Precinct Information Modelling

Technical Investigations:

Precinct Information Schema

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Title	Technical Investigations: Precinct Information Schema
ISBN	
Format	
Keywords	Precinct information schema
Editor	David Marchant
Publisher	
Series	
ISSN	
Preferred citation	

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Programme

LOW CARBON LIVING CRC

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 Model
IFC	Industry Foundation Classes
MVD	Model View Definition
PIM	Precinct Information Model

Executive Summary

This technical investigation presents the precinct information (PIM) data schema. The schema is an extension of the current IFC data schema that is used widely for building works. Apart from buildings, precincts also contain infrastructure objects such as roads, railways, bridges, tunnels, and outdoor civic spaces that contribute to the overall carbon impact and therefore need to be modelled. PIM considers buildings and infrastructure equally as “built facilities”. Additionally, PIM provides a means to model vegetation that will allow for mitigation factors to be determined when assessing urban heat island effects. The proposed extensions to IFC are defined in a way that generalizes, but does not break, existing IFC functionality.

Introduction

The core purpose of the Precinct Information Modelling (PIM) initiative is to develop a robust way of holding precinct-scale information to support accurate assessment (or measurement) of precinct performance and reliable methods of precinct management in order to achieve low carbon outcomes.

Object definitions are designed to mirror real-world entities as accurately and comprehensively as possible. So, a building, or a civic space such as a park, located within a precinct would be represented as an object with geometry, properties and relationships that closely match the real thing and which capture the meaning of the concept of that object.

Geometry is relatively straightforward and easily understood, though inherent in the object-based approach is the idea that an object could have varying geometric representations to suit the context of the analysis. It could be as simple as a point (or node) with a geospatial location in a large-scale mapping context, or at the other extreme, may be modelled in fine detail to support construction or maintenance of the physical entity.

Properties are typically managed in two ways:

- Objects have attributes (which may be mandatory or optional) that are assigned values for each instance of that object. So, a building may have a street address, but it also has a globally unique identifier within the precinct data model.
- Objects can be associated with property sets (a set of properties collected together and attached to the object through a relationship), providing a flexible way of attaching information to an object that may be required for specific applications; so, if you needed to track the maintenance of the building, you could have a property set that records things like date, cleaning contractor, cost, etc.

Relationships are used to define how objects fit within the context of other objects. For example, a green wall on a building, or a pipe network, or a bus stop may have a relationship with one or more companies that service those objects. Relationships are objectified, meaning that there are defined types of relationships that carry inherent meaning and can be applied to any type of object. For example, relationship types might include “associated with”, “decomposes”, “is decomposed by”, “belongs to”, etc. To establish the relationship between a building and a cleaning company, one might use the “associated with” relationship and, because it is objectified, it can be used as many times as needed. The advantage of that approach is versatility, while there is an inherent disadvantage if software implementers do not create explicit relationships when exporting model data.

When storing object-based information, object database technologies provide the most efficient search and retrieval procedures and are able to handle the large quantities of information needed to manage precinct-scale data.

Object databases are able to support all the normal data management tools like access security, data integrity, versioning, query-based transactions, distributed and cloud-based features, backup systems. etc.

Model view definitions (MVDs) are used to identify specific sub-sets of information, at an appropriate level of detail, to support a specific application or analysis need.

Conceptual Data Models

Given the key features of object-based technology described above, we can apply those principles to define an appropriate data model that reflects a view of precincts that will support rigorous assessment and management of designed precincts. This is an enormous task that requires input from the full span of potential users of the information in order to ensure that it reflects reality as accurately and comprehensively as possible. Some of the key aspects to this task include:

- Need to identify the “things” of interest, and the appropriate relationships between those things. The key challenge in that process is to match reality, while accommodating the specific views of all potential users.
- It is important to realise that “things” may represent physical entities within the real world, but they can also represent concepts that are required to support operations on physical entities. For example, a green wall exists as part of a building and can be linked to a maintenance schedule object.
- Things are often organised into structures. For example: cadastral lots are contained within a local government area; pipes are part of a service system; buildings are composed of products and assemblies. This mechanism of structuring information through objectified relationships creates a very powerful mechanism for understanding precincts. The challenge is to identify what spatial structures should form an explicit part of the information model, and which can be implemented only for specific applications.

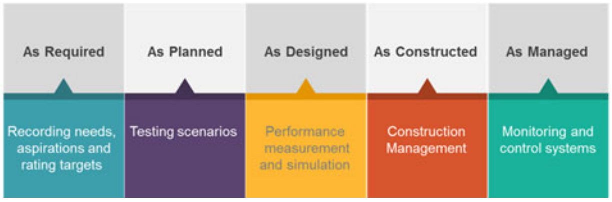
Precinct Analysis

In the broadest sense, precinct analysis refers to any type of software application that operates on information drawn from a PIM. That information will almost always be only a subset of the full information available, so we refer to that as a model view definition (MVD).

The analysis may well rely on additional information not actually held in the PIM. For example, using our green wall object, though we indicated previously that the maintenance information could be held in a schedule object associated with the green wall, it may be more appropriate to hold that data in a separate database maintained by a landscaping company. In that case, the maintenance information would be drawn from that source by the application. This can be achieved through the use of the external referencing mechanism (IfcRelAssociatesExternalDocument) that currently exists in IFC.

A PIM is a full life-cycle model. That is, it could be maintained throughout the life of the precinct as a support for planning and design, construction (or modification) and on-going maintenance or operation of the real world precinct. As such, it would really act as a digital mirror that parallels the real world.

