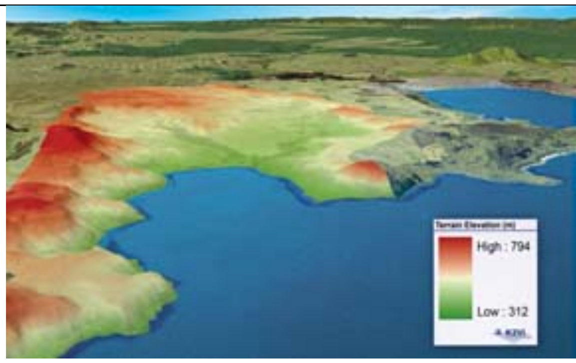
 Viewing on workstation, web or kiosk	 Overlay 3D planning envelopes
 Overlay 2D planning schemes	 Interrogate building attributes from internal or external source (eg. ArcGIS)

Visualize proposed buildings

Add street level photography



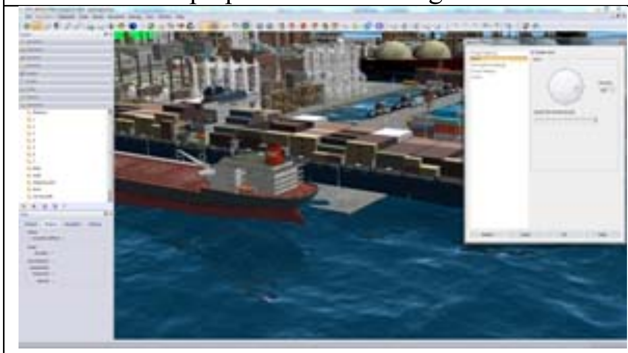
Overlay and visualize cadastral parcels



Consume web services

Turn surface opaque to view underground assets

Add realistic water modelling & reflections



Wave modelling with wind direction & speed

Accurate cloud and light modelling

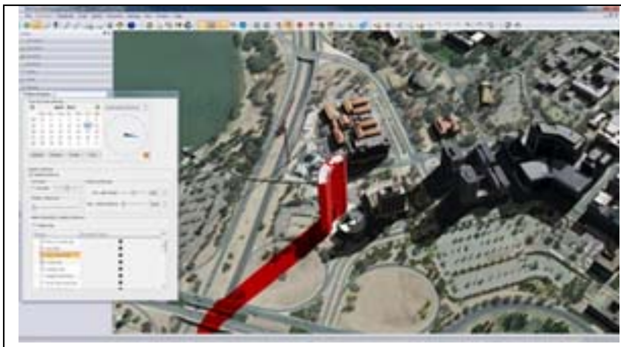
Overlay road markings and animated vehicles

Symbolise assets (trees) from database

Many of the visualisation examples shown above display complex mixes of spatial / textual / 3D data, in a realistic and informative manner. Because of the realistic backdrop over which the information is displayed, stakeholders unskilled in the spatial sciences are easily able to recognize location, heights and consequences of the information being presented.

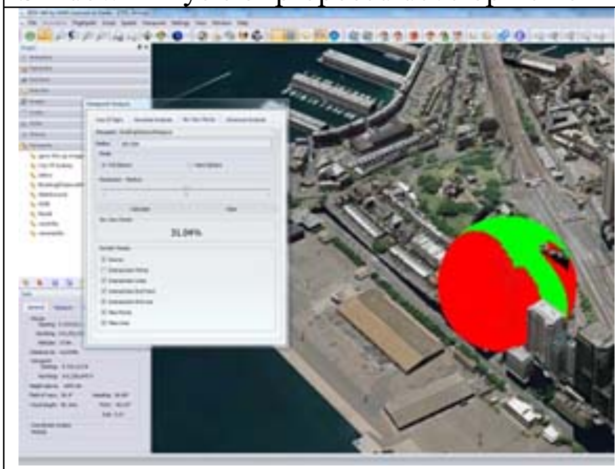
2.5 Functionality

Beyond visualisation, the virtual world can be analysed with specific planning and development functionality in the following ways:

