UrbanIT Partner Report
An Urban Information Framework to support Planning, Decision-Making & Urban Design

20 August 2010
Executive Summary

The UrbanIT project at UNSW consisted of a 2-year research and development project funded by the Australian Research Council in partnership with City of Sydney, NSW Department of Planning and Landcom. The project has progressed existing and emerging technologies with the aim of helping better inform urban planning by focusing on the sensitive point where an individual building interfaces with its urban context. This approach enables new initiatives to better visualise the city and its processes as transparently and accessibly as possible. The framework extends three key areas to form the foundation of a spatial decision support system for integrated planning:

Building Information Modelling – The UrbanIT framework has extended this technology that traditionally models single sites, to accommodate object-based databases with clusters of buildings across large urban precincts in a geospatial context, thus providing a powerful capacity for modelling the built environment.

Geographic Information Systems – The UrbanIT framework demonstrates the capacity for these systems to provide access to a finer grain of urban knowledge by bringing together information from distributed geospatial data sources, presenting them online and in three-dimensions.

Information Integration by Ontology – Using cutting-edge semantic-web techniques, this approach helps unify otherwise disconnected information at knowledge level and deliver meaningful (semantic) information and knowledge to decision makers and organisations as a whole.

This report presents the background challenges that inspired the research, details the development of the framework and demonstrates the prototype system as applied to Sydney’s Green Square. Having established this functional foundation for urban management, an exciting range of potential applications are now possible, spanning from detailed building analysis and contextual compliance checking, through to urban-scale and multi-stakeholder decision support systems critical for managing the development of our cities into the future.
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¹ http://www.inf.unibz.it/krdb/
² http://www.unibz.it
2. Background

The primary driver for this project was the challenge provided by the essential incompatibility between legacy GIS (geographic information system) datasets and BIM (building information model) representations of the built form. When dealing with urban scale information, GIS technologies use an overlay mapping metaphor to identify features or regions in the urban landscape and attach attribute data to those in order to permit analysis and informed assessment of the urban form. BIM technologies adopt an object-oriented approach to model the full three-dimensional characteristics of built forms in a way that captures both the geometric and physical attributes of the parts that make up a building, as well as the relationships between those parts and the spaces defined by the building fabric. Both approaches are widely recognised as serving well the needs of their respective domains, but there is a widespread belief that we need to reconcile the two disparate approaches to modelling the real world. This project has sought to address that disjunction between modelling approaches.

The following excerpt expresses the initial project aim formulated in late 2006 when the project application was submitted.

“... to demonstrate that a single information framework based on an emerging robust data modelling technology can be exploited to support better decision-making and successful management of metropolitan development in Australia through effective integration of diverse sources of geographic, demographic and planning information.”

The “robust data modelling technology” referred to in this aim is the open IFC standard developed by BuildingSMART for building information modelling, but extended to incorporate urban information. That was reflected in the more specific objective of the project expressed at the same time in these words:

“... to adapt an information modelling technology that is already gaining wide acceptance in the building industry for modelling at the individual building scale and apply that as an urban information model to facilitate coordinated decision-making based on scientific analyses to accomplish sustainable urban planning and management outcomes.”

This objective breaks down in to the three highlighted parts: technology development, application and outcomes. As the project unfolded, it became clear that there are three
information modelling technologies that impact on this project: the extended IFC schema to represent urban information models; the set of OGC-compliant standards for modelling geographic data; and ontology language standards that provide a formal explicit specification of a shared conceptualisation [Gruber 93]. These are all needed to integrate the heterogeneous and autonomous data resources, and to manage the embedded meaning of much of the information required to facilitate decision-making.

The project was formally approved in mid 2007, but did not commence fully until early 2008. We believe that we have delivered on that aim through the development of what has become known as the UrbanIT framework. It focussed on the management of diverse information sources, using Sydney’s Green Square precinct as a study area in collaboration with our major partners: City of Sydney, NSW Department of Planning and Landcom.

Figure 1 serves to illustrate the fact that specialised documents, such as the Local Environment Plan (LEP) illustrated, provide the controls to shape our urban environment. Although the written specifications and 2D diagrammatic maps provide the development controls, greater efficiencies in communication are achieved through the simple act of visualising that information in a 3D form.

Figure 1 - Revealing spatial information using 3D visualisation

This simple concept has led to a solid body of international research and development concerned with city modelling and urban visualisation (Laurini 2002; Kolbe and Gröger 2003;
Pons and Soubra 2008), but in our view that is only the first step towards a far more effective way of managing urban information. Our work is focussed on the embedded information associated with the objects that we visualise in our 3D models and the deeper semantics that is held in the relationships between those objects.

3. Project Overview

The central issue addressed by the UrbanIT project is the development, adoption and implementation of technologies to support the effective management of information to permit better planning, design and operation of the built environment. The most natural way of thinking about and managing discourse on the built environment is to adopt an object-oriented view of the world. In such a discourse, we can talk about the ‘things’ that make up the world in terms of their identity, properties, relationships and behaviours (often referred to in the literature as a “universe of discourse”). We illustrate this using a diagram (Error! Reference source not found.) that shows the scale of ‘things’ ranging from the very precise sub-component level through to the macro/national scale, overlaid by the key information modelling domains that include building information modelling (BIM), geographic information systems (GIS) and facilities management (FM). It is where those domains intersect that is the focus of the UrbanIT project, with effective GIS tools requiring greater access to information from the domain of BIM (down arrow) while effective assessment of designs modelled using BIM rely on an understanding of their context, traditionally the domain of GIS (up arrow). Significantly, FM concerns traverse both those domains, extending to incorporate things at all scales that require maintenance during operation and use.

The UrbanIT project has concentrated, therefore, on the development of a framework for managing information at the precinct and building level through the adoption of an object-
oriented database view coupled with an exploration of how ontology tools can be adopted to facilitate semantic information queries across diverse data sources based on a common urban ontology.

In order to focus the development of the UrbanIT framework, a number of use case scenarios were identified as shown in Figure 3. These data transactions are all concerned with moving information across that intersection between the “BIM world” on the left to the “GIS world” on the right. Today, all are carried out manually, but none with any ease or consistency, and certainly not automatically as is now commonplace in other industry sectors such as finance or large-scale manufacturing.

Figure 3 - Use-case scenarios

To improve the quality of information exchange requires defined data standards and processes that are agreed across the industry sector. In many of the use cases shown in Figure 3, we are seeing moves towards some form of automation. For example, the eDA project is a national ePlanning activity with pilots in all states of Australia implementing a new XML-based protocol for the submission, processing and assessment of Development Application (DA) documents. This is a critical first step towards the automation of that process, but still relies on human-interpreted documents for the approval process. If the DA information for a project proposal were embodied in a complete information model that
can be machine-interpreted within an understood urban context, then much of the routine assessment can be carried out automatically, leaving the human assessment task to deal with anomalies and exceptions. Similarly with BASIX: this is a web-based, best practice, sustainable development assessment tool for residential buildings administered by the Department of Planning, NSW. Assessments are based on an on-line process whereby applicants declare levels of compliance against a series of defined measures. If the user were required to submit a digital building model located within an urban context, then much of the compliance checking could be carried out automatically, removing the routine processes involved and improving the consistency of the assessment. The same principles could apply to each of the use cases, but only if there is a consistent way of exchanging meaningful information across that point of intersection of the BIM and GIS worlds.