Figure 1 Precinct life cycle



Many of the information exchange processes that support PIM analysis could be standardised. That would serve as a way of regularising core analysis processes without limiting the opportunity for the development of a proprietary application.

Data Dictionaries

These form a necessary part of the development of a PIM information platform, providing the ability to map nomenclature adopted by diverse application domains. An entity may be referred to as a “bus stop” in one domain, while another might very legitimately refer to it as a “bus stand”. Where the concept is identical, the nomenclature can be mapped via a data dictionary. The data dictionary also allows for multilingual naming of a concept.

This concept mapping mechanism is critical to support the integration of diverse data sets in a federated information environment, especially where many legacy systems are involved.

The data dictionary technology also allows for the “typing” of generic PIM objects. For example, local government and planners determine land use zonings for a precinct. The PIM schema provides a generic spatial zone object (IfcSpatialZone) that can be used to model these zones. However, the PIM schema does not explicitly define all the possible types of zone: general residential, mixed use, public recreation, and so on. These types are agreed and formalised in an online data dictionary in which every concept is uniquely identified and optionally related to other concepts to form an ontology – the buildingSMART Data Dictionary (bsDD). When a spatial zone (an IfcSpatialZone) is added to a precinct model, it can be tagged (either via its Name attribute, or by attaching a bsDD-specific set of properties that includes the name and globally unique identifier of the chosen bsDD concept). The spatial zone is defined so that it can also have 3D geometry and other specific properties attached as needed for the level of detail required within that precinct model. In this way, the PIM schema remains flexible, and is not overburdened with too many narrowly-defined object definitions.

Industry Foundation Classes (IFC)

IFC is a data schema that defines a comprehensive “user model” view of buildings that incorporates:

- The spatial structure of a building (site > building > storey > room);
- The separate building elements that make up the fabric of the building (categorised into disciplinary sub-models for architecture, structure, hydraulics, HVAC, etc);
- The semantic relationships between those building elements and the spaces that they define (e.g. aggregates, decomposes, connects, assigns, associates, contains, covers, etc);
- Strong object typing that captures the meaning of model components (e.g. a ceiling object is classified as a type of covering, thus indicating its purpose);
- The attributes and properties of the parts that make up the building model;
- Many concepts that support the management of the data model or the processes common to the disciplinary development and application of the model (e.g. concepts of ownership of the data components to maintain data integrity, time series concepts for managing change over time, performance history, surface rendition concepts to support visualisation, etc).

IFC is not a software tool, but rather a comprehensive specification of how building model information can be represented in either a file or a database format. Most data exchange today is managed as files (exported from or imported to proprietary applications), but the notion of a model database server technology that supports transactional exchange of defined sub-models or views of the entire database model offers the greatest versatility for information management.

There are several technical and cultural challenges to the adoption of an open BIM (or PIM) standard:

- Reliable and accurate import and export of open standard data by software vendors (especially where that requires a significant shift in concept representation, e.g. a curtain wall façade element being mapped to a space bounding external wall element with areas of glazing in it for the purposes of carrying out thermal calculations, or the differing concepts of how to represent a wall object in the various BIM editing applications);
- Mapping of common terms and language across geographic jurisdictions;
- Model building that accommodates or anticipates the needs of downstream users of that data.

The PIM research team have taken an approach to developing a PIM data schema that adopts the current building-centric IFC standard, and extends that to include other entity types that are parts of a precinct – in particular infrastructure and vegetation entities. This is a “harmonise-out” approach in that the scale of interest is expanded outwards into an area that is commonly mapped through geographic information systems (GIS). Any new entities proposed for PIM must therefore be able to have a semantic equivalent in a GIS interpretation. In simple terms, this means that the objects that might be expected to occur in information models using either standard can be exchanged easily and without information loss. For example, a cadastral lot, being the fundamental definition for the legal ownership of land, is one such entity. It should be noted that an alternative approach to developing PIM could have been to “harmonise-in” from a mapping perspective into a detailed building-level using GIS-defined entities. In either case, there is a crossover point where entities should be common.

Key concepts

Precinct

At the outset of the CRC for Low Carbon Living, and to assist in the framing of the research for Program 2: Low Carbon Precincts, a scoping study was undertaken among the research and practitioner community to clarify where the focus should be based. In this study, "the term 'precinct' is used interchangeably with neighbourhood, district and community. With the increasing adoption of digital city models, it is appropriate to define precincts in terms of the way they might be digitally represented. A precinct represents an urban locality of variable size that is considered holistically as a single entity in the context of broader urban planning processes. It typically comprises multiple land parcels occupied by constructed facilities (generally buildings or major infrastructures) or open space. For planning and analysis purposes, these precinct objects are clustered into urban zones that share some common characteristics and are supported by infrastructure services to manage energy, water, waste, communication and transport, as well as a range of social infrastructures related to health care, education, safety, retailing and entertainment." (Newton et al, 2013).

Urban Model Context

A precinct is a part of a wider urban context, identified for some urban management purpose (development, retrofit, operational management, etc.).

- As such, it is generally a temporal concept (for the life of the "precinct" project).
- A PIM must be geo-located: i.e. have at least one reference origin point (in Cartesian coordinates) that is accurately geo-located to spatial location; all geometric entities within the PIM are positioned relative to that reference origin.

Precincts as Collectors

A precinct may be thought of as a collection of precinct objects that includes built facilities (buildings, transport infrastructure, utility infrastructure, open space, etc.), lanscape elements (vegetation etc), and spatial zones (based on land use, ownership, governance, socio-political divisions, etc.). In terms of legal ownership and spatial containment, these are all tied to the concept of the cadastre.

