LOW CARBON LIVING CRC

Precinct Information Modelling

Project Progress Report

November 2016

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Title	Project Progress Report, November 2016
ISBN	
Format	
Keywords	
Editor	
Publisher	
Series	
ISSN	
Preferred citation	

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Acknowledgements

This research is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative.

The authors would also like to acknowledge project partners AECOM, Aurecon, Brookfield Multiplex and buildingSMART Australasia.

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Acronyms

BIM	Building Information Modelling
bsDD	buildingSMART Data Dictionary
bSI	buildingSMART International
FES	Floorspace Employment Survey
GIS	Geographic Information System
IDM	Information Delivery Manual
MVD	Model View Definition
OGC	Open Geospatial Consortium
OWL	Web Ontology Language
PIM	Precinct Information Modelling
UHI	Urban Heat Island
W3C	World Wide Web Consortium

Executive Summary

This report outlines the scope and progress of work that has been undertaken as part of the PIM Project for the CRC for Low Carbon Living. It is recognised that the project has suffered setbacks in its collaboration with other CRC projects, but the report makes the case that the core deliverables have progressed strongly and the project has made significant contributions to the development of international (and therefore, national) standards for modelling the built environment at a precinct scale. The utilisation of that work will be assured as those standards are implemented in software over the next 5-8 years, providing a solid platform for better management of the built environment to achieve low carbon outcomes through all the programs of the CRC, while delivering very significant productivity dividends in the infrastructure and urban planning sector that should meet the milestones set for the CRC.

The report outlines the activities of the Project Team to deliver on the core deliverables related to the development of an open standard for sharing precinct scale information, establishing the PIM platform described in the project proposal and meeting the broader CRC Milestones articulated for the CRC.

While acknowledging the setbacks in our collaboration with existing CRC projects, specifically the Empowering Broadway project that was to be the exemplar of our work during the second two years, we describe the specific deliverables that are on track to be completed by the project completion date. These opportunities are outlined in the final section of this report, with separate expanded reports addressing the specific opportunities for the Broadway Precinct, ICM, ETWW and the up-coming UHI Mitigation Decision-Support Tool.

Introduction

The concept of Precinct Information Modelling (PIM) applies to a scale of development that is more often managed by Local Government and City Planners, but also includes institutional or large private/industry led commercial developments. Within the context of Smart Cities, it can be applied generically across the whole of the built environment. Within the context of the CRC, its focus is on effective carbon management, but PIM must still be understood within that larger context.

This report explains the concept of PIM by first exploring some of the major use-cases that have driven its emergence as a major contributor to the present and future management of the built environment, not only in Australia, but globally.

A key driver has been the need to plan and manage cities more efficiently, where the extent and disparate nature of information needed is ever expanding. In this regard, Building Information Modelling (BIM) has been an influential forerunner. BIM makes use of a 3D intelligent object model database for building works. It has become the global norm of many governments, beginning with the Nordic countries, it has now been formally adopted in the UK, US, and other major countries across Europe and Asia. At an industry level, BIM has been adopted by most leading design and construction firms because of of its multi-disciplinary capabilities and powerful object modelling tools. For example, automated clash detection enabled by BIM provides many business benefits. It reduces errors, removes risk, improves reliability and speeds up delivery. BIM provides precise, useable data for the operational management phases of a facility. In essence, BIM delivers high quality structured data!

PIM takes advantage of these generic strengths by extending BIM into the broader domain of urban development in our cities, adding new infrastructure entities such as roads, bridges, utilities and civic space to the current building-centric entities of BIM. This extension is a core objective of the PIM project - to allow for the integration of diverse data held and referenced by multiple owners, government agencies and industry specialists. The purpose of this effort is strive for better quality and greater reliability of the information that is used to inform decision-making in the built environment.

Since we first proposed PIM as part of the successful CRC bid in 2011, the need for this kind of development has been recognised in many other parts of the world. The PIM Team has become actively engaged in that work, bringing the lessons learnt from our own work into that international effort, while also drawing on that work to inform our own PIM development. This is explained more fully in the next section.

An excellent use-case of the application and benefit of PIM is the City of Sydney's *Floor Space Employment Survey* (FES), fulfilling the need of local government to have systems to better understand their precinct portfolios. Updated every five years, this survey tracks the occupancy characteristics of all city buildings. It contains data on each floor, each room, the activities undertaken, and the types of businesses resident in every building. This data provides a strategic view of the changes in the patterns of activity across the city and guides decision making. The source data is currently held in a GIS format, but has been converted as one task of the PIM research project into an embryonic PIM model of a part of the city. Using tools developed by the PIM team, the information can now be visualised, and data accessed on a single instance basis or across a group of facilities. This pilot precinct model of the Broadway Precinct, now in an open standard PIM format, supports the collection and management of a wider and more diverse range of asset data than is possible in its present form.