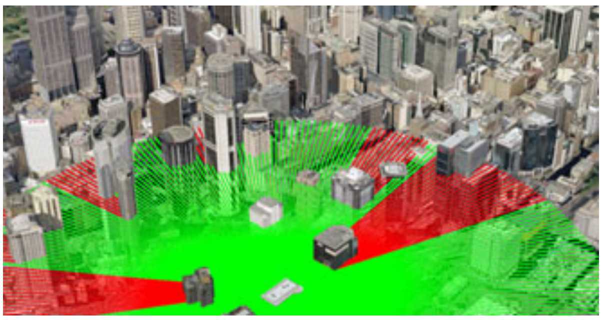


Shadow analysis of proposed developments

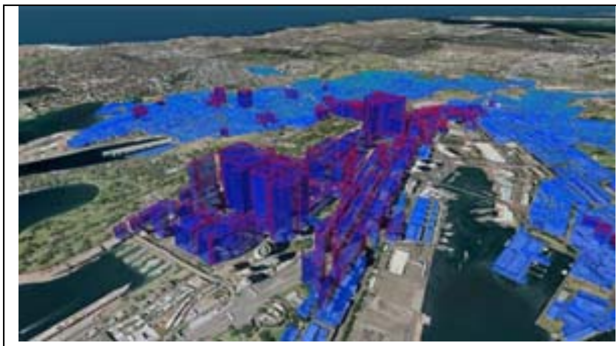
Measurement: linear, areal, slope, aspect



Display sky visibility from nominated point



Conduct line of sight analysis

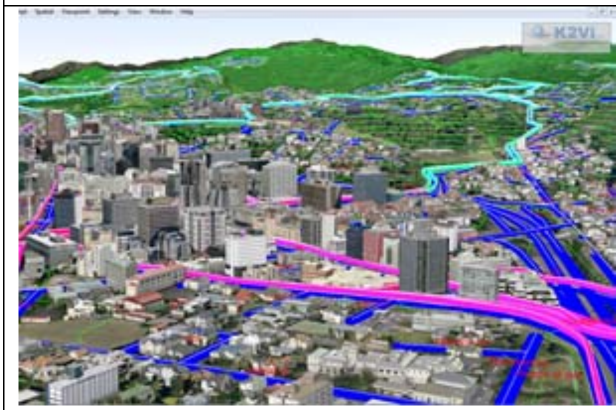


Overlay external statistics, eg. population

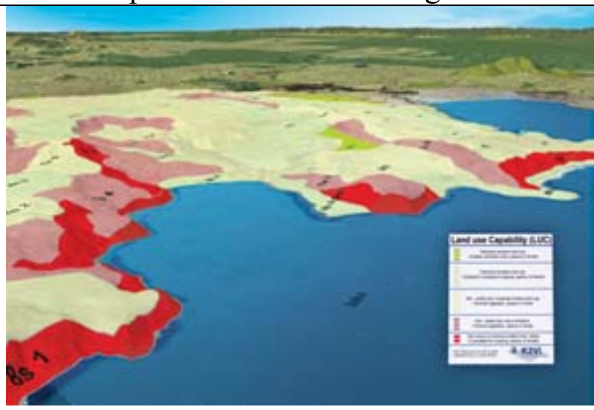
Search models by SQL Query

Visualise water inundation

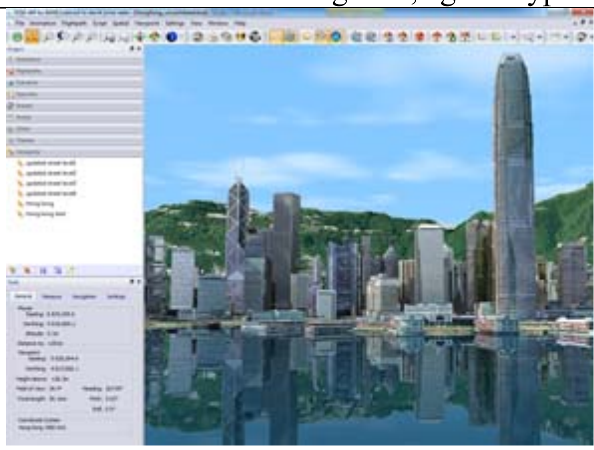
Screen capture and movie making



Interaction with transport corridors



Interaction with land categories, eg soil type



Ability to spatially embed a handheld photo (above left) into the citymodel (above right)

2.6 Maintenance

Creating an urban citymodel is a significant process so it must be accompanied by a viable plan to keep the model up to date. The degree of currency can be decided from requirements gleaned from the User Needs Assessment. There are a number of methods to keep the citymodel up to date. Whilst purists might like to mandate specific processes to maintain the model, it is likely that budget and resource limitations may dictate that a degree of pragmatism exists within the updating program. The author contends that a level of pragmatism is acceptable, as long as the data quality thresholds established at the start of the program are maintained. In other words, the maintenance program should dictate the ***quality*** of new models introduced to the citymodel, and not necessarily the ***methodology***.

Typical maintenance programs to keep an urban citymodel up to date include:

1. **Planning Process** The introduction of the citymodel is accompanied by a mandate that all new planning applications are accompanied by a digital model of the new structure. This allows the planning authorities to assess the impact of the new model upon the current environment, as well as providing the new model to insert into the citymodel.
   Advantages:
   - cost efficiency, as no additional survey is required;
   - reliable, as a rigorous process will avoid updates being missed;
   - current, as prompt processing will keep the citymodel up to date; and
   - neat, as the approved design then resides in the urban model.