Cadastre

Cadastre is the legal definition of land (or strata) title, specified spatially and recording ownership. This entity can both contain buildings as well as be a fundamental land parcel unit for land environment planning, demographics analysis etc.

PIM Views

A precinct may be viewed differently in terms of both LOD ("Level of Development", loosely related to life cycle stages), professional disciplines, or other stakeholders. As a consequence, a single real-world object can be mapped to several representations (with corresponding sets of properties), depending on the model view.

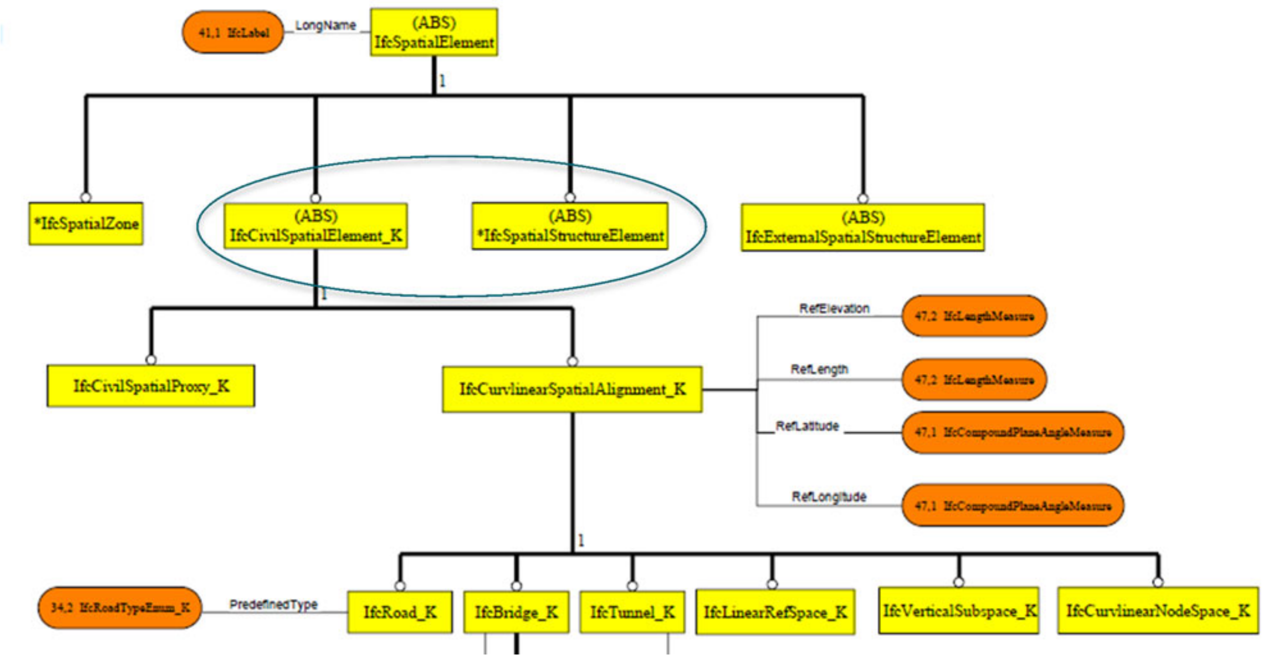
Extending BIM to PIM

All data models require a formal definition of the data structure that will be used to store the data. This is referred to as the “data schema”.

Recent initiatives for an infrastructure schema

Pre-dating the PIM research work, several research projects have proposed extensions to IFC to address infrastructure entities. These include the European IFC-Bridge and IFC for Roads (Lebegue 2013), the Korean IfcRoad (Moon 2014), and a more recent Chinese initiative for railways. What all of these projects have in common is a distinct separation between building entities and civil entities. For example, figure 2 shows a portion of the Korean proposal. The proposed infrastructure entities are all subclasses of a new IfcCivilSpatialElement_K, whereas buildings, building storeys, and spaces are located currently in IFC as subclasses of IfcSpatialStructureElement.

Figure 2 Portion of Korean proposed schema extension for infrastructure (Moon 2014)



The PIM proposal

For the PIM research we have also chosen to extend the current version of the international standard for building information (IFC4, 2013) to include new infrastructure, vegetation, and cadastral entities. However, we have done so by generalizing man-made environmental spatial objects as built facilities, rather than distinguishing buildings (the current focus of IFC) from infrastructure and outdoor public spaces. Similarly, we propose that both building and infrastructure physical objects are generalized as built facility elements, meaning that objects such as columns and beams for example have equal applicability to bridges as they do to buildings when considered as vertical or horizontal-oriented load-bearing elements. A new vegetation object is proposed to be used in representing trees, shrubs, grasses, and other forms of vegetation as this is expected to find use particularly in urban heat island assessment applications. We also extend IFC with several new relationship entities that are used to record requirements as a means to preserve design intentions in the precinct information model. For sustainability metrics (including carbon) associated with precinct-level objects we use the existing IFC environmental indicators and environmental metrics property sets to address the CRC LCL's focus on carbon (these property sets have been added in the latest release of IFC after expert consultations within the European community).

Spatial entities

Our PIM proposal generalizes the entity IfcBuilding. A new entity called IfcBuiltFacility is proposed by the PIM team. Buildings can then be redefined as subtypes of this IfcBuiltFacility entity on an equal footing with infrastructure entities such as roads, railways, bridges, tunnels, and civic spaces.