The Broadway Precinct model, covering the Central Park site, UTS, and TAFE NSW, was created to support the *Empowering Broadway Project* (RP2018), and the PIM team's role for that project was to host the additional data being gathered by that research team to support the feasibility of sharing energy and water between institutions within the precinct.

Although the Empowering Broadway Project has been discontinued, we are using the surveyed data comprising A/C plant location and condition, energy consumption, building type and occupancy to demonstrate how this data can be associated to the correct concepts in the model (e.g. building, space, equipment, building element) to support the analysis of loads and usage patterns, and as the context for shared services and a combined lower embodied carbon measure.

This illustrates one of the key benefits of PIM, to provide a comprehensive source of reliable information about the objects that make up the built environment at a level of detail that suits the requirements of a particular use case. The Broadway PIM provides a 3D context for space usage and ownership, plus the essential location of the major water and energy plant and meters. This was designed to support the analysis needs of the Empowering Broadway project.

Another important use case and benefit of PIM is the ability to expand the scope of urban-scale modelling down to a greater level of detail that encompasses the other components of urban infrastructure, namely road and rail entities, civic space (both green and hard-paved) and the utility distribution networks that pervade our cities. One of the enormous challenges that face city planners and managers is how to collect and keep track of that sort of data. PIM, based on an open standard format, offers a partial solution to that problem by providing a repository for holding such information in a form that can be re-used once it has been collected for a specific purpose.

the PIM team, through a collaboration with a Sydney landscape architect (McGregor Coxall) began to address that issue by creating a prototype PIM model for an open space precinct development at Green Square, featuring a water recycling system. A similar pilot has been undertaken with 12D Solutions, a civil/roads software vendor in Sydney, to produce a trial road network model on the Broadway site. Further discussions are on-going to develop a small subset of the Broadway model as a richer prototype to demonstrate open space and infrastructure concepts.

One of the challenges to establishing comprehensive precinct models is that underground utilities are controlled by multiple government agencies - including water, waste, electricity and gas. Accessing this information is difficult, unreliable, and to-date has been predominantly in hardcopy format. In preparation for the Sydney Light Rail project, Transport for NSW (TfNSW) undertook a survey (in 3D object model format) of underground services in George St.

This is a good example of the broader scope that PIM can provide. It is about maintaining complex, reliable repositories of information, held in a 3D geometric form, that can be readily understood, interrogated and used to manage the physical built environment.

However, if that information, once collected at significant cost, is held in a proprietary software format, then its value may be compromised if needed for other purposes at a later time. The PIM Project proposes an open. non-proprietary approach to the representation of urban model data, providing a more robust and enduring source of information about the built environment.

As stated previously, the PIM Team has deliberately positioned itself within a large international undertaking to extend the existing open standard for BIM (known as IFC) to include infrastructure components of the built environment. The PIM project has made a substantial contribution to this work (as reported in more detail below).

Developing a PIM standard

The timeline for any standards development involves allowing for a global expert community to propose and agree the intention and wording of the standard. The foundation IFC protocol was started in 1996, and has since issued 6 major versions (see **Error! Reference source not found.**). The IFC2x3 release is now widely available and supported by the main design and construction industry software vendors. IFC4 (2013) has been released and the same international vendor community are now implementing new versions of their software that will be available by early 2017.

That time delay between the release of a standard and its widespread adoption by industry is symptomatic of the challenges of this work. However, there are signs that the progress is speeding up a little. The increasing demand for standards-based BIM (often referred to as openBIM) has been driven by the large number of governments today that have either mandated or prescribed the use of IFC. We are seeing the same trend in Australia, with the creation of the Australasian BIM Advisory Board (ABAB) representing significant government agencies across the eastern seaboard states and WA. This group held its inaugural meeting in November 2106 and adopted a vision to coordinate government's adoption of BIM and provide a national forum for industry and government collaboration. Another group, the National Digital Engineering Working Group set up under COAG, is focussing on infrastructure developments and Austroads has recently partnered with buildingSMART Australasia to align and harmonise their work with international open BIM standards.

All this has strengthened the use of openBIM, and encouraged increasing interest from the infrastructure sector. Indeed, the recognition of the advantages of a global open standard are seeing the deployment of much larger resources towards defining the next version IFC5. This will represent a radical strengthening in the coverage of the standard to embrace the whole of the built environment, including infrastructure entities in particular, and is expected to be released by the end of 2018 (Figure 1).

As explained more fully in the next section, the PIM Project Team has actively contributed to the current international standards work leading to the release of IFC5. This contribution is not strictly within the work program funded by the CRC, but is based to a large extent on the learning from the PIM Project.

Based on past experience, it will then take a few years for software developers to implement the new standard, both in Australia and overseas. As that new standard filters down through industry, it will begin to have an accelerating impact across the entire design and construction sector, impacting not only building construction and large-scale infrastructure development. Significantly, it will also provide a solid open platform for the growth of smart cities and the overall planning, design and operation of the built environment, including carbon management and remediation. Accurate and reliable information is the key to successful implementation of urban strategies and open PIM represents a significant contribution to that goal.

