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Geographic Data and Systems in Project Planning

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New project management models for productivity improvement in infrastructure

Sustainable Built Environment National Research Centre

Project Partners

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Synopsis

Spatial data is traditionally accessed via GIS systems. Advances in technology now allow GIS and CAD/BIM to be combined. This next generation of tools is capable of capturing more detailed and accurate information to deliver effective geographic analysis.

Local and global standards have followed these advances. Software developers and digital location finding devices need to have protocols to transfer data. Google Earth, Cloud Repositories and E-government websites inform the public of the potential of spatial data. Thus, application and use of the enhanced spatial data is an opportunity for more effective and efficient management of construction projects necessitating ISO global standards.

Building Information Modelling (BIM) is also being incorporated into GIS spatial data systems. Combining the 3D and 2D models provides tools to locate people, places and services within buildings. GIS spatial data images and analysis are further tools illustrating the importance of location for construction.

Two worlds of building and infrastructure modelling involve project-based digital positioning models and land-based coordinate systems. Both are required for designing and managing infrastructure projects. Reconciling these two worlds requires extensive further research.

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www.sbenrc.com.au

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GEOGRAPHIC DATA AND SYSTEMS IN PROJECT PLANNING

This report explores spatial data and its potential in project planning for sustainable construction and management of infrastructure. It explores the meaning of spatial data, and spatial data availability. What is important is the large number of datasets available and the need for the user to select the most suitable source and application. The software available for spatial data processing is discussed with emphasis placed on the movement towards the integration of mainly 2D spatial data with 3D data for building and infrastructure models. Possible applications of spatial data are presented and discussed. Finally a recommendation is made for further work to explore the gap between digital modelling practice and geodata standards and the problem this presents for interoperability in modelling infrastructure.

What is Spatial Data and What is Available?

It is true to say that every object has a location, whether it is on the earth, in the air or underground. Considering just the surface of the earth, every location can be defined in terms of latitude, longitude and height (usually taken with reference to mean sea level or the geoid). The geoid represents the shape of the earth without features such as mountains and is known to be approximately a squashed sphere.

Spatial data can take many forms but recently the Australian and New Zealand Land Information Council (ANZLIC—a body made up of representatives of the States and Territories and the Commonwealth with New Zealand) has proposed ten foundational data themes of national importance forming the Foundational Spatial Data Framework[1] (FSDF):

1. Geocoded Addresses
2. Administrative Boundaries
3. Positioning
4. Place Names
5. Land Parcel and Property
6. Imagery
7. Transport
8. Water
9. Elevation and Depth
10. Land Cover

Each of these data themes is typically made up of a number of datasets. It is worthwhile explaining each of the data themes and providing examples of practical applications with specific reference to Australia.

1. **Geocoded Addresses** attach one or more locations to an address permitting the determination of both the existence and location of an address.
   Example applications: a courier firm would determine if an address existed before sending a package; an emergency service can get the location for navigation.
2. **Administrative Boundaries** include jurisdictional boundaries (national, state, territory, local government, parishes, regions and suburbs), Australian Bureau of Statistics boundaries, Australian electoral boundaries and maritime boundaries.

1 http://www.anzlic.gov.au

Example applications: information about who is responsible for implementing policies; the institution responsible for making the laws in each area.

3. **Positioning** underpins all other spatial data because it provides the coordinates with reference to the Earth. It consists of coordinates and their uncertainty with respect to the Australian Fiducial Network and the Australian Height Datum. Positioning is supported by survey marks, Global Navigation Satellite Systems (GNSS), geodetic modelling (coordinate transformations) and the geoid and bathymetric reference surfaces.
4. **Place Names** are held in the National Gazetteer of Australia which is the conflation of place names provided by the states and territories. A place name is defined as a cultural and physical feature along with the location and extent or area.

