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Including stakeholder intent in precinct information models

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Abstract

Planning, building, and occupying a precinct, involves many stakeholders over significant periods of time. The development and evolution of the precinct is determined through decisions made by these stakeholders, jointly or singly, in response to perceived existing problems, or to satisfy anticipated future needs. The stakeholders are therefore all participating in an ongoing “design” process for the precinct. The current state of the precinct (its physical, social, psychological “fabric”) at any given time is a result of their cumulative decisions. However, the dynamic that drives the evolution of the precinct is expressed through stakeholder indicators of future intent (stated problems and/or aspirational visions).

Stakeholders come and go over the lifetime of a precinct. Their interests in, and perspectives regarding, the precinct vary, which means that the information they require or generate about the precinct also varies. Additionally, the software they use varies, so information has tended to remain in separate repositories (financial, urban planning, building design, and other specialities) This disaggregation of interest over time can lead to losses of information, miscommunication between stakeholders, and ultimately to a lack of any shared meaning about the precinct especially if the intent of stakeholders that has driven decisions is not retained.

The ongoing Precinct Information Modelling research project within the CRC for Low Carbon Living seeks to address the issue of information sharing for precincts. This paper describes the data entities defined in the author’s own research on design briefing that now have been appended to the proposed standardised PIM data schema to allow for this perceived need to integrate stakeholder intent.

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1. Introduction

A precinct is defined here as an identified area of land that contains a collection of natural and/or man-made features. The man-made features that the construction industry provides and maintains in precincts are built facilities: buildings, bridges, roads, railways, and other man-made structures and places. Many construction projects are now designed and managed digitally, and there is the emerging ability to locate and interact with that digital information from a shared (single or federated) data repository for the use of all of the participants in a design project [1]. Since, in practice, designers and authorities deal with many different product designs, so a single standard for structuring the data in these design models is desirable as a basis for common understanding, interpretation, and validation. A relevant data schema in the architecture / engineering / construction (AEC) domain is the ISO international standard Industry Foundation Classes (IFC) [2]. The development of IFC has to date focussed on buildings, but there are current international initiatives to extend IFC to address built facilities more generally, in particular infrastructure works. The precinct information modelling research project [3] within the Australian CRC for Low Carbon Living is one such initiative, albeit focussed on the low carbon aspects across the life-cycle of a built facility product from planning and design through into its operational use.

The precinct, its constituent man-made features, and the many subcomponents of those features, are all “products”. 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 building 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).

In a building and infrastructure construction environment where risk can be high, profit margins are generally low, and communication fragmented, integration around a shared understanding of the building project should help to reduce waste caused by misunderstandings and lost information. Kiviniemi [7] describes that during the process of design, construction, and use, requirements direct the provision of solutions, but those chosen solutions can also affect the formulation of further requirements, or force a rethink of the original requirements. This intimate link between requirements and solutions occurs for decision-making at every scale of resolution from the precinct considered as a whole, through to every individual component of that precinct.

The delivery times for a building project within a precinct can be relatively long (years) and the occupancy and use of that precinct can be even longer (many decades). Therefore, we propose that an integrated record of design intent along with the description of the design can serve to aid the understanding of the many interested parties who come and go over the full course of a precinct’s lifecycle. This paper, then, describes how a digital precinct information model can contain both requirement and solution information. While designing, the requirement information can be used in a forward-chaining manner: requirement statements form the brief for decisions yet to be made. Post the design phase, by retaining the requirements related to the solutions in the information model, means that the design intent (the “why is it so”) is preserved which can help understanding with regard to future changes over time during use and development of the precinct.