The value of being a contributor to this development is very high in the short term, allowing Australian expertise to be included as well as keeping the design and construction sector intimately informed of developments. The real impacts will occur in the long-term when our contribution to this work will yield significant sustainability impacts across the triple bottom line of social, environment and cost (productivity).

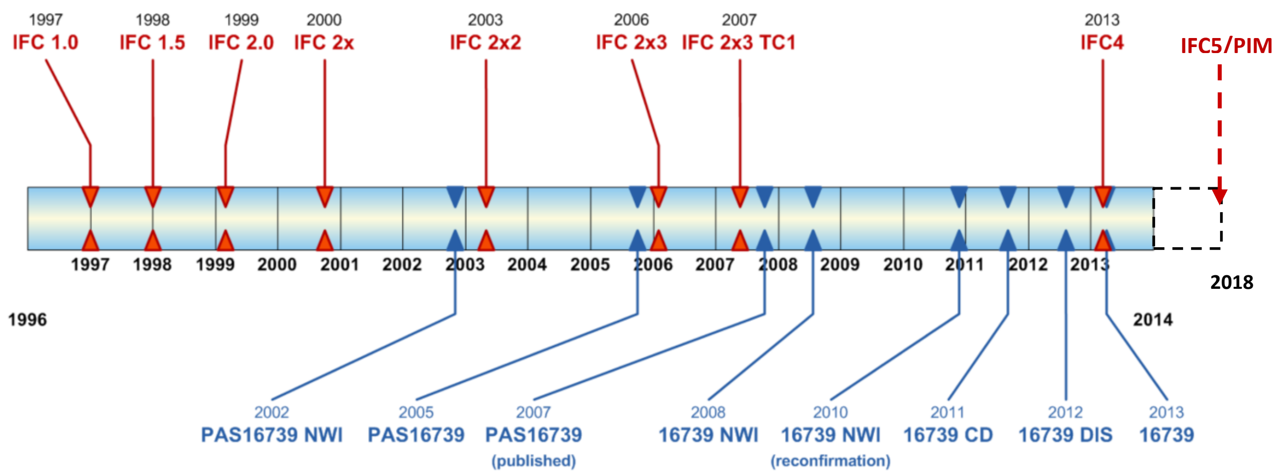

Figure 1 Unveiling IFC4 - The Next Generation of OpenBIM, T Liebich, 2013 (with addition of IFC5/PIM)

Core Deliverables

This section provides a review of the business case that drives the development of each of the core deliverables for the PIM project, and then reports the work completed up to the present time. The focus is on reporting progress and status, rather than providing the technical detail, which is contained in other technical documents and published outputs.

Note that this section deals with the elements that make up the PIM platform from a research perspective, including our engagement with the international standards community to establish our work within that context. Though reference is made here to imperatives drawn from our work with CRC partners, a more detailed description of our project collaborations with other CRC partners is provided in the next major section and supplemented with separate collaboration reports for each project.

PIM Schema – Proposed IFC Extensions

The primary deliverable addresses the need for a shared way of digitally describing a real-world precinct (throughout its entire life cycle) so that all stakeholders (using their preferred software tools) are able to work with a common digital representation.

This has been achieved by taking the existing IFC schema (developed internationally by buildingSMART and published as ISO 16739) and proposing extensions that support the full range of concepts needed to represent precinct-scale models. As noted in the Introduction, although our work has a deliberate focus on carbon management of the built environment and low carbon design, the modelling principles are common to many other use-cases for precinct models.

In order to meet the medium-term utilisation objectives of the PIM project within the context of the CRC LCL, it is critical that the proposed schema extensions form part of the evolving IFC standard. This has been a significant goal of our work on PIM and ensures its implementation by software vendors (both internationally and within Australia) and flow-on adoption by Australian industry and government stakeholders. Already, the Australian industry is reliant on IFC within the building construction sector, reflected in the very recent decision by Standards Australia to directly adopt ISO 16739 (IFC) as an Australian Standard. As explained in the previous section, over the next decade, we will see that standard applied across all aspects of the design of the built environment, including infrastructure and urban planning and design.

That goal to have PIM directly influence that international standard has necessarily required working closely with buildingSMART International (bSI) to ensure that our work is consistent with (and takes advantage of) parallel work being undertaken elsewhere, while at the same time, ensuring that the work is seen as both credible and valuable as inputs to that international effort. As evidence of that work, Appendix 1 lists the major international committee and working groups that are active in this work, and shows where members of the PIM team are actively participating.

The following activities have ensured the delivery of a comprehensive and credible set of PIM schema extensions. They are outlined here and documented in greater detail in a separate working document entitled, “Technical Investigations: Precinct Information Schema”.