   Example applications: navigation; determining cultural sensitivity to proposed development.
5. **Land Parcel and Property** is concerned with the cadastre (a system to identify the location and extent of all rights, restrictions and responsibilities related to land and real property) land administration and property. Datasets cover land and strata information, easements, roads, crossings, rail and water. Example applications: ownership identification; determination of various types of land rights.
6. **Imagery** mainly concerns panchromatic, multispectral and hyperspectral images captured by satellite and airborne sensors. Aerial data is processed to extract defined object information (such as land use) that is registered with the Earth's surface. Resolutions are available from <2.5m pixel spacing for local areas to >80m pixel spacing for the whole of Australia. Low resolution data is regularly acquired (daily) whereas high resolution data is acquired at longer time intervals.

   Example applications: quick manual visual interpretation of land use, road location etc. For construction, an interesting use by local government is the checking of imagery (such as *Nearmap*)[2] for potentially illegal construction work through time-lapse (monthly) property images.
7. **Transport** datasets include: roads, railways, airports, crossings (e.g. tunnels) traffic control devices and navigation aids/ obstacles (transmission lines, buildings, towers etc.). This is a very important theme because of the economic and safety factors of the movement of people and goods. Example applications: commercial delivery navigation; integrated transport planning (along with traffic density information and population predictions).
8. **Water** is a specifically identified dataset because of its importance to life. This is especially true for Australia. The mainland continent is dry and relatively flat meaning water can flow a long way unobstructed. The water dataset covers surface hydrology (rivers, lakes, canals), catchment boundaries, obstructions (dams, weirs), flow direction grids, groundwater boundaries, bores and dependent ecosystems.

   Example applications: predicting the probability of flooding of proposed property developments; monitoring of water resources.
9. **Elevation and Depth** are concerned with the height of the land or depth of water. Data is provided from traditional surveys (discrete points) through to the Shuttle Radar Topography Mission (SRTM). Recently aerial LiDAR (essentially radar using light)

2 Nearmap.com

has been used to acquire much higher accuracy data, concentrating on the Australian coastal fringes. Higher levels of accuracy are important because most Australians are coastal dwellers[3] currently experiencing the negative effects of rising sea levels. Accurate elevation has two definitions. Digital Elevation Model (DEM) is typically taken to be the surface of the earth after vegetation and buildings have been removed. Digital Surface Model (DSM) includes all the surface objects.

Example applications: planning road and rail corridors; extreme weather event recovery.

10. **Land Cover** is concerned with the biophysical coverage of the earth's surface: vegetation, soils, rocky outcrops, water bodies, plantations, crops and the built environment.

    Example applications: monitoring land use (compliance with regulations e.g. land clearance); the effects of bush fires.

The FSDF is a very recent activity with the first draft of the policy released in November 2012. Following revision, the current version was released in April 2014[4]. More information about the FSDF can be found online at the regularly updated ANZLIC website[5].

Many of these datasets are derived from those held by the states and territories. Data pertaining to each state or territory can be obtained directly. For example, Landgate in WA hosts the SLIP portal[6] that allows access to datasets concerning Landgate land administration. The SLIP portal also provides access to location datasets from other WA state agencies. Web sites for NSW[7], Queensland[8] and Victoria[9] also provide portals for state specific data.

Sources of Spatial Data

Australian Government data sources

A variety of spatial datasets are collected and maintained by government agencies for public and private use. However, individual states and territories have different types of cost recovery or user pays pricing policies[10]. For example, Queensland and NSW are promoting a free open data policy online whereas WA has a two tier system; some data is freely available, but other datasets have a pricing mechanism.

Spatial datasets provided by government agencies are traditionally taken to be authoritative. However this is changing with the increasing popularity of commercially available datasets. In Australia, the Public Sector Mapping Agency (PSMA) is a commercial organisation that takes state and territory data and produces national datasets for which there is a commercial

3 http://www.crcsi.com.au/about/history/australian-urban-dem-project/

4 http://www.anzlic.gov.au/__data/assets/pdf_file/0017/47321/FSDF_Booklet_edition_2_web.pdf

5 http://www.anzlic.gov.au

6 https://www2.landgate.wa.gov.au/web/guest/about-slip

7 http://data.nsw.gov.au

8 http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

9 http://www.data.vic.gov.au

10 Kenley, R, Harfield, T & Bedggood, J (in press) Public data re-use policy, but not for road construction procurement documents in Australia.

demand. PSMA commercially available datasets include the road network, the cadastre and administrative boundaries.