The entity IfcBuildingStorey is also generalized. Building storeys are vertical subdivisions of a building, while many linear infrastructure entities such as roads and railways can be defined in terms of horizontal spatial segments. For example, a road is composed of segments (length of road between intersections) and the intersections themselves. Therefore, two new abstract entities are defined for vertical and horizontal sub-divisions of constructed entities, IfcVerticalSpatialDecomposition and IfcHorizontalSpatialDecomposition respectively. The existing entity IfcBuildingStorey is then relocated to be a subclass of the vertical subdivision concept IfcVerticalSpatialDecomposition. The horizontal segmentation issue for linear infrastructure elements such as roads and railways is addressed through the addition of two sub-classes under IfcHorizontalSpatialDecomposition: IfcSpatialSegment and IfcSpatialJunction.

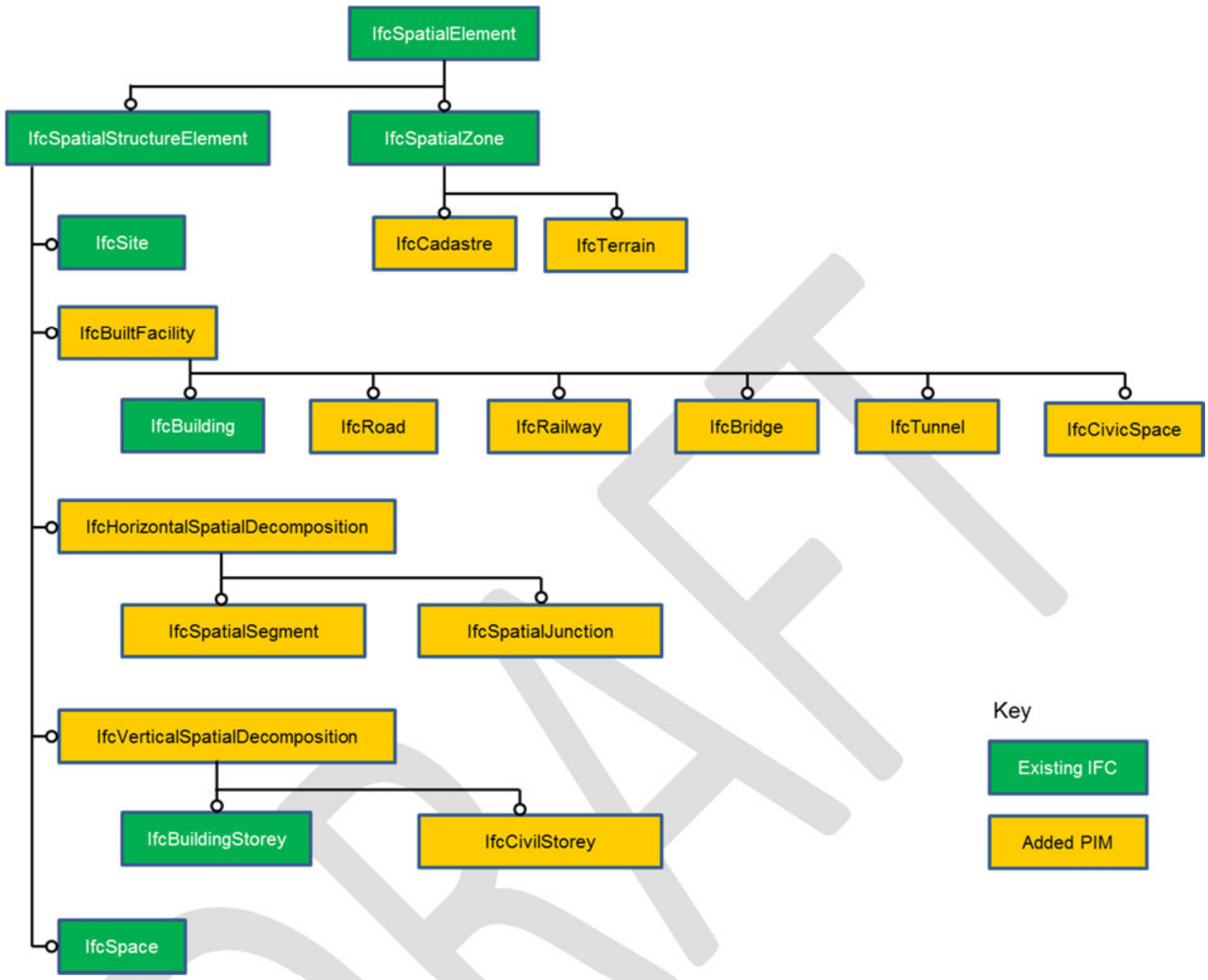
Cadastre entity

An important bridging concept between the urban- and building-level scales is the idea of a spatial zone. The IFC standard already has an entity, IfcSpatialZone that can be used for schematic planning. For example, instances of IfcSpatialZone can model land use areas as defined by local government authorities such as "Low Density Residential", "Light Industrial", or "Public Recreation". Development types within land use zones (eg. attached dwelling, airstrip, carpark, etc) can also be modelled as spatial zones. These more detailed spatial zones can be collected together as part of the containing land use zone using an IfcRelAggregates relationship. In this way, a hierarchy of precinct functional/spatial zones can be modelled. These concepts are explained in more detail in the document Orecinct Information Modelling Technical Investigations: Land Use and Development Types.

We propose the need for a new entity IfcCadastre as a subclass of IfcSpatialZone to hold the legal and spatial definition of property. In this way, cadastral entities at the building scale are the lots on which built facilities exist, and at the urban scale they are the fundamental spatial units of local environment and regional plans.