- **PIM Schema**. As an on-going part of our work, the schema is being refined as specific technical issues or CRC project-related challenges are identified. The spatial organisation of precincts was identified early as a critical aspect to be considered, providing support for placing precinct entities within a spatial context, e.g. associating permissible development types within land use zones. Specific physical entities, typically associated with a precinct, are added to the PIM schema as use-cases arise, but the challenge is to keep those to a minimum and re-use existing concepts wherever possible, e.g. we are proposing a new ifcCadastre concept in order to represent legal ownership of land and provide linkages to a geospatial context. Some of the related issues that have been researched include: entity typology; versioning; capturing briefing data (design intent); managing the scale and complexity of precincts may require the use of federated models in lieu of a single fully integrated model; how to integrate data across the domains of BIM and GIS; handling links to reference data, including real-time data feeds.
- **Linear Infrastructure**. The primary push by buildingSMART over the past few years has been the development of IFC extensions for linear infrastructure (road, railway, bridge and tunnel), beginning with a specification of how the alignment of such entities must be defined. The PIM Project Team has been represented on the international Steering Committee (Appendix 1) that drives that work, ensuring that we are in a position both to contribute to and benefit from that work. Since infrastructure is a central aspect of precinct management, especially when modelling transport systems, this has led to direct engagement in specific projects as detailed next.
- **Overall Architecture**. Early in 2015, bSI recognised that the extension work for linear infrastructure required a robust definition of some core concepts common to the different types of infrastructure and proposed the need for a new bSI work item to define the common schema extensions and develop guidelines to ensure consistency. That idea was taken up and led to an industry-funded standards project that ran throughout 2016. We participated actively in that project, contributing specifically to the definition of a spatial hierarchy for all forms of infrastructure. That became a specific case where our PIM Project has led to some agreed extensions to the IFC standard. The report of that work is due to be released at the end of January 2017.

- **Common Definitions**. In late 2016, we contributed to a discussion within buildingSMART about how to pull together work done independently in different parts of the world within specific infrastructure domains (roads, railways, etc.). This has resulted in a new buildingSMART International project to be executed in 2017 that will harmonise and rationalise that work by locking in common schema definitions. A Working Group (see Appendix 1), convened by PIM Project Leader Jim Plume, is currently working on the preparations for that work, as defined in the Working Group Work Plan (draft, available on request). Our PIM research influenced this thinking by recognising the challenge of modelling at a precinct scale, while keeping the underlying schema manageable and not too complex to implement in software. Figure 2 illustrates the approach, where existing standards projects form the platform for the linear infrastructure extensions (road, rail & bridge), with an initial 1-year project to identify the common definitions that span those domains.

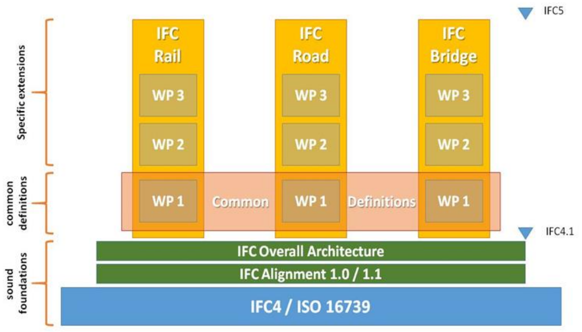

Figure 2 On-going IFC schema development for infrastructure

> *Transport networks within precincts are critical to effective carbon management, evidenced by the ETWW project, but accurate modelling of such infrastructure using PIM, along with other types of outdoor space, will also be important for UHI analysis.*

- **Consistency with Spatial Standards**. PIM has always stood at the interface between the detailed modelling of built facilities and the spatial modelling technologies that revolve around Geographic Information systems (GIS), the latter widely adopted in urban and regional planning. Jim Plume is a member of a group (see Appendix 1) that met in London in early November 2016[1] leading to a proposal to establish a Joint Working Group, co-chaired by Jim Plume (bSI) and Carsten Roensdorf (OGC) to have the on-going responsibility of establishing and maintaining the framework of the collaboration between the two international standards organisations. This is critical for effective carbon management in the future, as the standards in both those domains will guarantee access to all the data available about the built environment to support effective planning, design and operation. The PIM schema must not only form part of IFC, but must be consistent with emerging standards such as InfraGML and IndoorGML, both of which stand as key links to open reference data.

Software Prototype Implementations

Software prototyping is a practical implementation that follows on from the core deliverable of an extended IFC schema to support open sharing of precinct information between software tools. Whilst there are many software tools in the marketplace that support the visualisation and object navigation of a model stored using IFC, these are developed relative to existing releases of the IFC standard. PIM is a proposed extension of IFC and therefore no existing commercial software tools in the marketplace are capable of recognising models represented in that format.

In order to show the feasibility of our proposals, we have developed our own software, known as the PIM Viewer, to interface with models defined using the PIM schema extensions. The tool serves as a testbed for several aspects of the work described in this section, allowing us to implement test use-cases as well as navigate PIM databases. It has been implemented using publicly-available open source libraries that handle IFC, with customised extensions to handle the PIM extensions.