The generation of the government datasets are also typically contracted to commercial organisations, and in particular survey companies. Data collection is through a wide variety of technologies; from *Total Stations* (modern theodolites with built in GPS and laser ranging devices) to full 3D static or mobile laser scanners and photogrammetry cameras. For example, state road networks are surveyed with terrestrial laser scanners or mobile laser scanning systems to acquire 3D point clouds. These data are processed to extract the relevant information such as road centrelines, profiles and the location of kerbs[11].

Alternative data sources

The Internet also supports development of crowd sourced datasets[12]. Open Street Map[13] was originally generated as a response to restricted access to Ordnance Survey data in the UK. Open Street Map is becoming accepted by users globally as authoritative, and its credibility arises from the ongoing and transparent capture of experiential data to ensure accuracy.

Data collection technology

Aerial mapping and measurement by Unmanned Aerial Vehicles (UAVs) is becoming increasingly popular. Traditionally, aeroplanes have been used to acquire either imagery or LiDAR data that generated DEMs and DSMs. UAVs, and in particular small lightweight ones, are mainly restricted to aerial photography because of constraints based on Civil Aviation Safety Authority (CASA) restrictions (such as vehicle weight, areas where flying is allowed and payload limits).

What can be regarded as essentially model aeroplanes, helicopters and multi rotor “drones” are proving popular for aerial mapping. Accuracies in the sub-metre range are currently possible. With the advent of modern lightweight (eg. *Faro*) LiDAR scanners, UAV can now also be used[14].

Of increasing prominence is the acquisition of accurate comprehensive 3D data represented as point clouds (a series of discrete points with 3D coordinates that when viewed in a 3D viewer appear as 3D objects) from laser or LiDAR scanning systems. Data collection can be static, aerial or terrestrial-vehicle mounted. Land-based (and even UAV mounted[15]) LiDAR data can be accurate to a few millimetres allowing precise measurements at densities of many hundreds of points per square metre. Apart from visualising the point clouds for human interpretation, interactive and automatic methods are also being developed for:

11 Much of the scanned data is discarded after the necessary information has been extracted.

12 Crowd sourcing is the process of obtaining content by soliciting contributions from a large group of people, and especially from a (generally volunteers) online community.

13 http://www.openstreetmap.org

14 Roca, D, Armesto, J, Lagüela, S & Díaz-Vilariño, L (2014) Lidar-equipped UAV for building information modelling. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* doi:10.5194/isprsarchives-XL-5-523-2014.

15 http://www.sabresurvey.com/sky-pod-s120.html

- Measurement of infrastructure geometry such as road profiles, centre lines and widths.
- Identification and location of street-side assets such as trees, traffic lights, building façades.
- Generation of 3D models of buildings such as BIMs and CAD descriptions, and other structures including roof profiles and shapes.
- Location of power lines, poles and other infrastructure.

These advances are increasing the amount of data and hence information that is available in 3D digital form, superseding the traditional paper based 2D maps. Digital formats are leading to advances in thinking around 3D property models and a 3D cadastre[16] (a system to identify the location and extent of all rights, restrictions and responsibilities related to land and real property).

Real-time datasets

Spatial datasets have, until recently, been static in that they have been acquired at specific times (as and when necessary). Digital technology and the Internet allows for real-time or regularly updated data to be available. Weather data (such as temperature and pressure) is available online for various locations. There is much interest in data acquired from mobile phones as these contain many sensors including those for acceleration, rotation, temperature, sound and importantly location via GPS.

All these datasets form part of the "Internet of Things". This repository is accessible through all electronic devices to upload or download the spatial datasets. For example, construction sites, buildings and the occupants can now be monitored for aspects such as location, health hazards, progress, etc. over the wired and wireless Internet and mobile phone networks.