Figure 3 shows how the proposed entities fit within the existing IFC schema.

Figure 3 PIM schema for spatial entities

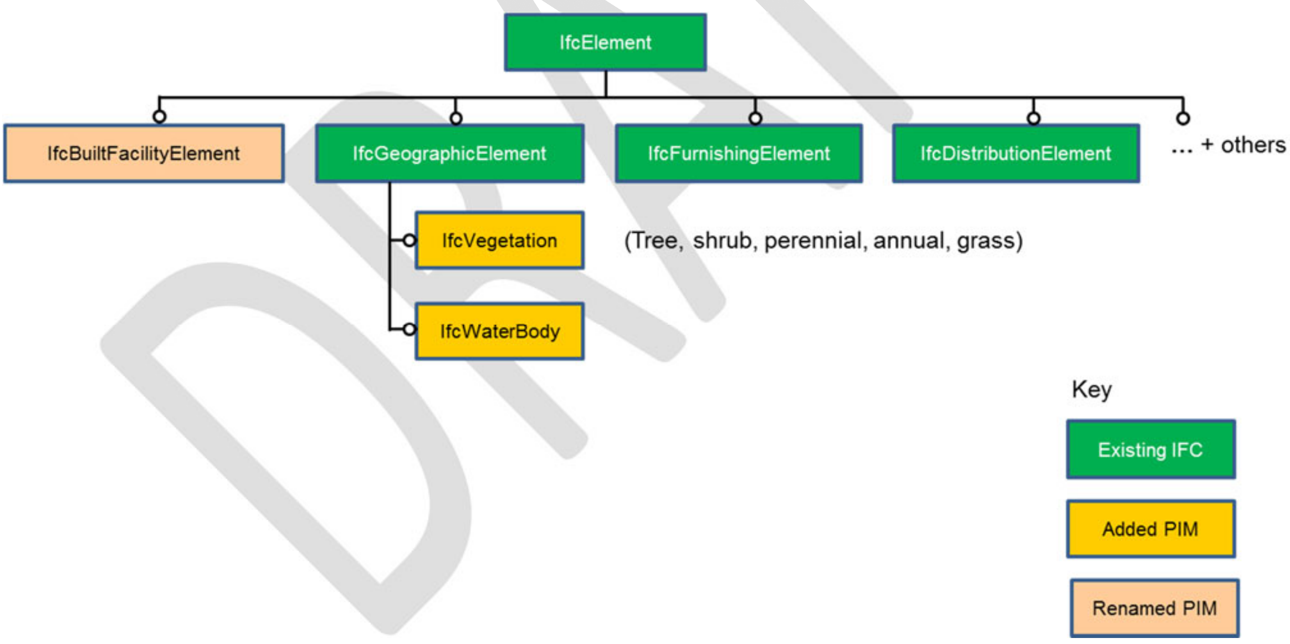


Physical entities

There is a clear distinction made in the IFC class hierarchy between spatial entities (IfcSpatialElement) and physical entities (IfcBuildingElement). As done for spatial entities, the PIM proposal is to generalize so that existing building-centric entities in IFC can equally be interpreted in an infrastructure or other precinct context where the functionality of the element is equivalent. For example, an IfcColumn is a vertical element, and an IfcBeam is a horizontal element, both of which support structure above. PIM therefore generalizes the abstract entity IfcBuildingElement to become IfcBuiltFacilityElement in order to be consistent with IfcBuiltFacility in the spatial class hierarchy. The existing IFC entity IfcCivilElement is deleted because, with the generalization due to IfcBuiltFacilityElement, it is now redundant. Where a new entity is required for infrastructure purposes that is not already covered by the existing IFC building elements, that entity will be added as a subclass of IfcBuiltFacilityElement. IFC also contains an entity at the same level as the IfcBuiltFacilityElement called IfcGeographicElement. This is intended as a catch-all for geographic features such as trees, light poles etc that in GIS occur as points on a map. For PIM, we have added two specializations of IfcGeographicElement: IfcVegetation and IfcWaterBody. IfcVegetation has an enumeration of predefined types - tree, shrub, perennjial, annual, grass – that corresponds to what our research has shown to be the way landscape architects categorise. Properties associated with IfcVegetation include height, spread, shading coefficient etc that will have particular relevance for use in urban heat island analyses. There are many possible types of IfcWaterBody so the choice of types for this entity is best handled using the same data dictionary approach as previously described. Some possible types relevant to precinct scale models include pond, canal, creek, river, lake, and bay.

Figure 4 shows how the proposed entities fit within the existing IFC schema. Other physical entities will only be proposed by the PIM team as subclasses of IfcElement where there is relevance to precinct-scale modelling and where there is a clearly defined difference in usage relative to the current set of entities.

Figure 4 PIM schema for physical entities



Property sets

The previous two sections described entities ("things"). When instantiated[1], these entities have unique identifiers, names, and ownership attributes but no other properties that relate to environmental metrics. In order to add this sort of data to entities we make a relationship (IfcRelDefinesByProperties) to a property set. The property set is a container for a group of properties that belong together under a common organising principle. There are already two property sets in IFC for environmental metrics that have been defined by expert consensus. These include properties that relate to carbon metrics, in addition to other energy, water and waste factors. The following two tables show these standard property sets in detail:

[1] The PIM schema is the definition of the information structure of entities."Instantiation" is when an instance of one of these entities is placed into a PIM model and one or more of its properties are filled in with data.