The PIM Viewer will be used as the basis for developing interfaces for both the ETWW and UHI mitigation projects, providing a demonstration software platform for holding a precinct model, with the ability to import/export the data needed to support those applications. A more detailed discussion of how those two projects can be supported with PIM is provided in separate collaboration reports for each project.

Since PIM databases can be held within either a single file or on a network object database server, the PIM Viewer has been designed to access a PIM model from either source. Once loaded, the PIM Viewer currently has the following capabilities (others will be implemented as the project need arises).

- **Model Navigation**. The precinct model can be visualised in a standard 3D view, with tools to move through the 3D environment, as well as navigating through an object hierarchy that reveals the organisation of the object that make up the model.
- **Object Property Inspection**. Objects within the model can be selected to view their attributes and properties, including handling types and aggregations of entities, as well as added functionality to hold requirements information (part of the extended PIM schema), important for both briefing a new project and subsequently verifying performance against those requirements.
- **Alternate File Formats and Property Editing**. Models can be opened and saved in various IFC file formats (a function of the open source libraries)

[1] http://buildingsmart.org/geospatial-built-asset-collaboration/

including ifcXML, and there is functionality to edit property values.

- **Reference data access**. The tool is able to lookup reference data from external sources where the reference links are stored in the PIM model.
- **Supports queries**. This is a useful feature that is built into the open source libraries used to build the tool, and can be used equally for PIM databases.

As a separate software implementation activity, we have developed add-ins for a couple of commercial BIM authoring tools (Revit and ArchiCAD). These do not have the capability to build PIM models as we have to work within their existing modelling capability, but they do have the capability to access external property definitions, as elaborated in a later section.

Model Setup – Managing Geographic Context

During early work on the Broadway Precinct project, it was realised that there is an implementation gap in the way land ownership (cadastre), site survey accuracy and map referencing are managed by many BIM software applications. The problem is more acute on large sites (precincts), but also applies on more conventional building design projects where multiple consultants, using their own preferred software tools, need to collaborate using a single building model.

John Mitchell, a member of the PIM Project Team, initiated a buildingSMART International project to address the need for stakeholders to have an agreed way of setting up a new project using BIM/PIM technology, particularly when the model is made up of separate disciplinary models that at some point will need to be integrated into a single representation. For precincts, the issue is made more complex because of the scale of the modelled region.

The *Model Setup IDM* project, run under the auspices of buildingSMART International, is adding to the IFC standard a globally-agreed method for setting up digital model projects with the correct map referencing systems. The much larger extent of a PIM development, such as the work on the Broadway Precinct model that covering a zone of 1.5 x 2.0 KMs, requires geodetic coordinate systems to ensure measurements are accurate. Sub-models (a building and its immediate context), require a process to ensure updates can be imported back into the master model at their correct location.

The model setup project team is an international group from the major European nations, Japan, US and Australia. It has attracted experts in both the built environment and spatial domains.

Though not specifically a part of the Model Setup project, this work links to the wider issue of integrating information held in the currently disparate spatial and built environment domains, often described as BIM/GIS integration. The Project Team have been active in that international debate and contributing thought leadership through publications that lie outside the CRC, but are informed by this work (Plume, et al. 2015, Plume 2015).

Plume is co-chair of an international Integrated Digital Built Environment Working Group, drawing its participants from both buildingSMART and the Open Geospatial Consortium (OGC). Members of that WG are engaged in the Future Cities Pilot being led by OGC, as well as the Linked Building Data Community Group established under the auspices of the World Wide WebConsortium (W3C). In that way, that group draws together an international panel of those who are leading the curent thinking about the role of open information modelling standards that will form the foundation of the Smart Cities of the future.

The work being done within the PIM Project is impacting that thinking and will inevitably have a substantive impact on the way we think about city-making and the operation and management of cities over the coming decades.

Information Exchange – Model View Definitions

Given that precinct models, due to their sheer scale, are likely to become very large and complex, industry stakeholders need automated, use-case specifications for data exchange that extract sub-models from a master model that contain just the information required to support a particular process.

These are known as Model View Definitions (MVDs) because they prescribe the contents of a sub-model (extracted from a more complex precinct model) to support a specific use-case.

To illustrate that concept, an example can be drawn from the CRC ETWW project. In order to undertake a demand forecasting assessment, the ETWW tool relies on specific information about a precinct (technically referred to as a model) that includes only that information required to execute its analysis. Furthermore, it needs to exchange precinct information with four different analysis tools (energy, transport, water and waste), exporting data to support those analyses, and then importing the results back in an iterative process to determine the aggregate demand across the four measures under different scenarios. A goal of the PIM project is to address the management of those information exchanges in a more robust manner through the use of the PIM standard and a set of MVDs.

The concept of an MVD is based on an established buildingSMART solution to that process, known as IDM (which stands for Information Delivery Manual and is prescribed in ISO 29481-1 2016). As the CRC LCL representative on the Australian Mirror Committee (BD-104) to ISO TC 59/SC 13, the PIM Project Leader, Jim Plume, was an active participant in WG 8 that was responsible for the revision of that ISO standard, released in early 22016.