Spatial Data Standards

A wide variety of spatial datasets are available in different digital formats. Access is via uploading, downloading, ftp requests or, in some cases, via couriered hard drive. The complexity of multiple processes for transferring data between individuals, organisations or institutions has led to the creation of the Open Geospatial Consortium (OGC)[17]. The OGC builds on other standards bodies such as the World Wide Web Consortium (W3C)[18].

The OGC promotes the development and use of standard methods for spatial data collection, processing and transferring. Popular standards include:

- the Web Map Service (WMS) that delivers a map in one of a number of formats including jpeg displaying the required spatial data
- the Web Feature Service (WFS) that delivers vector data (points, lines and polygons).

These services are available using standard world wide web protocols that enables utilisation of the spatial datasets within many software systems when needed.

Of specific relevance to infrastructure is LandXML[19] that describes survey and civil engineering data in XML. LandXML is popular for land development and transport activities and

16 www.icsm.gov.au/cadastre2034/StrategyPrint.pdf

17 http://www.opengeospatial.org

18 http://www.w3.org

19 http://www.landxml.org

has been exploited in 70 software products[20]. LandXML covers such aspects as points, surfaces, parcels, profiles and pipe networks.

Currently, LandXML is being investigated for inclusion as an OGC standard as an alternative to developing a new standard (InfraGML) that is aligned with current OGC and ISO standards and conventions.

A BIM perspective

The dominant standard in Building Information Modelling (BIM) is the BuildingSMART Alliance which has developed Industry Foundation Classes (IFC) for commercial building. BuildingSMART has recently turned its attention to land-based infrastructure, such as roads, railways and bridges, but has discovered that adapting the IFC model to these cases is not simple. Accordingly, a joint BuildingSMART/OGC project commenced in September 2014, to bring together the two worlds of IFC object libraries and OGC standards common Unified Modelling Language (UML).

"The plan, in summary, calls for starting fresh and developing a new candidate standard—the OGC InfraGML Encoding Standard—that provides a use-case driven subset of LandXML functionality, but that is implemented with the OGC Geography Markup Language (GML) and supported by a UML (Unified Modelling Language) conceptual model.

> *"The OGC LandInfra SWG has begun this work, and very importantly, the work is being done jointly with buildingSMART International, the organization that is actively working on a set of Industry Foundation Classes (IFCs) for Building Information Model (BIM) interoperability. Specific cooperation is with the IFC Alignment object library development team"[21].*

Modelling infrastructure

Proprietary support for interoperability in infrastructure modelling remains inadequate for construction needs.

Globally accurate spatial data is increasingly important to the design and management of infrastructure. It might therefore seem obvious that physical infrastructure, such as roads and railways require real world coordinates. Site set-out uses survey tools that comply with OGC and ISO standards but it is not true that design and construction tools equally comply.

Indeed, most design tools utilise an internal project coordinate system that usually requires at minimum translation into real-world coordinates. The physical distortion from a "flat" surface that represents "horizontal" in the real world is poorly handled by infrastructure design tools.

The lack of design tool interoperability, with each other and with OGC and ISO standards, remains a vexed issue in practice. While there are digital modelling protocols to assist with interoperability (such as the open source IFC[22]) the integration of these with infrastructure (IFC Alignment, IFC-Bridge, IFC-Road) remains in early development, with the already developed LandXML being only one aspect of a complex solution.

20 Bansal, VK & Pal, M (2009) Construction schedule review in GIS with a navigable 3D animation of project activities. *International Journal of Project Management* doi:10.1016/j.ijproman.2008.07.004.

21 Guest post by Paul Scarponcini, 02/09/2014 http://www.opengeospatial.org/blog/2098

22 http://www.buildingsmart.org/standards/standards-library-tools-services/

Software Systems of Relevance

Much of the use of spatial data in the past has been in Geographical Information Systems (GIS). These are typically desktop products concerned mainly with 2D spatial datasets including remote sensed imagery, vector data such as administrative boundaries and road networks, and point data such as the locations of points of interest.

Functionality includes visualisation of the data as overlapping layers allowing visual analysis as well as analytical techniques for specific applications. Some examples are: determining travel times, population capture areas for railway station placement, spatial statistics and generation of probability or heat maps to show the effects of pollution.