Since this research has been conducted in an academic environment with government partners, it aims to maximize public accessibility and longevity of proposed solutions. Wherever possible, this implies the adoption of open standards and less reliance on proprietary systems that impose their own information exchange solutions. This coincides with national and international initiatives in the development of Open Source Software (OSS), open formats and a movement toward open data access. There is a significant role to be played by proprietary software developers in providing tools to support this work, but they must have the capacity to access and interoperate with open approaches so as to better accommodate existing infrastructure and workflows.

The prototype developments undertaken as part of this project have relied on the following international standards, open source software applications and standards-based proprietary systems.

- Use of open standards for information management
  - **ISO/PAS 16739**: IFC (Industry Foundation Classes), developed by buildingSMART and adapted for urban models
  - **OGC/W3C formats used**: COLLADA, GML / CityGML, SVG, KML, SQL, HTML, XML, OWL / SPARQL / GeoSPARQL / EQL (Epistemic Query Language), RDF

3 http://www.w3.org/TR/gov-data/ and; http://www.w3.org/TR/egov-improving/
• Adoption of object-oriented database management systems (OODBMS) and object-relational database management systems (ORDBMS)
  o **Model Server**: Express Data Manager (EDM) by Jotne EPM Technology, Norway.
  o **Databases**: PostgreSQL / PostGIS, MySQL, Oracle

• Use of a mix of open-source and proprietary software tools and applications
  o **Editors/Software**: Protégé, Google Earth, ArchiCAD/Revit, Solibri Model Checker, ArcGIS/uDig/QuantamGIS/GRASS, OBDA plug-in for Protégé, QuOnto reasoner for OBDA
  o **Programming Languages**: JAVA, PHP, and STEP/EXPRESS-G

A key benefit of using the IFC standard for defining the object-based framework is that it is not just another file format (though it is commonly seen and used in that way), but it is in fact an object oriented database schema that enables us to hold complex urban models in an Internet-accessible database form. We have used a proprietary model server technology, Express Data Manager (EDM), which is based on the open IFC standard, to test the development of an urban information model repository.

The geographic information datasets that remain intact and sit within the overall UrbanIT framework are hosted on PostgreSQL, an open-source object-relational database using the PostGIS extensions. This enables accurate geolocation of objects and their associated attributes, web-based access and dynamic topological queries. To mediate among heterogeneous datasets, ontologies form a semantic layer to share concepts and connect the UrbanIT framework user to many autonomous data sources. This is illustrated in Figure 4 and explained in greater detail in the next section.

**4. The UrbanIT Information Framework**

This leads us to the core output of the UrbanIT project. The purpose here is to describe the essential character of the UrbanIT framework, with later sections discussing the prototype implementations of the two key components.

The framework is illustrated in Figure 4 and made of up of the following key components:

• **User Application**. At the heart of this work is any kind of user application that requires access to the vast set of information sources related to urban planning, design and management processes. It may be a Web portal that supports a planning process or an analysis application that draws information from an urban context. As discussed
previously, that data is commonly held in disparate databases, drawing from both the GIS and BIM worlds.

Figure 4 - The UrbanIT framework

- **Urban Datasets.** These are illustrated across the bottom of the diagram and include all kinds of legacy urban data held in GIS databases, census data, customised datasets maintained by particular planning organisations (the Floor Space and Employment Survey data held by the City of Sydney would be a good example), land title data, district boundaries and associated information, and so on. The information contained in these kinds of sources are typically maintained by diverse organisations and government instrumentalities, largely for their own purposes and in formats that are fit for purpose, and not easily integrated. In general, any proposed framework needs to allow these datasets to remain undisturbed, at least in the short term, unless there are compelling reasons to do otherwise. The Open Geospatial Consortium (OGC) has a core mission to facilitate the development of standards to allow interoperability and exchange of data between these types of data sources.
• **Semantic Layer.** A key aspect of the UrbanIT project work has been to explore the possibility of using ontologies to facilitate the exchange of information between these diverse databases, while still maintaining the semantic integrity of the data. We refer to that as the semantic layer that acts as a knowledge filter when managing queries that would interrogate those information sources. This is discussed in detail in a later section.

• **BIM Repositories.** Building information models are increasingly used to facilitate the design and construction of buildings (new and refurbished) and the potential exists for these to be stored in network-accessible database repositories in an open-standard format such as IFC. Although not common practice now, it is envisaged that this could create a very rich source of detailed information about the built environment. Standard database management techniques can provide appropriate security of access to these repositories as well as support controlled transaction level querying of the data.

• **UrBIM Repositories.** Another key contribution of the UrbanIT project has been the development of a proposed extension to the IFC schema for modelling buildings to encompass the concept of a cadastral lot. This seemingly simple extension creates the opportunity to maintain urban-scale object-oriented database repositories that seamlessly incorporate information across the full scale of things defined in Figure 2. One can envisage a repository that encompasses an entire urban precinct, including all the cadastral lots and full information models of the buildings contained within those lots. Though not yet implemented, it is conceptually possible to extend that schema to accommodate urban infrastructure models (roads, bridges, tunnels, etc) as well as urban service networks (water, energy, transport, etc).

• **Information Links.** Arrows used in Figure 4 indicate the possibility to move information from the urban datasets, via the semantic layer, in to the respective information repositories as well as the user application. Since those repositories are object-based and contain explicit representations of the many entities contained or recognised in the real world, it is always possible to embed in to those repositories any descriptive or attribute data associated with those entities and extracted from the urban datasets. There is a danger here of creating data redundancies and clearly, the maintenance of data in the urban datasets remains the responsibility of the respective controlling authority or organisation. For that reason, the UrbanIT framework is careful to protect
and maintain the integrity of those legacy approaches while offering an alternative information management strategy that could be adopted in the future.

- **Project Specific Repository.** One opportunity offered by the urban information model concept is to set up database repositories that are specific to an urban precinct, draw their data as a once-off process from a diverse range of sources and are then used to support a specific design or planning purpose. The sourced data could be refreshed at any time, but the repository would serve as a single integrated database for that project. This is shown dotted in Figure 4 to denote its transient and optional nature.

The UrbanIT framework provides a visionary picture of how urban scale information can be effectively managed by the adoption of a standards-based object view of large-scale urban precincts. The following sections discuss the two key components of this framework in greater detail (first the urban information model and then, data integration through the urban ontology) and then a further section describes some prototype implementations of typical use-case scenarios.

### 5. Urban Information Modelling

A core contribution of the UrbanIT project has been the development and implementation of the concept of an urban information model. As stated previously, this approach is quite different to much existing work that focuses on the development of city models (Laurini 2002; Kolbe and Gröger 2003; Pons and Soubra 2008) where the emphasis is on visualisation of the urban landscape at a variety of levels of detail, with the addition of metadata to add some meaningful content to the entities represented. Those kinds of systems provide very powerful tools for navigating virtual models of cities, for accessing that metadata and even providing visualised links to more complete databases. In Section 0 of this report we illustrate the use of this kind of visualisation technique in a series of data retrieval scenarios, including an example that retrieves a building shape outline from our urban information model.