In order to support this process, buildingSMART International have developed another standard that allows the definition of an MVD in machine-readable form, allowing MVDs to be customised to support any BIM business process. The PIM Project Team have been investigating that technology to see how it can be adapted to the proposed PIM schema and define MVDs to support exchanges such as for the ETWW or UHI projects. This is on-going work, but will be used to demonstrate this process with appropriate CRC collaborations.

PIM Object Library – Data Dictionary

Since language, terminology, and the way things are classified, varies across different jurisdictions and even within different organisations, there is a need to provide tools that allow those differences to be managed. For example, Australia has its own compliance standards for products, urban land use and building performance, and these even vary from state to state in many cases. The terms used to express these requirements can also vary, creating problems for anyone who is responsible for managing the built environment.

Since the PIM Project is focussed on information management to reduce carbon, we have undertaken substantial work to address this issue of concept definition, including the identification of properties and measures that are used to assess carbon performance across a range of factors (energy, water, transport, etc.).

These sets of terms or concepts that are used within a specific context or jurisdiction are referred to as ontologies. At present, there are two available technologies for handling ontologies:

- buildingSMART has developed an on-line repository of concept definitions called the buildingSMART Data Dictionary (bsDD) that assigns a unique identifier for every concept used within the broad built environment sector, including equivalent terms used across different jurisdictions and languages;
- the World Wide Web Consortium (W3C) has developed a standard called OWL (Web Ontology Language) that can be used by anyone to define an ontology that is then publicly available to assist Web search engines, or any tool that manipulates Web data, to interpret the unstructured information held in Web repositories (generally referred to as the Semantic Web).

One of the core activities of the PIM project has been to investigate these technical solutions to manage the terminology used in precinct modelling: what are the essential objects/concepts needed in order to describe precincts when modelling them for the use cases relevant to the CRC?

We have concluded that the bsDD provides the most appropriate platform for hosting precinct terms and property definitions in the context of our work. This is because it should provide an authoritative and stable platform for wide use. OWL Ontology databases are more suited for very localised use, perhaps by a single organisation that has very specific terminology requirements and wished to host a bespoke concept library.

This question has led to a number of work packages undertaken by the PIM Project Team.

- **Sustainability Performance Standards**. We have undertaken a survey of international work in the application of environmental and sustainability performance data standards and have identified property sets covering carbon performance of materials and products. This is reported in a technical report (Mitchell, et al 2016a).
- **Precinct Object Library**. The PIM Project Team has been contributing to the development of the buildingSMART Data Dictionary (bsDD). The bsDD provides a means to define concept definitions and the relationships between concepts that can form the basis for standardising an international object library that includes precinct-level objects. For example, the PIM Team have added the definitions of land uses and development types derived from the NSW Department of Planning guidelines (Mitchell, et al 2016a) and linked these to the definition of a spatial zone, and through that, to a standard set of environmental indicator properties that apply (including carbon measures). That work provides the "slots" into which data values can be placed. The development type concepts, for example, provide defined concepts such as "detached dwelling", "boarding house", etc. However, the challenge has been to obtain accurate carbon data to populate the properties of objects at this level of detail in a precinct object library. Building cost databases provide reliable data at a material, elemental, or area by function level based on referencing many projects, in many locations, over time. The equivalent data for carbon is somewhat available at a materials level, but has not yet been aggregated against enough actual cases to be reliable for precinct-level objects such as "dwelling house" (Mitchell, et al 2016b). This is an issue we have been identifying for the CRC LCL Integrated Carbon Metrics research project.
- **Web Service Database**. A very simple web application has been created by the PIM Team (intended as support for the ICM project) that demonstrates how a software tool can access carbon data held in an on-line database using a standard Web service query. It is a proof of concept. We refer to that as reference data and the datrabse can expanded as more data becomes available. We envisage that the unique identifier keys used to reference relevant data will be set to correspond to the globally unique identifiers that the bsDD uses, thus correlating the object library and the referenced carbon data.
- **Precinct Planning Processes**. The Broadway Precinct has served as the basis for an implementation of planning protocols, making use of the Local Environment Plans (LEP) used by NSW Councils to regulate development. We have implemented a trial example of the LEPs for the City of Sydney and two other council jurisdictions to show early concept scenario planning possibilities that make use of the bsDD (Mitchell, et al 2016a).
- **Prototype Software Implementations**. In order to test/demonstrate the principles outlined above, we

took two of the main BIM authoring packages and developed some add-in software (more detail in Mitchell, et al 2016a). In ArchiCAD, we developed an interface that could create a simple volumetric form in a precinct context and then draw from an external list of permitted development types for that jurisdiction in order to properly identify that entity. A Revit add-in went a little further: it supported the definition of a land use zone as an area within a precinct, and massing objects to represent development types. The classification of these objects is done by the user selecting from a list derived through a lookup connection to the bsDD. The parameters of the standard Revit object types (families) for area and massing are extended with the environmental indicator properties automatically derived from the bsDD by virtue of their relationship to the land use and development type concepts. The next piece of work for the Revit add-in software is to show the carbon properties being populated through a lookup to the external carbon data reference source.