Commonly used commercial GIS systems are produced by ESRI (ArcGIS), Intergraph, Autodesk, Bentley (Microstation) and Pitney Bowes (Mapinfo). Open source packages of note include GRASS and QGIS. Wikipedia[23] provides a comprehensive and reasonably up to date list.

With the global availability of digital computing, the build environment 2D GIS systems have been upgraded through three mechanisms.

1. In some instances 2D GIS modelling systems have added 3D extensions.
2. A popular vehicle for change has also been through company mergers and takeovers. In other cases 2D GIS has been combined with 3D Computer Aided Design (CAD).
3. In addition CAD systems have morphed into Building Information Modelling (BIM) systems that essentially add more functionality including semantics about the various components (e.g. identification of a pump in the model complete with manufacturer, serial numbers, description etc. attached).

Virtual globes

Visualisation of spatial data has rapidly become publically accessible. Radical digital advances have occurred with the use of "virtual globes". Linking 2D GIS and 3D models means that 3D models of buildings can be geo-located in their environment. This is an important feature of the most popular virtual globe *Google Earth*. Other virtual globes of note are *Worldwind* (NASA)[24], *Bing* (Microsoft), *Caesium*[25], *ArcGlobe* (ESRI), and *Skyline*.

The functionality of virtual globes continues the rapid expansion of ITC capability and capacity[26]. All can display 2D spatial data, 3D objects such as buildings, and the terrain showing hills and valleys. Some can display underground services, the location of the sun and shadows, video (from surveillance cameras), animations and changes over time.

Skyline is a high quality virtual globe that is used by defence organisations for planning (airstrips or helicopter landing pads).

One significant advance made for many of the virtual globes is the way they seamlessly display

23 http://en.wikipedia.org/wiki/List_of_geographic_information_systems_software

24 http://worldwind.arc.nasa.gov/features.html

25 http://cesiumjs.org/

26 Kenley, R, Harfield, T & Vafaei, A (in press) From WBS to COBie: working towards integrated construction management information. The base imagery usually comes from satellites and at the highest resolution would be many terabytes of data (Google maps current holds 20.5 petabytes of satellite, aerial and street level imagery).

However, this amount of data is impossible to hold on a client machine to provide access and downloading visualisation. Even with fast methods to only upload the data required for viewing at one point in time, too much navigation around virtual globes results in excessive downloads onto personal computing systems.

The server-sided approach to obtaining spatial data (as and when required) is becoming the preferred method of organisations and software suppliers. Virtual globes are being adopted by Australian Commonwealth, state and territory governments, for the visualisation and access to their stocks of spatial data.

Google Earth Enterprise (GEE) was first used by the Northern Territory around 2006, followed by Queensland and NSW in 2013. GEE stores spatial data internally for government agencies. LandgateWA went further and stores their spatial data in the Google cloud to guarantee 24/7 access via the Google Map Engine. In 2014 the Commonwealth adopted Caesium WebGL Virtual Globe and Map Engine to display national level datasets such as those held by Geoscience Australia[27].

Apart from visualisation, the virtual globes allow spatial data to be accessed, downloaded and viewed via open source platforms.

Spatial Data Methods

What needs to be emphasised about the software systems described above is that they are very much geared towards manual and interactive use. Although there is much underlying automation (such as access to data, translation from different file formats) most of the interpretation and operation is controlled by an operator who invokes one or more operations or building blocks to satisfy the task and typically builds a map to view.

Simple methods such as buffering (finding distances between features) and logical operations (and, or) are widely used and can be built into process flows that can be stored and used repeatedly. Overlays of various data layers are used to enable correspondences between them to be determined through visual interpretation.

For some operations that are well defined such as route planning, there are automatic methods available in most software systems. In some cases, new operations need to be generated and many systems enable this through programming languages (Python and Visual Basic are the most popular).

Traditionally spatial analysis has followed the “download the data and process on a desktop computer” paradigm. This is changing to be more web-based and server-sided because of the growth of cheap and effective mobile digital devices, increased bandwidth and escalating computing power. This combination allows easy processing for needed data from an array of obtainable datasets.