The primary distinguishing feature of the urban information model (or UrBIM) is that it is based on a robust object-oriented database view in much the same way as the widely-used concept of a building information model (BIM). Figure 5 shows a typical internal view of a
building information model (viewed in a proprietary BIM application) where all objects are represented, including space entities, and very importantly, these are classified into element types that have shared properties (thus providing much deeper semantics). A critical feature of BIM is that the objects have relationships to other objects: here, for example, the stair is associated with storey 0 of the building. It is the ability of an object-based approach to capture very rich semantics that sets it apart from more traditional database structures.

![Figure 5 - Typical internal view of a building information model.](image)

The drivers for the adoption of UrBIM are very similar to those that are driving the adoption of BIM in construction industry. The first is the need for reliable, accurate and
comprehensive information. In the construction sector, poor information leads to inefficient and costly errors and variations on the construction site. In the same way, poor urban information leads to bad policy decisions and mismanagement of public assets in areas such as security, emergency response and transport (to name only a few). The other aspect of information modelling is the opportunity to measure performance across a whole range of metrics with greater accuracy and reliability. This becomes critical when faced with impending climate change and the imperative to develop more sustainable built environments.

The following two sub-sections explain our approach to the development of a robust urban information model, first by a succinct overview of our methodology, and then with an illustrated example of the implementation.

5.1. Proposed Extensions to ISO/PAS 16739 (IFC)

Our approach to the development of an urban information model has been to propose extensions to ISO/PAS 16739, the international standard for modelling building information that is commonly known as IFC (Industry Foundation Classes). Our reason for adopting that approach is primarily our deep commitment to the adoption of open standards to facilitate the exchange of information across the built environment professions, but also because IFC is based on a robust object schema that can be used to construct a web-accessible database able, theoretically, to handle the vast quantity of data needed to model urban-scale information. The database solution comes with well-established protocols for handling data security, integrity, versioning and transaction processing or querying.

Details of the proposed IFC extensions, the rationale and argued case for them, and precise technical details are provided in the document entitled, “A Note on Cadastre” (v4.03, 1 July, 2010) included as Appendix 1. This is an active document that is still before the technical committee of buildingSMART International awaiting final endorsement and hopefully, adoption in the next release of the standard (IFC 2x4). As such, it subject to further refinement as this work proceeds beyond the formal end of the ARC Linkage Project.

The purpose of this section of the report is to pick up key aspects of that proposed urban information model.
What, then, is needed to represent cadastral information?

We maintain that it should be related to the nature of the land itself: ideally, this would be a 3D volume representing the terrain model, to which we attach a boundary, denoting the extent of ownership, and currently represented as a set of 2D points. Those could be 3D points in order to increase the utility of the resulting object by capturing any property to which the owner has legal rights, such as airspace or subterranean holdings.

Therefore, the most appropriate spatial unit is a single cadastral lot or land parcel, being the definitive concept that describes the ownership of land defined by a boundary, typically a 2D bounded polygon mapped to the land surface. This is complemented with its modern counterpart, strata lots. These provide shared ownership of a land parcel by several sub-entities, where each owns shared parts of a parcel at ground level with common access stairs and corridors, plus privately-owned apartments arranged over one or more storeys (Jones, Rowe et al. 1999; Onsrud 2003; Nasruddin and Rahman 2006).

So, already there are a number of concepts:

- **Lot** - a boundary defining the extent of a land parcel, and sometimes accompanied by the location or footprint of one or more buildings on the land
- **Strata lot** - a type of land title, being in addition to the land parcel, represented by a 3D description of the space volumes in the building defining the extent of common and private ownership
- **Space** - a 3D volume where certain activities are carried out
- **Terrain** - the form of the physical land

Cadastral data forms a core of the UrbanIT integration framework. At this stage we omit utilities, but note that an IFC implementation appears straightforward based on the extension of building services systems to the urban context. Any built structure can be represented in IFC, so it is fair to say that at a conceptual level, we can model any urban form, though this needs to be the topic of further research.

It is important to note that this work has been undertaken collaboratively with the Norwegian “Geo-referencing Project” under the auspices of Statsbygg and BE, Norway. In
particular, and as discussed in detail in Appendix 1, we adopted their recommendations for capturing geospatial positioning information in the UrbanIT schema. In essence, we adopt the entity type known as *ifcSite* to represent a cadastral object and locate it within a Cartesian coordinate system relative to a project origin (*ifcProject* being the high-level container for an urban information model made up of a complex set of sites). Associated with each *ifcSite* entity, there are two defined Property Sets: *ifcCoordinateReferenceSystem* that captures the map reference data in a form consistent with the country that hosts the site; and *ifcMapConversion* that allows a local site origin to be accurately positioned relative to the map datum. In that way, a building is positioned relative to a site origin that is in turn positioned relative to a project origin (being the urban precinct represented by the urban information model), and all are positioned geospatially relative to a defined map datum according the a known mapping reference system.

A key concept in the urban information model is the notion of multiple geometric representations of entities. This is strongly supported in the IFC schema and allows us to handle appropriate visual and semantic representations of any entity to suit specific application needs. For example, an *ifcSite* can be represented by a surface terrain object, a 2D polygon that specifies the legal boundary of the land parcel in the traditional manner adopted by the Land Titles Office (or equivalent) or a 3D polyline entity that is mapped to the surface of the terrain and defines the position of the spatial site boundary on the ground, or an aggregation of spatial entities that defines a strata title holding.

Similarly, the *ifcBuilding* entity can be represented at various levels of detail to suit the planning context within which the object is being manipulated. This can range from a 2D building footprint, a simple extrusion of that footprint to denote a building volume, a more complex bounded shape that represents the building form including the roof shape, and an even more complex volume that includes the articulation of the façade and wall openings. These representations correspond roughly to the Levels of Detail (LoDs) as defined in the CityGML schema for city models, providing potential integration with that OGC standard. Of course, within the object hierarchy, a building entity is broken down into all its component parts, so we are only talking here of its geometric representation as a single discreet entity.
The structure of the UrbanIT framework, therefore, matches the real-world analogy of the built environment’s natural spatial hierarchy: cities are composed of clusters of ‘sites’. The sites may contain a building (that must have an owner) or many buildings. A building may have one floor or many, and a floor may have one or many tenancies, or discrete ‘units’. In turn, these units are aggregates of conceptual spaces and zones.

The need to accommodate a growing population in Sydney is propagating denser, multi-unit developments, ideally clustered around existing infrastructure. The Strata Title system in NSW acts as documentation of location and ownership of properties at a sub-cadastral level. Although similar in concept and practice to the conventional 2D cadastral system, Strata tiles have a strong 3D component. Currently, when registering a strata scheme, the applicant must submit a set of 2D drawings defining the floor area, lot numbers and space boundaries. A repository exists of these drawings as scanned pdf files. Not only is this information a two-dimensional representation of a three dimensional system, but the ability for this format to be spatially queried and analysed is compromised. Furthermore, the terminology used in the strata title legislation is not consistent with cadastral terminology. For example, a cadastral lot is the equivalent of a strata scheme’s site, and is referenced in the cadastre by a strata plan number (SP). In the context of strata title administration, a ‘lot’ refers to an individual tenable unit. The existing Cadastral, Strata and Valuer General datasets have no explicit connection. This problem can be addressed by the UrbanIT framework by linking BIM and GIS not only with regard to the spatial mapping, but also semantic linking of like concepts.