PIM Publications

The following book chapter, conference papers CRC Technical Reports have been prepared or accepted for publication:

- Newton, P., Plume, J., Marchant, D., Mitchell, J., Ngo, T. Precinct Information Modelling: a New Digital Platform for Integrated Design, Assessment and Management of the Built Environment. Book chapter to be published 2017.
- Plume, J., Marchant, D., Mitchell, J., Newhouse, O. (2016) Proposal for an open data model schema for precinct-scale information management. SBE16 Conference, Sydney.
- Marchant, D., Plume, J. (2016) Including stakeholder intent in precinct information models. SBE16 Conference, Sydney.
- Mitchell, J., Marchant, D., Plume, J. (2016a) *Technical Investigations: Land Use and Development Types*, Technical Report, CRC LCL (in draft).
- Mitchell, J., Marchant, D., Plume, J. (2016b) *Technical Investigations: Precinct Object Library Implementation*, Technical Report, CRC LCL (in draft).
- Marchant, D., Plume, J., Mitchell, J. (2016) *Technical Investigations: Precinct Information Schema*, Technical Report, CRC LCL (in draft).
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Exemplars proposed or under development

With the discontinuation of the Empowering Broadway Project (RP2018), and the prior withdrawal of Tonsley Park as a test bed, our efforts are now focussed on engaging with alternate PIM pilots, and taking the results of other CRC for LCL projects and applying them to PIM.

While the previous section focussed on the core research deliverables, here we focus on specific collaborative activities that relate to other CRC projects. We treat these in two categories: those that are currently well-defined, agreed and in progress; those that are still subject to final negotiations, or links to projects not yet running. A final section outlines linkages that have resulted from approaches from groups outside the CRC, but are not specifically related to carbon. They are only included to demonstrate the broader issues that might be addressed by PIM.

Confirmed Collaborative Project Outputs

- **ETWW Project**. The first collaboration with the ETWW project, has been to implement the input data for Lochiel Park and Tonsley in PIM format. The data is all non-geometric. The expected next steps are to test this data format as an interface to the various analysis tools for that project, and to explore whether any additional 3D data that may be available for those precincts can be utilised effectively. Further details of this collaboration is given in Marchant 2016b.
- **Empowering Broadway**. At the end of the first year of the Empowering Broadway Project, we were provided with spreadsheets that included the audit data that was collected. It relates to a relatively small number of the more significant buildings and will be populated within the existing precinct model of Broadway in order to demonstrate the capability for holding such information at the appropriate scales for carbon management. This work will also highlight some of the challenges that occur when drawing together poorly-alligned sets of data (Further details of this collaboration is given in Mitchell 2016.).
- **Data Linking in an Urban Planning Scenario**. A proposed demonstrator has been scoped out that will entail a specific use case at an urban development scale. This will show the various software tools and add-ins all interacting with a precinct model based on the PIM schema, to demonstrate steps in a planning proposal (Mitchell, et al 2016a).
- **Precinct Object Library**. A prototype library system has been implemented for land uses and development types (to support zonal planning) as outlined in an earlier section. However, the insertion of the appropriate embodied carbon values against the relevant properties of these objects is still required. We had envisaged that this work could draw on the ICM project as a source for carbon data. Alternatively, we also now have a firm commitment from The Evah Institute to facilitate calculations of embodied carbon data for typical precinct infrastructure entitities (road, open space, etc.). We also envisage that the new Low Carbon Housing project will provide additional object library types for residential building elements. That is, alongside the land uses and development type objects, showing the generic applicability of our approach to multiple scales of resolution within a precinct model. Further details of this collaboration is given in Marchant 2016a.

Project Collaborations to be Confirmed

These represent opportunities for on-going collaboration and application of the PIM project work.

- **Urban Growth**. We have a firm commitment from Urban Growth to collaborate with the PIM Project in the development of a precinct model. The two alternate precincts under consideration are the White Bay site (part of the Bays Precinct) and the Parramatta precinct development. We are waiting on advice from Urban Growth on which one they prefer to work with, before appropriate plans can be made to identify an appropriate use case, scan the sites to create a precinct model, and implement that on a PIM server.
- **Urban Heat Islands**. We have agreed to contribute to the new CRC project entitled, “Microclimate and Urban Heat Island Mitigation Decision-Support Tool” to commence at the start of 2017. Our role in that work will be to scope out the development of an exemplar precinct model, based on the PIM schema and linked to an object library, that could support the analysis. Since the two projects overlap by only 6 months, the full extent of that engagement will depend on resourcing. Further details of this collaboration is given in Plume 2016.
- **Low Carbon Housing**. The new project RP1024: “Facilitating the transition to low carbon housing, Integrated Building Systems” aims to “extend and improve the functionality of existing 2nd Generation NatHERS tools”. The new interface being developed by CSIRO and others will use IFC as an exchange format enabling all current BIM authoring tools to be compatible with this system. The PIM project’s work in the PIM Object Library and property sets will be directly applicable and would provide a new opportunity to analyse precinct scale residential developments.