27 http://nationalmap.nicta.com.au/

Traditional commercial GIS providers, such as ESRI, have expanded their services. ESRI offers server-sided processing plus data storage, along with tablet and phone applications for accessing these services.

Potential Built Environment Applications of Spatial Information

There are many ways spatial data can be used to improve the efficiency of construction. Many applications produced in other disciplines that could be applied for infrastructure projects.

Efficient mass-haul

Many construction projects require the movement of large quantities of earth (Mass Haul). Determining whether or not to go over hills or around them along flatter routes, or a combination of the two is based on many factors. Minimisation of both inputs and outcomes depends on specific project features. Questions always asked are: is it possible to reduce fuel consumption?; how can haul vehicle tyre wear be reduced?; is it possible to limit travel time?; can total mass-haul costs be reduced by realignment?

The availability of DEMs in GIS/CAD systems and appropriate algorithms assists in determining cut to fill mass-haul routes for major linear infrastructure projects. Infrastructure alignment is maintained through a common practice, excavating from a hill and filling in a valley to minimise the movement of earth. In fact there is an algorithm called the "Earth Mover's Distance" first proposed by Gaspard Monge in 1781[28] that can determine how much earth to move, where to move it, what route to take and how much it will cost.

The mass-haul problem can be divided into two parts. The route that the haulage is to follow (route planning) and the optimisation of the individual hauls. The former is potentially a GIS problem while the latter is a earthworks management and optimisation problem[29].

Similarly, route planning has two aspects: construction cost minimisation, and lifecycle user cost minimisation (minimisation of user vehicle fuel costs for example).

Route planning

Route planning is probably the most popular application for spatial data. The road network and address data have been used for different types of vehicle (cars, trucks, ambulances) since the 1980s. Originally the road network data was simply a vector file of lines and junctions with some information on the types of road. The spatial datasets have become more sophisticated and now include:

- Traffic density at different times of the day—much of this is obtained from GPS and mobile phone tracking, and surveillance cameras.
- Road widths, number of lanes (road capacity), location of traffic lights.
- Roadworks and other construction activities reported by various agencies
- Height data allowing the identification of the gradient of each road.
- Location of bridges including weight and size restrictions.

28 http:// http://en.wikipedia.org/wiki/Earth_mover's_distance

29 Kenley, R, Harfield, T & Pirzadeh, P (2012) *Mass-haul Environmental Impact Minimisation: A practical method for greening road procurement*. Industry Report, Project 1.8, Sustainable Built Environment National Research Centre (SBEnrc). Online: www.sbenrc.com.au.

- Location of power lines and other overhead obstructions. Surveying companies are now actively using mobile mapping systems based on cameras and lasers to locate and measure such obstacles.
- Specific information: for example government policies on the movement of hazardous materials; or additional information on locations of urban and other areas.

Given the above information as well as other non-spatial knowledge an expert with one of the desktop GIS systems mentioned in the previous section, can determine a reasonable route for the particular vehicle and materials. However this is not likely to be optimised.

Intergraph use the *I/CAD* solution[30] for ambulance dispatching taking into account some of the above information. *Nokia Here*[31] is singled out as having an automated solution that takes into account all of the above restrictions.

Route planning for construction:

- This involves the movement of heavy plant and materials, sometimes over long distances. Fuel costs need to be minimised
- There is a need to maximise the use of plant. Travel time and distance between jobs needs to be minimised compared with the time spent at work. Knowledge of the location of each construction job along with the road network and restrictions will enable more efficient transport of the plant.
- There is a need to minimise the cost in movement of construction materials.

Construction activity clusters

Having datasets of the location of basic services will assist the linking of maintenance and construction activities across organisations to reduce disruption and improve efficiency. For example services including electricity, gas, water and telecoms provide reports with information about when and where a road will be dug up to access the services.

The coordination of all services construction activates for a specific road means that it only has to be dug up a minimum number of times. In addition, multiple activities in an area should be coordinated so that a minimum number of roads are affected. The integration of the scheduled activities with spatial data including the road network, location of all types of services, will enable more intelligent decisions for construction activities scheduling.