5.2. Implementation of the Urban Information Model

The implementation of the urban information model is best explained through a series of screen shots that highlight different aspects of the model.

Figure 6 shows a plan view of the Green Square cadastre derived from Lands Department data and loaded in to a project model on the EPM Model Server. For the purposes of clarity, only land parcels have been included in this model, so the road lots are simply left blank. The hierarchical list in the left pane of the application shows the underlying structure of the server database. Here a single object database can have several repositories (or
“workspaces”), which in turn, can have several project models. In this case, we are looking at a repository called GSPProject that contains a single model called GreenSquarePrecinct (in IFC2x3 format). The model has a single ifcProject (second pane from the left) that consists in this simple model of a long list of ifcSite entities, each named using the LPMA CADid and the Plan Label (starting with DP for deposited plans and SP where the lot has a strata title). The view pane shows a plan view of the entire model. Note that the gaps are a caused by the graphic viewer where small tightly clustered lots (typically row housing) are not displayed at this view scale and actually only appear as you zoom in on the view.

Figure 6 - Plan of the Green Square cadastre viewed in the Model Server Client

Figure 7 shows the data attached to one of the cadastral entities, highlighted in red. In the background window, various tabs show different aspects of the IFC entity. The selected tab shows its property data, including the two geospatial property sets described previously, giving the map conversion coordinates relative to the map datum defined in the second property set called CRS (ifcCoordinateReferenceSystem). The overlaid window shows the ownership of the data that is held in the model. In this case, the data came from the Land and Property Data Authority (LPMA) and was supplied by David Taylor (from their Bathurst
office) and was produced by a small Java application developed by the UrbanIT team that converts DXF cadastral data into IFC format.

In the next diagram (Figure 8, over the page), we have selected a specific site, located in the Green Square town centre and with a rather unusual shape, and placed a couple of sample BIM models on different parts of the site. In this case, the property data shows the two-way relationship between the site that contains three buildings (using the IsDecomposedBy relation) and the backward relationship of the site belonging to its parent project (using the Decomposes relation). These are relationships that are implied, and appropriately captured, by the object hierarchy in the IFC model schema.
Figure 8 - Object relationships in the IFC schema

Figure 9 - Strata Title example
Figure 9 switches to another site within the Green Square precinct where we placed a strata title development that we named the Gadigal Apartments. The BIM was constructed from the strata title plans for that site, so does not accurately model the true building, but does serve this example. It illustrates the ability of the UrbanIT information model structure to represent strata information. The figure shows that on level 8, there are 5 space entities defined where the highlighted one (in red) is all or part of lot 62. Figure 10 then shows how the IFC schema allows for the definition of a zone that consists of a set of disjoint space entities, meaning that we can represent the concept of a strata lot that is made of public and private spaces on different levels of the building (spaces assigned to zones in this way are not duplicated entities, but merely point to the defined space associated with the corresponding storey as in Figure 9.

Figure 10 - Strata Lot 67 - aggregation of disjoint parts

The final screen capture in this sequence (Figure 11 over the page) shows a view of the prototype model with a cluster of buildings near the town centre and Gadigal in the background. Some of the BIMs are quite complete with sun shading devices, handrail details, interior fittings and even door hardware.
Figure 11 - Green Square Precinct (1800 lots, 600 road parcels, 14 models, 9 visible in this view)

This image (Figure 11) was captured from a live demonstration that showed how the data model can be extracted from the urban model server and loaded into another IFC-compatible viewing and auditing tool (known as Solibri Model Checker). This allowed an inspection of the detailed components that make up the model, moving from the large urban scale and moving in to the precise details of individual building elements such as wall materials and fixtures.

6. Data Integration using Ontologies

The base meaning of the word ontology is related to hermeneutics and the way we interpret the meanings of words within the context of a particular worldview. In the context of computer and information sciences, an ontology defines “a set of representational primitives with which to model a domain of knowledge or discourse.” (Gruber 2009)

Ontological research has been one of the key drivers in Web 2.0 development towards what has become known as the Semantic Web (Berners-Lee, Hendler et al. 2001). In essence, when searching the Web for information, we are concerned with the meaning of the concepts so that traditional keyword searching is no longer seen as an effective way of
locating useful information within the amorphous data sets available on the Web. Our project adopts that technology as a way of effectively browsing and retrieving concepts, their properties, relationships, and importantly, geometric/geospatial representation, from the diverse information sources that inform urban planning. There is a growing body of research around the application of ontologies to model and interpret urban information. Our work forms part of that larger international initiative. A key example of that is the UK Ordnance Survey’s GeoSemantics work where a set of ontologies describing the built environment are available for download and development in an open-source environment.

Ontologies are designedly flexible and consequently, can adapt to a particular domain’s knowledge structure to serve a number of purposes. The process of logically ordering and organising this knowledge makes it explicit and easily communicated among different stakeholders. It also provides the bridge between high-level human conceptualisation and low-level physical or logical database schema. Further to this, the expressive capacity of an ontology approaches First Order Logic. Once a framework has been established, inter-relationships, rules and logical rationales can be elaborated to support reasoning, compliance checking and knowledge discovery.

### 6.1. Data integration issue

Urban management involves various stakeholders including urban designers, planners, engineers, politicians, maintenance staff, tenants and, up to and including, the general public. These stakeholders have different interests such as city development, sustainability, emergency management, communications, transportation, entertainment, and so on. Each of these organised endeavours create and store detailed repositories of digital information in various forms. These related data sources are complex, massive, fast updating, and diverse. Our research concludes that ontologies provide the best means of accessing those data sets for those stakeholders through a high level, user-friendly, commonly understood and meaningful description for retrieval, analysing, evaluation and decision support.

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4 [http://www.ordnancesurvey.co.uk/oswebsite/ontology/](http://www.ordnancesurvey.co.uk/oswebsite/ontology/)

An ontology defines a common vocabulary and structure for the various stakeholders who need to share mutual understanding of their domain information. In turn, these machine-interpretable definitions of essential concepts and relationships among them fulfil a great need of human-centred modelling services that are pursued by modern urban planners (Katranuschkov, Gehre et al. 2003).

Figure 12 - The Semantic Web Stack, after Tim Berners-Lee

Figure 12 shows the Semantic Web Stack as proposed by Tim Berners-Lee [Berners_Lee 01]. It represents a layer-based model that takes low-level machine data and ‘humanises’ it toward the higher levels. The ontologies are expressed as an intermediary layer. Within the scope of the UrbanIT project, we have been examining the ability to apply these concepts spatially, with a particular focus on the ontology component - we are able to map the technical elements in our data or low level schema to metadata or higher concepts a person can easily understand or share common understanding about the built environment.
6.2. Data Integration using ontologies

The Ifc Schema lists all the components related to a building from the site level, down to connections, fittings, services and systems. Figure 13 shows a visualisation of the 1138 elements that form Ifc Schema (the yellow dots represent each entity). This illustration not only shows the complexity of the schema, but also reveals the patterns and clustering that organise the schema into a formally structured directed graph. This formal structuring provides a basis not only for building an ontology, but merging this building-oriented domain with other similarly structured schemata.