Pset_EnvironmentalImpactIndicators

Environmental impact indicators are related to a given “functional unit” (ISO 14040 concept). An example of a precinct-level functional unit is a "Dwelling house" and the unit to consider is "one square meter of floor area”. The first five properties capture the characteristics of the functional unit. There is an international consensus agreement for these first five. However, the rest of the indicators are not yet fully and formally agreed at the international level. Nevertheless, this property set is still very applicable for PIM purposes. As all the indicators achieve consensus, LCA software providers such as SimaPro and others will have a common interface through which to provide data, and designers/users will be able to confidently store and exchange data in an agreed format.

Table 1 Pset_EnvironmentalImpactIndicators

Property name	Property type	Data type	Description
Reference	Single value	IfcIdentifier	Reference ID for this specified type in the project model.
FunctionalUnitReference	Single value	IfcLabel	Reference to a database or a classification.
Unit	Single value	IfcText	The unit of the quantity the environmental indicators values are related with.
LifeCyclePhase	Enumerated value from: • Acquisition • Cradletosite • Deconstruction • Disposal • Disposaltransport • Growth • Installation • Maintenance • Manufacture • Occupancy • Operation • Procurement • Production • Productiontransport • Recovery • Refurbishment • Repair • Replacement • Transport • Usage • Waste • Wholelifecycle • UserDefined • NotDefined	IfcLabel	The whole life cycle or only a given phase from which environmental data are valid.
ExpectedServiceLife	Single value	IfcTimeMeasure	Expected service life in years.

TotalPrimaryEnergyConsumptionPerUnit	Single value	IfcEnergyMeasure	Quantity of energy used as defined in ISO21930:2007.
WaterConsumptionPerUnit	Single value	IfcVolumeMeasure	Quantity of water used.
HazardousWastePerUnit	Single value	IfcMassMeasure	Quantity of hazardous waste generated.
NonHazardousWastePerUnit	Single value	IfcMassMeasure	Quantity of non hazardous waste generated.
ClimateChangePerUnit	Single value	IfcMassMeasure	Quantity of greenhouse gases emitted calculated in equivalent CO_2.
AtmosphericAcidificationPerUnit	Single value	IfcMassMeasure	Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO_2.
RenewableEnergyConsumptionPerUnit	Single value	IfcEnergyMeasure	Quantity of renewable energy used as defined in ISO21930:2007.
NonRenewableEnergyConsumptionPerUnit	Single value	IfcEnergyMeasure	Quantity of non-renewable energy used as defined in ISO21930:2007.
ResourceDepletionPerUnit	Single value	IfcMassMeasure	Quantity of resources used calculated in equivalent antimony.
InertWastePerUnit	Single value	IfcMassMeasure	Quantity of inert waste generated.
RadioactiveWastePerUnit	Single value	IfcMassMeasure	Quantity of radioactive waste generated.
StratosphericOzoneLayerDestructionPerUnit	Single value	IfcMassMeasure	Quantity of gases destroying the stratospheric ozone layer calculated in equivalent CFC-R11.
PhotochemicalOzoneFormationPerUnit	Single value	IfcMassMeasure	Quantity of gases creating the photochemical ozone calculated in equivalent ethylene.
EutrophicationPerUnit	Single value	IfcMassMeasure	EutrophicationPerUnit: Quantity of eutrophicating compounds calculated in equivalent PO_4.

Some additional relevant properties are adopted for the PIM schema from the Sustainability Building Alliance Research Project and Ecospecifier as follows. Ultimately, these should be agreed and included in the above property set, but since that agreement is not currently the case the following additional property set (Pim_SustainabilityMetrics) is proposed as an interim standard for PIM usage.

Sustainable Building Alliance Research Project Metrics

Two standards are relevant:

EN 15804 EN 15804—2012 Sustainability of construction works, Environmental product declarations, Core rules for the product category of construction products

ISO 21930 ISO 21930:2007 Sustainability in building construction -- Environmental declaration of building products.

Table 2 Pim_SustainabilityMetrics

Property name (from SBA)	Property type	Data type	Description
A. Resource depletion			
Use of non-renewable primary energy	Single value	Functional equivalent kWh/m^2	

B. Indoor environment quality			
Thermal comfort	Single value	% time out of range	For summer and winter settings of minimum and maximum temperature
Indoor air quality	Single value	ppm	Concentration of CO_2 during the occupied period
	Single value	µg/m3	Formaldehyde concentration
C. Building emissions			
Global Warming Potential	Single value	Kg CO_2	Global warming potential according to IPCC 2001

Property name (from Ecospecifier)	Property type	Data type	Description
Human health	Single value	Green Tag HH EcoPoint	
Ecotoxicity	Single value	Green Tag Tox EcoPoint	
Biodiversity impacts	Single value	Green Tag BIOD EcoPoint	
Building synergy	Single value	Green Tag SYN EcoPoint	