External Interest in the PIM Project

Here we provide a sampling of the approaches we have received from groups with use cases outside the scope of the CRC, but which demonstrate the growing recognition of the importance of holding precinct scale information in an open format.

- **Ku-ring-gai Council** approached us on the Lindfield Hub project a project in the final stages of feasibility and about to proceed to detailed design. The draft plan includes a new library, community centre, low income housing, large underground carpark and new shopping facilities, with up to 6 storey development. The Council wanted to implement a PIM pilot to improve the embodied carbon performance for a typical suburban shopping centre such as this one. A number of these hubs are planned and would make excellent pilots. Unfortunately the State Government's Council Amalgamation project caused all such capital projects to go on hold.

- **Emergency Fire Services**. A recent discussion with the CEO of Fire Protection Association Australia has highlighted the challenges his teams have in responding to fires in buildings. At present when called, the responding team has very poor understanding of the facility. They have no details of access to the building, the configuration of the fire prevention systems, the usage and inhabitants of the building, the layout of the floors, escape route details, and location of Fire Assembly zones and security measures.

  A fire-services-specific model of a building, in its urban context (adjacent buildings, roads, public spaces, key utilities locations and access points), and accessible using tablet and cloud services, would transform their available knowledge, and is expected to reduce injuries and deaths involved in fire emergencies.

- **SE Water – Victorian Water Utility**. SE Water sees itself as a progressive utility, having a strong record in the adoption of digital technologies. They have identified a gap in the international standards development as it applies to their areas of responsibility, and have approached us for advice on how they might engage with the work on infrastructure, in particular, underground utilities. Clearly, this would have implications for carbon management, but the discussion at the moment is focussed on a broader set of challenges/opportunities for them.

- **Municipal Association of Victoria (MAV)**. The CEO of this group has approached us, expressing interest in hosting a meeting with a cluster of Victorian councils to review the opportunity that open standards offer in Local Government.

Appendix 1 BuildingSMART International Committee Participation

The following tables each of the Committees where PIM Project Team Members participate. In each case, the Convener/Chair of the Committee is listed first and the rest in alphabetic order.

bSI Infrastructure Room Steering Committee	
Christophe Castaing	France
Benno Koehorst	Netherlands
Hyunjoo Kim	South Korea
Jim Plume	Australia
Nobuyoshi Yabuki	Japan
Philip M Jackson	UK
Ronald Bergs	Netherlands
Tiina Perttula	Finland

bSI Overall Architecture Project Team	
André Borrmann	Germany
Christophe Castaing	France
Ge Gao	China
Hugh Woods	USA
Hyunseok Moon	South Korea
Jim Plume	Australia
Juha Hyvärinen	Finland
Julian Amann	Germany
Laura Mol	Netherlands
Paul Scarponcini	USA
Sergej Muhic	Germany
SUO Ning	China
Thomas Liebich	Germany
Tim Chipman	USA

bSI / OGC Coordination Planning Group	
Richard Kelly	UK
Mark Reichardt (CEO, OGC)	USA
Richard Petrie (CEO, bSI)	UK
Anne Kemp	UK
Bart De Lathouwer	USA
Carsten Roensdorf **	UK
Christophe Castaing	France
Denise McKenzie	USA
Jim Plume **	Australia
Leif Granholm	Finland
Mr Philip M Jackson	UK
Nick Nisbet	UK
Paul Scarponcini	USA
Scott Simmons	USA

** Appointed to Co-Chair ongoing *Integrated Digital Built Environment Working Group*.

bSI Linear Infrastructure Projects WG	
Jim Plume	Australia
Christophe Castaing	France
Laura Mol	Netherlands
Tiina Perttula	Finland

ISO TC 59/SC 13/WG 8 – ISO 29481-1 Revision Team	
Jan Karlshoej	Denmark
Eilif Hjelseth	Norway
Ghang Lee	Korea
Henk Schaap	Netherlands
Jim Plume	Australia
Kaj A. Joergensen	Denmark

bSI Model Setup Project Team	
John Mitchell	Australia
Andreas Kohlhaas	Germany
Behnam Atazadeh	Australia
Bjørn Lura	Norway
Brian Renehan	Australia
Darren Bennett	Australia
David Shorter	Australia
Jan Karlshøj	Denmark
Jeff Stephens	UK
Jeffrey Ouellette	USA
Jim Plume	Australia
Johnny Jensen	Norway
Jonathan Mirtschin	Australia
Kjell Ivar Bakkmoen	Norway
Lee Gregory	Australia
Neil Brown	Australia
Nick Nisbet	UK
Otto Newhouse	Australia
Peter Parslow	UK
Tomi Henttinen	Finland
Yoshinobu Adachi	Japan

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