   Disadvantages:
   - inconsistency, as models supplied from different proponents will look different to each other and different to models compiled by survey; and
   - low accuracy, as major buildings are often altered during the construction stage.

2. **Specific Update** The Planning Process is used to identify specific changed buildings, and a new model is defined by the most appropriate survey method.
   Advantages:
   - reliable, as a rigorous process will avoid updates being missed;
   - current, as prompt processing will keep the model up to date; and
   - versatile, as various survey methods can be utilized to define the building to agrees data quality standards.

   Disadvantages:
   - individual model updates can become costly as the

number of transactions increases;
- more complex metadata required (to record the currency, source and accuracy of each building);

3. **Complete remap**

   The entire city area is remapped at periodic intervals.
   Advantages:
   - citymodel remains homogeneous as everything is updated by the same methodology at the same time;
   - citymodel can benefit from technology advances each epoch; and
   - no chance of areas of update being missed.

   Disadvantages:
   - more costly, as the whole city is remapped every epoch; and
   - citymodel becomes out of date as time from the last epoch passes.

4. **Partial remap**

   New survey data is acquired over the more dynamic areas of the citymodel regularly (annually?) and visually or automatically inspected for change. This method is usually accompanied by a complete remap undertaken less frequently (5 yearly ?).

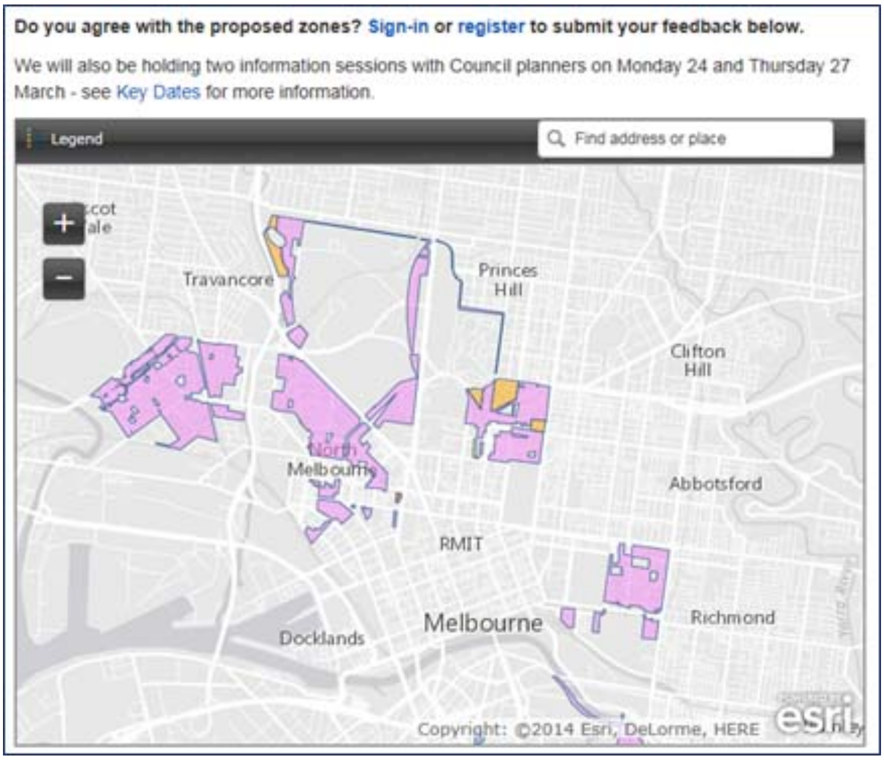
   Advantages:
   - more efficient data capture as resources are not spent gathering data over essentially unchanged areas;
   - change detection routines can assist identifying those models which need updating; and
   - citymodel can benefit from technology advances each epoch.

   Disadvantages:
   - areas not updated need another method;
   - more complex metadata required (to record the currency of each building);
   - individual altered buildings may be missed by the inspection looking for change.

Of course, not all of these methods are mutually exclusive. Method 4 (Partial Remap) can benefit from including Method 1 (Planning Process) to maintain the changes outside of the dynamic areas of change.

2.7 Proposal Dissemination

Once the planning process adopts a virtual world, new possibilities open for proposal dissemination and stakeholder input. The City of Melbourne Planning Department is one such progressive organization which has embraced social media and uses Facebook to help disseminate planning schemes to stakeholders. The City is using its Facebook site to ask:



Ref: http://participate.melbourne.vic.gov.au/new-residential-zones

The visualisation tools described in Section 2.4 above can be used to provide stakeholders (including ratepayers, investors, planners and politicians) with images and videos showing a proposed development on convenient and mobile platforms. Ratepayers could visit the development site, view the proposal in 3D, and register their preferred option using ubiquitous social media tools.