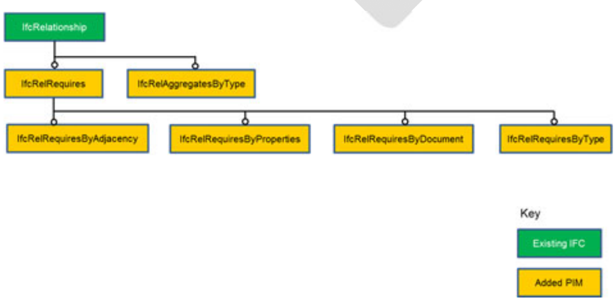
Requirements

An integral component of the design process for a product and the on-going use of that product is that it should satisfy requirements of various kinds. Requirements may come from the client who commissions the product, from current or representative potential users of the product, from the designers themselves, or from one or more regulatory authorities (for example, usage, quality, and safety standards). Briefing (or programming, as it is known in the US) is concerned with defining the context, vision and client requirements for a proposed project. Pena [4] refers to the goal of briefing as to 'state the problem'. Blyth and Worthington [5] distinguish the act, or process, of briefing, from the outputs of that process: 'briefing is the process by which options are reviewed and requirements articulated, whereas a brief is a product of that process'. In other words, briefing should be considered to be continuous throughout the process of designing. Wade [6] describes the inherent inter-connection of problem definition (briefing) with solution generation (design). To this end the PIM schema also includes the ability to record requirements (that is, design intentions, needs and wishes at any time during the lifecycle of the precinct from design through ongoing occupancy and evolution) within a precinct model. This is achieved through the definition of four new relationship entities as subclasses of a new abstract requirement relationship (IfcRelRequires) that is in turn a subclass of the existing abstract relationship class IfcRelationship (as shown in figure 5):

- Requirement by properties (IfcRelRequiresByProperties)
- Requirement by type (IfcRelRequiresByType)
- Requirement by external reference (IfcRelRequiresByDocument)
- Requirement by adjacency (IfcRelRequiresByAdjacency)

Another relationship (IfcRelAggregatesByType) is also proposed to allow for a shorthand method to indicate existing numbers of a type (for example, the current number of residents living in the precinct).

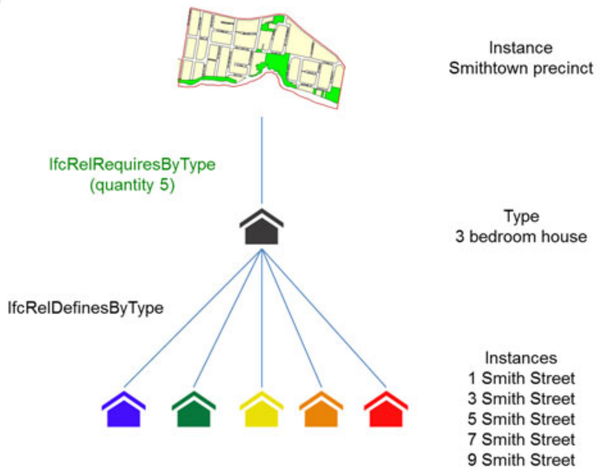
Figure 5 Requirement relationships



Requirement by type

The IFC (and therefore PIM) schema distinguishes types from instances. This is most easily explained using an analogy. A "3 bedroom house" is a type whereas "house at 1 Smith Street" and "house at 2 Smith Street" are actual individual instances of the generic "3 bedroom house" type in a precinct data model. The "3 bedroom house" type is defined as having a default floor area of 120 square metres. However, while "house at 1 Smith Street" is an instance of a "3 bedroom house", it is slightly smaller at 100 square metres. It is still a "3 bedroom house" though. Types are used in design briefing as generic placeholders for later instantiation of actual instances of the type, or as shorthand means to describe an existing situation. For example, here is a requirement for a quantity of the "3 bedroom house" type – "Provide 100 x 3 bedroom houses in the Smithtown precinct". This example shows a relationship for a required quantity between an instance object (the actual Smithtown precinct that exists in the PIM model as an IfcSpatialZone) and a type entity (the 3 bedroom house). Types can also be related to other types in the same way. The "3 bedroom house" type "contains" a quantity of 3 of the "bedroom" type, a quantity of 1 of the "kitchen" type, and so on. The IfcRelRequiresByType relationship contains an attribute for quantity and allows for linking a type to another type, or an instance to a type (but not the inverse - type to instance - as this is logically inconsistent). Validating the requirement is relatively easy at the completion of design, or subsequently, if the relevant relationships are used as shown in Figure 6. Because each instance is defined by its type, and because the quantity by type requirement links the precinct to the type, we just need to count the number of instances of the type and compare this against the quantity defined in the requirement.

Figure 6 Requirement by type (5 required / 5 achieved)

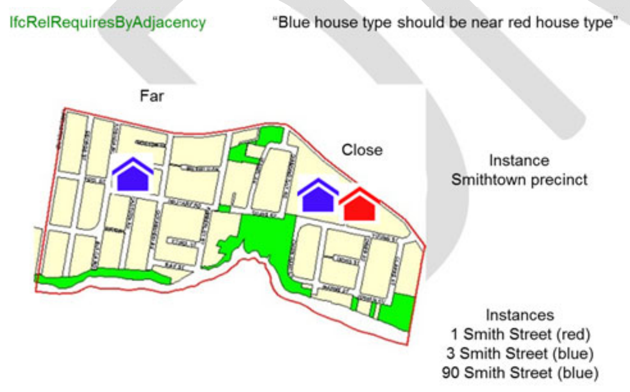


Requirement by adjacency

At an early briefing stage of design, requirements regarding adjacency are often expressed in words. The entities that are required to be adjacent (or apart) are named but do not yet have geometric definition. For example, in a precinct context, “the commercial zone should be adjacent to the main transport hub” or “the heavy industrial area must be located at least 5km from any residential area”. Both these statements indicate a topological relationship between two proposed land use zones. The zones can be defined in current IFC using the entity IfcSpatialZone (without associated geometry at first, but this can be added as design proceeds). The requirement could be expressed in IFC as an adjacency property in a property set associated with one of the two zones but that would mean that there would be no corresponding inverse adjacency property against the other zone. Using a relationship entity that is linked to each of the two zones to capture the adjacency requirement is a stronger means to capture the semantics of this statement. Furthermore, the IfcRelRequiresByAdjacency (that is in the PIM schema which extends IFC) is defined with an attribute to indicate the degree of adjacency required, so the “requirement level” of the clause can also be expressed.