Integration of 2D GIS and 3D CAD/BIM

GIS has until recently, been concerned with 2D data. The integration of 3D CAD and BIM data with 2D GIS allows more sophisticated analysis including planning and scheduling. A recent paper (Porter et al. 2014)[32] outlined methods for security planning in buildings using BIM. This required the extraction of routes through the building allowing optimal paths for intruders to be defined to avoid sensors and various obstacles. The BIM enabled the intruder to decide whether to break through, for example, a wall, door or window using one or more tools. 3D CAD models of buildings combined with 2D GIS have been used to determine evacuation strategies of

30 http://www.intergraph.com/landing/ps-cad9resources.aspx

31 http://here.com

32 Porter, S, Tan, T, Tan, T & West, GAW (2014) Breaking into BIM: Performing static and dynamic security analysis with the aid of BIM. *Automation in Construction* doi:10.1016/j.autcon.2013.12.002.

crowds of people for buildings and pathways to get far from the buildings.

Indoor construction planning

The availability of 3D building models or BIMs in conjunction with 3D and 2D GIS systems has enabled analysis and planning for indoor construction and maintenance. Software such as Invision from Penbay[33] combines GIS with building models to allow the spatial location of people, offices and infrastructure and allows much analysis to be performed such as determining how far each person is from their designated car park, and all the offices for a specific operation in close proximity. Such systems have been used by universities such as Curtin and MIT to identify laboratories associated with different departments and the effect of public transport developments on vibration sensitive laboratories.

Emergency and disaster recovery

Spatial information has great potential for emergency and disaster recovery. One of the most recent examples of this has been the Haitian earthquake that demanded the production of maps to help rescue efforts and to plan future reconstruction. The evidence for the need for spatial data was the success of crowd sourcing to build maps using Ushahidi[34].

Closer to home has been the reconstruction of Christchurch in New Zealand following the earthquake. Traffic route planning is an important part of their recovery effort following the 2010-2011 earth quakes. Disaster recovery is enriched using virtual reality combined with GIS data to provide residents with historical, current and future images of their built environment as reconstruction continues.

The need to determine where to build, what to build and how to plan the reconstruction is making much use of spatial data and leading to novel methods to help. One example is an application that informs people which roads are blocked on a day to day basis allowing residents to plan their routes around the obstructions[35]. Roads are opened and closed on a daily basis, which normally would cause significant disruption without the application.

Visualisation of the 3D environment including the use of virtual reality has been developed so that residents, on their mobile devices, can see where buildings existed and what is planned for the future in their particular location[36]. Laser scanning and imagery have been used to acquire comprehensive information about buildings that will be demolished to keep a record of the city.

Location-based management

Location-based management (LBM) is an emerging methodology for construction management. LBM requires the use of a location-breakdown structure (LBS) as a container for project data. LBM can be used for many project aspects but in particular the planning, scheduling and control of complex projects.

33 http://penbaysolutions.com

34 http://www.ushahidi.com/

35 http://www.cera.govt.nz/

36 http://www.hitlabnz.org/index.php/products/cityviewar

As location is a key aspect of this methodology, locational information becomes critical. For example, in road construction, positioning information is used in modelling, planning mass-haul, monitoring vehicles and loads, measuring and monitoring progress (eg. LiDAR scans for measuring work in progress for progress claims). Currently the connection between digital models and LBM lies through the BIM. However the lack of OGC and ISO standards compliance provides a barrier to integrating survey data into automated management systems.

Other uses for spatial information in the built environment

Position magazine[37] is the only ANZ-wide independent publication for the spatial industries. It contains news, views, and applications stories, as well as coverage of the latest technologies that interest professionals working with spatial information. It is the official magazine of the Surveying and Spatial Sciences Institute.