One such example is the CityGML schema. CityGML is has been adopted as an official standard by the Open Geospatial Consortium (OGC) to describe the elements, relations, uses and three-dimensional characteristics of urban objects. To help present information appropriate to a range of urban scales, the schema defines 5 levels of detail (LoD:0 to LoD:4) where the lowest is suitable for expansive geographic visualisation, and the highest level of detail describes not only the cladding and fenestration of a building, but the interior spaces and corresponding uses of the space. This presents an opportunity to apply the semantic layer to stitch together the similar overlapping concepts and help extend the IFC schema to incorporate city level concepts, while linking the CityGML schema to harness the greater level of detail that IFC offers. As illustrated, Figure 14 extends on Figure 13 by merging the IFC schema with the CityGML schema and visualising the resulting form.

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6 See http://www.caida.org/tools/visualization/walrus/
7 See http://www.citygml.org/
24
Figure 14 - The CityGML Schema combined with the IfcSchema.

By combining these information models, common concepts can be visualised and the clustering patterns and formal hierarchies revealed graphically. All these ‘things’ form an exhaustive taxonomy of the built environment ranging from the urban scale down to that of its components. As such, this verbose list of elements and concepts forms the base level for a ‘bottom-up’ approach. In reference to Figure 14, this union encompasses both the BIM and GIS domains, and consequently should serve as a foundation to attach corresponding nodes and concepts found in other datasets formed about the urban domain.

One such dataset is the City of Sydney’s Floor Space and Employment Survey (FSES), visually represented (in part) in Figure 15. The different colours indicate different space uses; for instance, pink represents covered circulation areas, and green indicates outdoor spaces as extracted from the GIS-based data. These conceptually homogenous spatial clusterings have strong parallel concepts described in the IFC and CityGML schemata. A test of the UrbanIT framework is to map these concepts across these different datasets and schemata. For the purposes of this research, we have focussed on the IFC schema by mapping the existing
concepts to site-specific data and extending its scope beyond that of a single site, to encompass groups of sites (or cadastral lots) that form an urban precinct.

Figure 15 - An excerpt from the Floors Space and Employment Survey

6.3. Application of ontologies

The previous section illustrated a bottom-up approach, however, when dealing with the complexity of urban environments, simplifying and distilling the important elements into a concise, manageable set of entities helps focus and structure the framework in a top-down fashion. When using ontologies to connect the various datasets needed to support urban decision-making with a structured schema such as IFC, we can identify the common concepts across them and map their terms together. In this case, the concepts that were important for our application were simply Sites, Buildings, Storeys, and Spaces.

The schematic ‘IfcBuilding’ can be mapped to the similar concept described in the FSES, listed at ‘Building_2006’. Similarly, ‘IfcSite’ maps directly to ‘Site_2006’ and so on. Once these concepts are connected, we can map out how these elements relate to each other—for instance, “The Building sits on a Site”. This introduced logical relationships into the
framework. The predicate ‘sitsOn’ is explicitly mapped as an object property. Elaborating these relationships increases the reasoning power of the ontology so that it becomes an important decision support tool: it serves as a layer that not only serve a technical role of harmonising datasets, but also assists the end user with intelligence, potentially otherwise undiscovered.

Table 1 - Semantic mapping across government resources and documents concerning the built environment

<table>
<thead>
<tr>
<th>CONCEPT</th>
<th>FLOORSPACE &amp; EMPLOYMENT SURVEY</th>
<th>BASIX</th>
<th>IFC SCHEMA</th>
<th>STRATA</th>
<th>SEPP65</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE(s)</td>
<td>Site_2006</td>
<td>tagcadastre</td>
<td>IfcSite</td>
<td>Address</td>
<td>Context, Streetscape</td>
</tr>
<tr>
<td>BUILDING</td>
<td>Building_2006</td>
<td>building_details</td>
<td>IfcBuilding</td>
<td>Firsthousenum, 'Name'</td>
<td>Built form</td>
</tr>
<tr>
<td>STOREY</td>
<td>Floor_2006</td>
<td>building_details</td>
<td>IfcBuilding</td>
<td>Floor_num</td>
<td>Scale: Bulk, height</td>
</tr>
<tr>
<td></td>
<td></td>
<td>storeys</td>
<td>Storey</td>
<td>(usually NULL)</td>
<td></td>
</tr>
<tr>
<td>SPACE</td>
<td>SpaceUnits_2006</td>
<td>Dwelling details</td>
<td>IfcSpace</td>
<td>Lot_num vs.</td>
<td>Units, Room: Dimension + Shape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IfcZone</td>
<td>unit_num</td>
<td></td>
</tr>
<tr>
<td>PROJECT</td>
<td>Establishment</td>
<td>project_details</td>
<td>IfcProject</td>
<td>Strata Plan (SP)</td>
<td>Process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tag_cadastre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PERSON</td>
<td>Tenant, Surveyor</td>
<td>Accredited</td>
<td>IfcPerson</td>
<td>Owner,</td>
<td>Social Dimensions, Density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assessor</td>
<td>IfcOccupant</td>
<td>Organisation</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 illustrates the common concepts spanning our different data and information sources, such as Site, Building, Storey etc, and lists the corresponding concepts identifying name from each data source. The data presented in the table comprises the following:

- City of Sydney Floor space and Employment Survey (FSES)
- BASIX – The NSW Building Sustainability Index
- Industry Foundation Classes, the Ifc Schema
- The NSW Strata titles database, containing property ownership data at a sub-cadastral level of detail, and
- SEPP65: The NSW State Environmental Planning Policy that specifies the guidelines to maintain and improve design quality of residential developments.

Sometimes there is a direct connection between concepts, as with IFC and FSES, but other times inconsistencies, ambiguities and indirect references are present. This is mainly due to
the fact that different data has been structured and collected in different contexts for different purposes. When the ontological layer spans across all these different sources, it has the capacity to homogenise them in a structured, meaningful way.

The BASIX system is an initiative that sets a series of targets for new developments in NSW to meet regarding a proposed development’s energy and water use. As such, it disaggregates the development into components and relationships, with corresponding targets that must be met to achieve an overall score. Currently, this application process relies on text-based input form an end-user/applicant. Potentially, however, each element can be mapped to its corresponding entity in the IFC schema so that the input required to fulfil a BASIX application can be extracted automatically from a Building Information Model that complies with the IFC schema.