3. CASE STUDIES

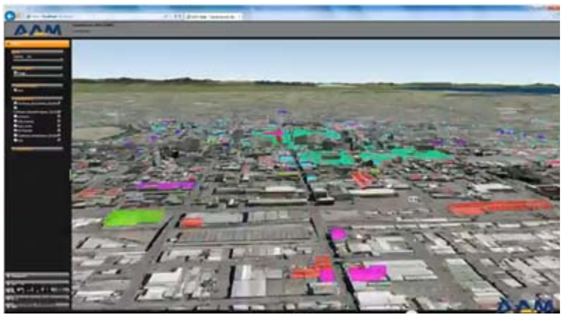
Case studies demonstrate how the Virtual World can assist in many of the specific topics of FIG's Spatial Information Management and Spatial Planning and Development Commissions, including Managing Urbanisation, 3D/4D Models,Urban and Landuse Planning, Spatial Data Infrastructure and Web and Mobile GIS.

The following Case Studies show how the Virtual World can effectively bring government and society together, by spatially enabling the planning and approval process.

3.1 Managing Urbanisation

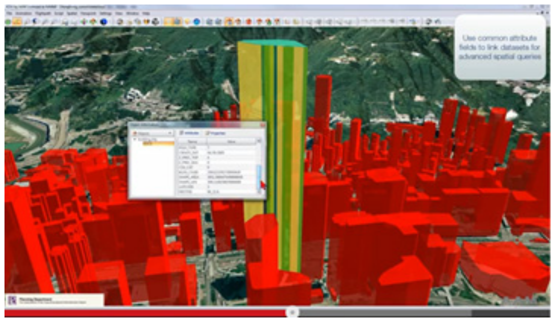
This Case Study involves linking a City Council's ESRI asset database to an urban citymodel with K2Vi software. The assets in the database are displayed in the Virtual World. Deleting the tree, rubbish bin or pole in the database, will remove the asset icon from the visualisation. http://youtu.be/jf3HIZWzBW4

3.2 3D / 4D Models



This Case Study involves visualising 2D and 3D data from before and after the 2011 Christchurch earthquake. It demonstrates accessing large GIS data sources from multiple sources in realtime. The model was deployed on desktop PC, web interface and mobile devices to provide spatial functionality to people in the field.http://youtu.be/0dxpCnIeu5I

3.3 Urban and Landuse Planning



This Case Study demonstrates exporting objects for inclusion in 3D PDFs, performing area-based queries; accessing underlying GIS attributes; open linked planning documents; using attribute fields to link datasets for advanced queries; replacing existing buildings with planned developments; extracting proposals and publishing to web for public consultation http://youtu.be/jWNV2_ysndY

3.4 Spatial Data Infrastructure

This Case Study shows a State Planning Authority visualize centres of activity and planned growth. It describes an interactive planning tool; analyses environmental and visual impact assessment of shadows, rain, haze, wind and light; showcases the links between education centers-to-transport;heavy transport corridors-to-future growth corridors-to-current infrastructure. The Planners conclude that that "seeing is believing, but seeing in 3D is even more believable".http://youtu.be/i9fBlLUqaMs

3.5 Web and Mobile 3D GIS

This Case Study shows how a web interface can view and access the same 3D urban citymodel as appears on the workstation. It shows the building height restrictions overlaid on the current Sydney citymodel. It allows access to Council workers or the General Public to view proposals and share ideas with the planning team. People in the field can view 3D urban citymodel, contours, imagery, vectors, and parametric proposed buildings, underground features.

http://vimeo.com/user12459532/review/49894907/d1ca8263e1

4. Closing

The path to a successful Virtual World is well established, but there are several significant stages along the way. The key principle is one well known to the surveying profession: work from the Whole to the Part. It is vital to start with a whole-of-project overview and an agreed destination so that each component can play an appropriate role in achieving that final result.

This holistic approach will provide guidance and thresholds at the individual steps along the path. This paper has discussed some of the key components of the process:

- uncover and clarify the needs to be met
- design a Virtual World to meet those needs
- define the functionality to utilise the Virtual World
- outline the data to support the functionality
- establish maintenance programs to provide enduring confidence in the Virtual World.

Spatial professionals are well placed to pilot a Virtual World program and ensure that the data, functionality and processes are all coherently addressing the User Needs, With such guidance, a Virtual World will provide a significant boost to the efficiency and effectiveness of all stakeholders involved in the Urban Planning and Management process.

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