These activities have been reported in *Position Magazine* recently*:*

- Augmented reality to show where underground services exist replacing "Dial Before You Dig" (*Position* 73).
- Data from aerial scanning of existing sites for infrastructure planning that is more efficient than traditional surveying methods (*Position* 73).
- Monitoring of mine site stability and landform evolution during the rehabilitation stage to inform mine closure plans using 3D laser scanning (*Position* 72).
- Facilitating the building of full 3D models of the real world via the creation of "property rights in the digital environment that can be traded". It is envisaged that trading the rights will create the funds to create and acquire the needed data (*Position* 72).
- Augmenting traditional paper plans with ground penetrating radar, 3D laser scanning and aerial imagery for better facilities management (*Position* 71).
- The use of UAVs for many aspects of mine site planning: matching excavation and dumping equipment to the right locations, vegetation and topsoil monitoring, gas emission monitoring and deformations (*Position* 70).
- Disaster resilience through the development of maps of reliable radio propagation for emergency workers (*Position* 70).
- Nokia Here (*Position* 68).
- The SENSIS Locator national address file that contains addresses, suburbs, post codes and state polygons, transport access points matching the StreetNet transportation database (*Position* 67).
- Mine automation with autonomous vehicles such as drag line excavators relying on spatial data and using vehicle mounted laser scanners to monitor the excavation process (*Position* 66).
- Efficient assessment of the availability of residential and business land in Auckland. Needed to understand zoning regulations for different land types. Spatial analysis needed to identify where construction could occur as infill i.e. between other buildings. Used FME Desktop (*Position* 65).
- 4D flood modelling using 2D grid and 3D particle hydrodynamic simulations using DEMs and other GIS layers with Eonfusion software (*Position* 64).
- Above and below ground road infrastructure design and construction for Brisbane. Planning and construction used 3D models

37 http://www.intermedia.com.au/print/news-item/position-magazine and 2D spatial data using Bentley Microstation (*Position* 63).

- On the fly groundwater resource visualisation from real-time data from 275,000 bores and data concerning mineral springs, aquifer exploitation entitlements and geology layers (*Position* 63).
- Application of the Continuously Operating Reference Stations (CORS) network in mining. CORS will enable 2cm positional accuracy across large portions of Australia by linking geo-referenced land-based stations with GPS and other GNSS satellite systems (*Position* 60).
- CORS system described in detail as of March 2012 (*Position* 57).
- GNSS, other sensors, aerial imagery, and GIS are used in precision agriculture to describe and adapt to in-paddock variability in soil type, moisture and crop yields. Making good use of positional data to 2cm positional accuracy (*Position* 56).
- The problem of unreliable GNSS is overcome by Locata that builds land-based constellations. Advantages include working indoors and overcoming the intentional or unintentional jamming of GNSS signals (*Position* 54).
- Tracking and management of water infrastructure assets using GIS by LinkWater in S.E. Qld. The GIS links the pipe network, customer records and financial data (*Position* 53).
- GIS and spatial data used for the planning of high voltage transmission powerlines, especially underground in cities that is more costly than having the powerlines above ground (*Position* 52).
- Determining the location of a new sewage treatment plant using GIS, spatial data and a number of modelling stages to reduce the number of possible sites from 800 down to nine. Constraints including geology, topography including deep river gorges, and a proximity based ranking method (*Position* 44).

The Way Forward

This paper has discussed spatial data and its relevance to the built environment. There is a wide variety of spatial data available and the various sources of such data have been described for Australia as well as for New Zealand.

Spatial data has been traditionally accessed via GIS systems but this is changing with the integration of GIS and 3D CAD and the availability of visualisation tools such as the many virtual globes. There are many analysis tools available for construction and management (maintenance) of the built environment but many of these need to be manipulated by an experienced GIS/CAD user. This is especially the case when new methods need to be developed.

Significantly, this paper has highlighted the differences between the two worlds of

- building and infrastructure design, represented by project-based digital positioning models, and
- land-based coordinate systems employed by survey and land-based infrastructure projects.

It has been noted that reconciling these two worlds has only recently been attempted. Obviously a great deal of further work is required to support Australian infrastructure clients, contractors and consultants as they construct and maintain Australia's infrastructure.

Future work is now proposed in the SBEnrc Project 2.33 which will explore the relationship between these disparate digital models and their use and interoperability in practice.