Figure 16 - Using an ontology editor (Protégé) to link similar concepts across datasets

Figure 16 presents a screenshot from the Protégé development environment. It shows how an ontology editor can be used to explicitly map the connection between IfcBuilding from the Ifc schema, and ‘MultiUnitBuilding’ from the BASIX schema.
6.4. High order reasoning for data extraction

Mapping connections in well-structured datasets is relatively straightforward, but the real strength of the semantic techniques we are employing come into play when semi-structured, messy or otherwise disorientated data is being interrogated. Figure 17 illustrates an experimental approach attempting to codify SEPP 65; a (text-based) government policy document that prescribes a set of guidelines to improve the design quality of residential developments. The document deals with objective and quantitative measures, such as the bulk and height of buildings, but also covers the qualitative and sometimes subjective aspects to urban developments. For instance, the policy states that:

“Good design responds and contributes to its context. Context can be defined as the key natural and built features of an area. Responding to context involves identifying the desirable elements of a location’s current character or, in the case of precincts undergoing a transition, the desired future character as stated in planning and design policies. New buildings will thereby contribute to the quality and identity of the area.” State Environmental Planning Policy No 65-Design Quality Of Residential Flat Development - Reg 9

These elements and interrelationships can be documented logically and systematised so that the framework can carry out a process of reasoning and logical testing.
For instance, the building’s context can be deduced as ‘everything but the building, within an area, location or precinct’. It also can encompass time-based concepts such as ‘precincts undergoing a transition’. In this case, the system might highlight a corresponding Development Control Plan that is relevant to the time and place under consideration.

An ontology provides data access by using many different channels for an urban planner. In our context, a channel could be a web interface, a knowledge base, an ontology editor, a knowledge acquisition system or an object oriented/relational database, which are all from various partners. For an end-user (e.g. an urban planner, decision maker or an urban information modeller), there is no need to be concerned about which channels are employed and what the connection is to each channel. Real-time, automatic processing and reasoning is handled transparently, so that the application acts as a one-stop experience to provide as much information as the user requires, through a service-oriented approach.

This facility can be extended to an inter-organisational scale, to better provide support specific to advanced metropolitan strategic planning, helping domain experts focus on modelling supported by semantically rich formalism. This serves to enhance inter-connectivity by fostering horizontal connections through open, unified and user-defined conceptual views.

6.5. Implementation Technologies

These ideas were tested using a series of technologies as explained in the following paragraphs.

OBDA

OBDA has been defined as an area of research in which the goal is to provide access to data in heterogeneous data sources through a semantic layer formed by ontology (Calvanese et al, 2009, DIG-OBDA, 2010). The main contribution of this research is to provide end-to-end (from end-user to data) system to build the semantic layer for integration, to classify and reason by an OBDA-enabled reasoner and retrieve data through a mapping process which associates the data and the semantic layer. Another added value of OBDA, which applies particularly to the domain of urban planning, is that constraints expressed by the ontology allow users to overcome incompleteness that is present in the complex and fluid data
captured from urban processes. The OBDA plugin for the Protégé is developed by the research group known as ‘Knowledge Representation meets Databases’ (KRDB) at the Free University of Bozen Bolzano in Italy.

The OBDA plugin provides:

- complete views on data sources in many relational database formats;
- a mapping, editing and testing environment which helps connect data sources and ontology entities;
- classification and reasoning built-into and evaluated at the mapping phase;
- SPARQL (Protocol and RDF Query Language) or EQL (Epistemic Query Language) queries reasoned by OBDA-enabled reasoners.

Furthermore, important features of this approach are that:

- OBDA assists users perform logical inference rather than query evaluation, like SQL in CWA (Closed World Assumption), which is computationally easy;
- Constraints posed from the ontology are considered at runtime;
- Database-like queries e.g. SPARQL, and the more advanced EQL, can be answered;
- Multiple information sources are targeted, which is a recurrent data integration issue.

**QuOnto**

QuOnto is a reasoner designed to support an OBDA-enabled ontology. QuOnto is able to use a Relational Database Management System (RDBMS) (extended to XML very soon) as an Abox repository as mapping between RDBMS and Ontology techniques is supported by DL-Lite_a (Poggi et al. 2008).

**Architecture**

The structure of an OBDA system is as it is described at DIG-OBDA (2010) but it does not show how SPARQL (on ontology only) or EQL (SQL + SPARQL) or SPARQL (through semantic mapping) works. Figure 18 presents a suggested architecture of an application driven by Protégé and OBDA or/and QuOnto.
Our query answering processes could be illustrated as those in Figure 19. Tbox refers to the terminological axioms expressed in ontology’s classes and properties. Abox refers to property assertions, so the instances of classes are represented by data in databases belonging to the ABox.
7. Use Case Scenarios

Green Square is a precinct earmarked for extensive urban renewal. The site is of interest to each of our government partners and presents an opportunity to test the systems developed during this research and apply them in a real-world context. Four use-case scenarios were developed to refine the functional requirements of the process. This phase involves identifying who the key stakeholders and actors (users) are and who are some rudimentary tasks that these people would be undertaking.

The scenarios depended on several preconditions:

- The models were to be database generated;
- Building data was generated in the BIM environment needed to have geographic coordinates compliant with the Map Grid of Australia;
- Geographic information was required at a sub-cadastral level and registered in three dimensions. For the purposes of these trials, the spatial accuracy of the coordinates was out of scope.

The first scenario is where a designer is seeking information to support a DA submission. Be able to deliver three dimensional, information-rich site data to the applicant in return for a 3D model of the building – this can be used for compliance checking and lodgement into a larger city model. Once this workflow has been established, a data visualisation and informational analysis scenario was undertaken.

The digitisation of this process allows online scenario testing and compliance checking in preplanning for Development Applications. There needed to be a two-way interoperability between the BIM environment and the GIS environment. The DXF2IFC application (Appendix 1) was developed to parse cadastral data in to IFC format so that it could be imported into the BIM server, likewise the BIM server had to output an LoD:1 (extruded footprint) that was positioned within the selected lot with the correct scale and orientation.

This overall, low-detail view of the focus area immediately helps orientate the user who might be interested in lodging an application to develop a site. In conjunction with the interactive 3D environment, links are provided to traditionally non-spatial documents such as the local development Control Plan (DCP). A typical such view is illustrated in Figure 20.
Figure 20 - A view of Green Square using Google Earth, illustrating the bringing together of several sources from GIS environments

Figure 20 shows the following themes:

- The Green Square administrative boundary in red;
- The existing building massing dynamically retrieved from the database in LoD:1 (extruded footprints);
- The colour coded maximum height envelopes extracted from the DCP.

7.1. Site context retrieval

The FSES repository provided the GIS site context data. The data was stored in a PostgreSQL/PostGIS database and accessed via a secure web interface. The only compulsory input requested from the user was to identify a single cadastral lot via a web form. The query was then processed via PHP to return a KML-based 3D model of the focus site and its notated contextual information.

Figure 21 shows a randomly selected site that an authorised user has retrieved. The immediate site context is shown colour-coded to use, and the adjoining sites and roads have
been dynamically identified. The user has the option to download a specifically generated KML file for use on a local machine and as a record of the transaction.

**7.2. Context Analysis**

Figure 22 shows the site selected by the user surrounded by its immediate context. This data is useful for generating shadow patterns, identifying attributes of neighbouring sites, such as space use types, operating hours etc and performing qualitative visual analysis of the building within its environment. This also serves a technical role, allowing the applicant to geospatially locate their building within the cadastral lot at the application stage. The ultimate aim of providing this context data is to support the user in making better-informed decisions and sharing information between applicants, council and other authorities, permitting a higher quality of dialogue. In this, a two-way information flow is facilitated, whereby the applicant is
provided with a three-dimensional site model and in return, the consent authority receives the development application directly from the applicant in digital form. This initiates a process of sub-cadastral spatial information development and collection at the early phases of the developments life cycle. Establishing this information foundation facilitates efficiencies by reducing duplications in information gathering and permitting greater depth of analysis throughout the life of the building, as illustrated in the next section.