An example for the use of this relationship in a CRC Low Carbon Living context might be to indicate a requirement for a tree type (IfcVegetationType) in close proximity to a civic space (IfcCivicSpace) to mitigate urban heat island effects. In this application, the adjacency requirement may be used together with the requirement by type relationship that could indicate the number of trees required. This use case can be further explored in association with the research project that is addressing urban heat island issues.

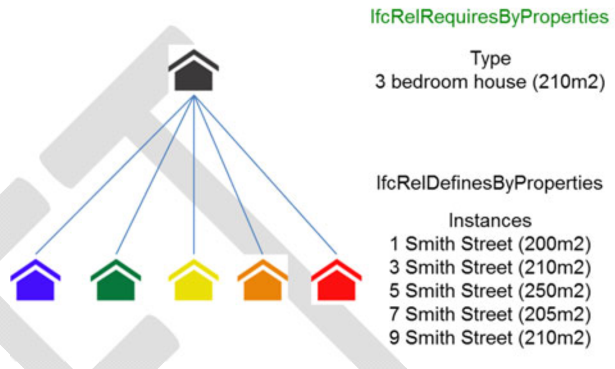
Figure 7 Requirement by adjacency



Requirement by properties

One way to state a requirement is by doing so using a qualifying property attached to an entity. For example, “a 3 bedroom house shall have a floor area of 210 square metres”. This can be done in IFC by including an area property in a property set with an IfcRelDefinesByProperties relationship to the building or building type entity. The area property could be named as RequiredArea, or alternatively, the property set can include “Requirements” in its name. However, an alternative construct is to use a specialized requirement relationship to link property sets to object instances or types, In this case, instances of standardized property sets can be understood as representing actual property values (‘definedbyproperties”) or required property values (“requiredbyproperties”) depending on the kind of relationship used to do the linking.

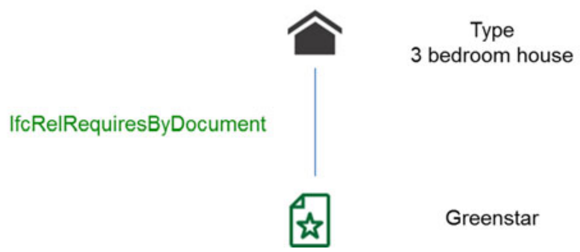
Figure 8 Requirement by properties



Requirement by reference

A requirement that is expressed as a reference to some source outside of the brief itself also can be instantiated using a relationship. In this case, IFC already has an IfcRelAssociatesDocument relationship that could be used, but if the same idea of qualifying the relationship as a requirement is applied, then both the explicit notion of “requirement” and the “requirement level” attribute can be expressed. For example, in the following statement the requirement level is a strong “need” relative to the external reference document – “the building shall be designed to comply with the Building Code of Australia”. This mechanism is one way in which design guidelines, standards, and rules can be associated with objects or object tpes in a PIM model. The extension proposed in the PIM schema for this type of requirement is IfcRelRequiresByDocument.

Figure 9 Requirement by reference



Summary

The work described here towards defining a PIM schema shows that relatively few extensions need to be added to the existing IFC schema in order to address precinct-level modelling. In particular, the PIM team have adopted a guiding principle that new entities are only proposed where absolutely necessary to clearly distinguish the function defined. For example, the additional infrastructure spatial entities that are needed for our CRC LCL context, because they contribute to the overall embodied carbon of a precinct, are proposed at the same level of the PIM schema hierarchy as buildings, all of which are defined equally as built facilities. Further detailed typing of entities is achieved by reference to the buildingSmart Data Dictionary. In this way, the PIM schema is concise and generically applicable. The concepts that have been identified so far through the PIM research work are equally relevant at scales larger than precinct-level. This is an area that may usefully be further tested and explored, expecially in relation to how broad scale and detailed scale modelling correlate across scales.

Reference

Blyth, A., Worthington, J., 2001. Managing the Brief for Better Design, 2001, Spon Press, London and New York.

Ecospecifier, 2016. GreenTag™ Certification. http://www.ecospecifier.com.au/certifications/green-tag-certification/

Huovila, P., Hyvärinen, J., Palos, S., Rekola, M., Chevalier, J., Fiès, B., Lebègue, E., 2012. Linking SBA metrics to IFCs and BIM. SB Alliance, France.

ISO 16739 (2013), Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. ISO TC184 SC4.

Lebegue, E., 2013. IFC-BRIDGE & IFC for Roads. buildingSMART Infrastructure Room.

Marchant, D., 2015. Capturing and integrating the design brief in building information models, PhD thesis, UNSW Australia.

Moon, H., 2014. Development of IfcRoad in Korea. Korea Institute of Civil Engineering and Building Technology.

Newton, P., Marchant, D., Mitchell, J., Plume, J., Seo, S., Roggema, R., 2013. Performance assessment of urban precinct design: A scoping study. CRC for Low Carbon Living, Sydney, Australia.

Pena, W., Caudill, W., Focke, J., 1977. Problem Seeking: An Architectural Programming Primer., Cahners Books International, Boston.

Wade, J., 1977. Architecture, Problems and Purposes. Wiley-Interscience, New York.