7.3. Visualising as-built performance

This scenario explores different ways of visualising the performance of a development, supported by a BIM and other data drawn from diverse sources—this instance we are testing how a user might view financial information about the transactions of buildings within a development extracted from the Valuer General data source and environmental sustainability information extracted from the BASIX data in relation to energy consumption.

It is important to note that for reasons of confidentiality, we have removed spatial and personal identifiers and substituted the real data with plausible values held in the same form as might be available in existing data sources.

Figure 23 is an example of a more advanced query a professional user might access. It shows an indicative range of values that the respective apartments in the building could have been traded at, with blue as the lower prices and red as the higher.

Figure 24 shows how energy use data might be retrieved and visualised from the BASIX database. The cooler colours (blue and green) reflect places that have energy efficient Air-conditioners fitted, while the red spaces are less energy efficient.
Figure 24 - Query result illustrating possible energy ratings of air-conditioners

7.4. Visualising an Application in Context

Figure 25 - BIM, GIS and planning information in one environment.
In this scenario, a full BIM has been submitted (uploaded) to the urban information model server, and retrieved via a query extracting the model as an LoD:1 representation of the building envelope (essentially, the footprint and height of the building). Once extracted from the server, the model is merged with contextual data from other sources and visualised using Google Earth (Figure 25).

In this case, the aim was to provide preliminary spatial information to assist in the review of development applications. Note the complete BIM modelling actually goes beyond the LoD:4 representation, as seen in Figure 26. The purpose of the demonstration is to view differing levels of detail appropriate for each purpose. The surrounding (BIM) buildings have been purpose built to demonstrate a range of different typologies, all housed in the BIM server with their corresponding cadastral parcels. The potential for expanding this model into finer sub-building analysis or broader urban-scale analysis is inherent.

8. Compliance checking & model auditing

In this section, we look briefly at the potential of the urban information model, housed on a Web-accessible model server, to be used to carry out compliance checking of an uploaded building model. For this proof of concept, we undertook an exhaustive analysis of BASIX, an on-line sustainability assessment tool developed by the NSW Department of Planning, to identify what information would need to be held within an information model in order to support automatic compliance checking. At present, BASIX compliance is managed by having end users work through a series of on-line questions, leading to an assessment based on the answers selected. In our scenario, an end user would upload a fully modelled BIM (that contains sufficient information to support a compliance check) to its proper cadastral site within the urban information model database and then work through a set of report
modules that examine the proposed development to check whether the required information is in the model and report the results.

The first step in this work was to write a comprehensive mapping specification to identify which IFC entities, attributes and properties are required in the model in order to complete a BASIX analysis. That document is entitled, “IFC Mapping: BASIX Submission” (Version 2.1, 18 June 2010) and is included as Appendix 2 to this report.

Figure 27 shows the model server interface with a project containing one site plus a small residential building and a backyard pool. The partial expansion of the model tree shows the range of entities defined in this model, with each storey having a *BuildingStoreyContainer* with all the building fabric elements listed, plus space entities associated with that floor. Note that the site entity has a street address associated with it, which is one of the standard attributes of the *ifcSite* entity.

Figure 27 - Model Server with the Pollina Residence loaded for a BASIX assessment

One of the built-in capabilities of the EPM Model Server client application is an IDM (Information Delivery Manual) tool that allows us to set up a hierarchical set of process steps that check a selected model and reports specific information found. Figure 28 shows a
structured set of reports that address all the compliance issues identified by BASIX under the four headings of project details, water, thermal comfort and energy.

The next sequence of screen shots shows a few simple examples of what these reports would look like, using the Pollina Residence model as a case study. We have made no attempt to implement the entire set of reports: although the analysis in Appendix 2 is exhaustive, these examples are for proof of concept only.

The first example (Figure 29) simply reports the site address held in ifcSite entity. Note that the address is reported as a single string constructed from the data elements contained in the model.
The second example (Figure 30) shows the project type (using the BASIX nomenclature), which in this case, would be mapped to a building type property held in a property set associated with the ifcBuilding entity. This is an example where the standard IFC schema does not have a building type property suitable for the purposes of a BASIX compliance check, but it can be easily accommodated by a specialised property set definition.

Figure 30 - BASIX Compliance Check - Project (Building) Type

The next sequence of screenshots on the following pages show two further examples.

Figure 31 shows a simple report that would allow BASIX to determine the number of occupants that can be accommodated in the dwelling. BASIX does this by counting the number of bedrooms, so this report simply counts the number of rooms that are identified by their names to be bedrooms. In this example, there is only one.

In a slightly more complex example, Figure 32 shows that the materiality and construction of wall entities can be reported from the model, while Figure 33 (page 43) shows an example of a full wall materials report from a building project.
Figure 31 - BASIX Compliance Check - Bedroom Count

Figure 32 - BASIX Compliance Check - Wall Materials and Construction

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9. Conclusion

We break the conclusion up in to a number of sub-sections addressing first some key considerations that need to be addressed as this work moves forward. We then summarise the key technological innovations in the work, the benefits that we see in adopting the UrbanIT framework and directions for further research and development.

9.1. Key considerations

The sustainable management of detailed (yet expansive) city models in the long-term presents a series of very challenging considerations, spanning from system design and logistics, through to issues of urban ethics and public policy. As stated at the beginning of this report, a pragmatic challenge is how to manage, both technically and operationally, such a large range of scales related to the urban environment. Issues surrounding this include data custodianship, accountability and quality control. Further, if the city model is seen as a simulacrum for the urban environment, the number of stakeholders extends to every person who has an interest in that environment. This raises issues of publicity, privacy, accessibility and security. Finally, how does this system support these stakeholders
in a manner that is appropriate and meaningful for a specific task? This raises issues of semantics, fitness-for-purpose, and overall governance so that a system facilitates freedom whilst ensuring stakeholders’ actions are in the broader civic interest. These issues extend from those challenges faced on the broader Internet, with the extra complexities of the spatial dimension.

In this section, we address briefly three considerations that are related to the above concerns: levels of detail; levels of security; and levels of spatial and temporal accuracy.

The CityGML concept of multiple levels of detail offers two advantages: at a technical level, it is used to manage the amount of information being processed by the computer; while from a user perspective, it permits the broader areas to be considered in low detail, and as the focus of the users attention narrows, more detail is revealed. This structure is part of the CityGML schema and transparently encoded at the data creation stage. In our object database-driven information model, any object can have multiple geometric representations that are fit for purpose to allow the visual reporting of information to be appropriate to the needs of the user. This is further enhanced by the notion of user views, whereby any information transaction with the urban information model can be constrained to a specific sub-set of the full information available. In the IFC standard, this is described by an information delivery manual (IDM) that prescribes a very precise information sub-schema to identify the specific information required to suit a specific purpose.

Following from the concept of having multiple levels of detail appropriate for different users and tasks, the issues surrounding security and accuracy can similarly be structured to define what data is in the public realm, and should be completely open and accessible, or what data is private and should be highly secure. Embedding this index into metadata, or individual objects could unambiguously define the controls over data release, and furthermore give custodian/stakeholders a degree of control over their spatial data. Again, the tools to manage security are fully embedded in the urban information model through the ifcOwnerHistory concept that maintains ownership of data at the object level to facilitate information integrity, while normal database access protocols are available to manage security of information.
A similar spectrum exists with the level of accuracy attained in a dataset. In professional circles, verified high quality data is a necessity, however with greater access to user generated spatial data, the level of accuracy of these sources is not registered or verified. This data is still appropriate for broad visualisation and place markers, however in the context of decision making within the built environment, custodianship and accountability to verify the quality of data is critical. This includes the preservation of Spatial Coordinate Systems (geospatial and 3rd Dimension), metadata, date of creation and relevant time spans (ANZLIC).

All of the above metrics can be collected at the time of data creation and add to the capacity for spatial urban data to appropriately inform and support stakeholders so they can perform tasks effectively. The demonstrated interoperability between the LandXML format and the SIX Portal is a good example of a structured data creation process appropriate for cadastral surveys.

9.2. Key technological innovations

At the time of writing, we are still waiting for formal endorsement by buildingSMART International of the IFC extensions proposed for handling cadastral data. The next ITM (International Technical Meeting) is scheduled for September 2010 in Copenhagen, Denmark. The technical note has been circulated widely (receiving generally quite positive support) and is on the agenda for that meeting. If endorsed (in either its present or modified form), then that will represent a significant technical innovation as it will open the way for wide, international adoption of the urban information modelling approach developed as part of this UrbanIT project. The opportunities afforded by that work have been discussed in earlier sections.

Other key technical features of this work include:

- The UrbanIT project fully endorses and relies upon the use of open standard formats for the management of all information;
- Software developed to support this work is generally open-source, dealing with protocols to access database repositories of information;
• The UrbanIT framework is database-driven and web-delivered, making it openly available subject to all the normal controls and protocols around transaction processing, data security and integrity, privacy limitations and user management;
• The UrbanIT approach supports dynamic management of datasets, embedded semantic richness at all levels of detail and the ability to manage full range of (geo)spatial information;
• All prototype implementations demonstrate live access to multiple datasets to answer typical use-case queries;
• The work is genuinely breaking new ground in opening up fresh ways to access complex geospatial information, giving it a significant level of national & international originality.

9.3. Identified benefits

There are many potential benefits that could be derived from the adoption of the UrbanIT framework and associated technologies. In this section we identify four key ways that this innovation could be exploited within the domain of urban planning and management. There is no suggestion that these applications exist at the moment, but the UrbanIT framework provides the mechanism that could lead to these kinds of innovations.

• **Creation & management of asset data**: an object-based urban information management system provides a very natural way of organising urban data at a precinct, local council or metropolitan level. All entities in the urban environment are appropriately classified and represented with both common attribute data and the ability to append customised property sets that contain data to support any specific purpose. Furthermore, the relationships between those entities are represented either explicitly or implicitly through the structure of the object hierarchy. Since the information is represented graphically, is geospatially located with a very high degree of accuracy, fully protected with all the normal database safeguards and entirely accessible using Internet data transactions, this technology provides a perfect vehicle for managing large-scale complex assets.

• **Compliance checking**: an urban information model provides the opportunity to hold the complete set of information that relates to a development or design proposal at any stage during its development, along with a full model representation of the urban
context of that development proposal. There are proven rule-based technologies that can be used to develop automatic compliance-checking applications that will interrogate those information models to determine first whether they contain sufficient information to support a competent assessment and then carry that assessment to create a fully-consistent and accurate compliance report. End users could upload their development models in to an urban model context and check compliance in an iterative fashion until full compliance is achieved so a formal application can be lodged. Clearly this approach would support DA & BA assessment, BASIOX compliance and occupancy certificates.

- **Planning policy and analysis**: evidence based planning and policy-making is wholly dependent on the availability of comprehensive and reliable information. The UrbanIT framework offers the potential hold all the data needed to support urban planning in a single place and in a form that makes it readily available, extensible and comprehensive. The ontological techniques pioneered in this project provide an opportunity to pull in the correct up-to-date data from authoritative sources at the time that it is needed, integrating that in to a single repository if appropriate and then extracting the data in the form needed to support whatever analytical tools are available to do the detailed analysis.

- **Sustainability & resource analysis**: one of the major challenges that face government instrumentalities and service utility providers in an urban context is the optimisation of service delivery networks to achieve efficient management and distribution of resources in order to maintain sustainable usage and demand load over time. This applies not only to the distribution of services (energy, water, communication technologies, waste disposal and management), but also in public and private transport networks, distribution of health care, education services and many other areas. All such processes rely on accurate and accessible information. The UrbanIT framework provides a single comprehensive database (subject to some further development to support infrastructure modelling) that can act as a repository for monitoring data collected during the distribution of services as well as the source of snapshot data used to analyse and optimise usage and control distribution.
9.4. Future Work and Further Research

The UrbanIT project is only a starting point, offering a robust framework for effective information management and some modest prototype implementations. Further research and proof of concept work is required to develop the framework, particularly to manage infrastructure components of the urban context (large infrastructure elements like roads, Transport systems, bridges and tunnels) and utility distribution networks (water, energy, etc). These are conceptually similar to elements contained in building models, so the innovation is around adapting existing concepts to handle the larger scale entities at an urban scale. Though not trivial, such work is very possible.

The more immediate opportunity for further work revolves around the application of the current framework and urban information modelling technologies to the immediate and short-term needs of our partners. These ideas must be driven by the needs of or partner organisations, but we here propose three possible “teasers” to suggest possible directions for further work:

- Develop a Model Guideline for the City of Sydney that would enable the Floor Space and Employment Survey data to be updated from a BIM. This would allow a more effective way of collecting and recording the data and could, ultimately, form part of a more comprehensive urban information model.
- Develop a model-based eDA submission process, allowing external users to lodge DA applications in the form of a BIM through a standard Web portal.
- Operationalise the urban information model of the Green Square precinct to support better management of that project, giving us a more robust proof of concept, and supporting submissions for PRECINX compliance.

10. References & Bibliography


Solove, D. J. A Taxonomy of Privacy, SSRN.


11. Appendices

The following appendices provide specific technical details of certain aspects of this work:

1. A Note on Cadastre, v4.03 • 1 July, 2010.
3. List of relevant Australian Standards and regulatory documents.
Appendix 3 - Relevant Australian Standards

Australian Standards present comprehensive guidelines to help control the quality of data at the point of creation and provide information about a geographic dataset’s accessibility, currency, completeness, fitness-for-purpose and suitability-for-use, including optional elements such as audience and coverage. Some examples of these are:

- Government Interoperability Technical Framework (AGIMO),
- Australian Spatial Data Directory (ASDD),
- Australian Government Locator Service (AGLS),
- Spatial Information Management Toolkit,
- National Data Network⁸,
- Harmonised Data Manual (ICSM 2002),
- National Community Services Data Dictionary (NCSDD),
- NSW Housing and Human Services Accord⁹, and
- Australia/New Zealand government Spatial Information Council (ANZLIC).

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