2. An extended data schema for requirements in a precinct information model

The PIM research project has adopted the IFC data schema as a basis for extension to a precinct scale. The approach taken has been to generalize existing building-specific entity definitions to become “built facility”. This means that “building” becomes just one of many possible types of built facility. Other constructed objects such as bridges, roads, and railways can then also be modeled with geometry and properties in just the same way that buildings alone have been modeled previously. The PIM-related extensions to the IFC schema are proposed in such a way that the fundamental class hierarchy of IFC is not disrupted, meaning that existing uses of IFC can continue

without modification. Similarly, based on previous work [8], the extensions proposed for the addition of requirements into the schema are also non-disruptive. This is achieved through the definition of 4 new relationship entities as subclasses of a proposed abstract requirement relationship (IfcRelRequires) that is in turn a subclass of the existing abstract relationship class (IfcRelationship):

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

A new aggregation by type relationship (IfcRelAggregatesByType) is also proposed to allow for a shorthand method to indicate existing numbers of a type. It is defined as a direct subclass of IfcRelationship.

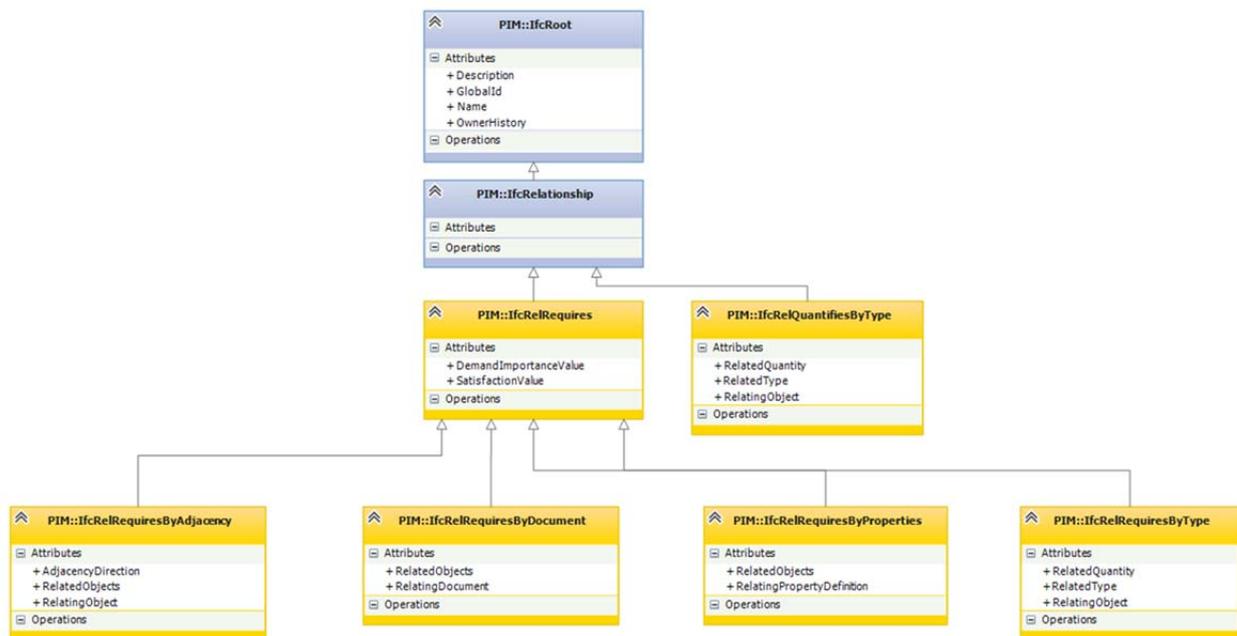


Fig. 1. Proposed relationship entities – subclasses of IfcRelationship (shown in gold)

2.1. Requirement by type

The IFC (and therefore PIM) schema distinguishes types from instances. This is most easily explained using an animal analogy. A “dog” is a type whereas “Fido” and “Spot” are individual instances of the generic “dog” type. The “dog” type may be defined as having 4 legs and a tail. However, while “Fido” is an instance of a “dog”, he has only 3 legs and no tail. He is still a “dog” 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 a particular building type – “Provide 100 x 3 bedroom houses in the Smithtown precinct”. This example shows a relationship for a required quantity between an instance entity (the actual Smithtown precinct) 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 2. 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.

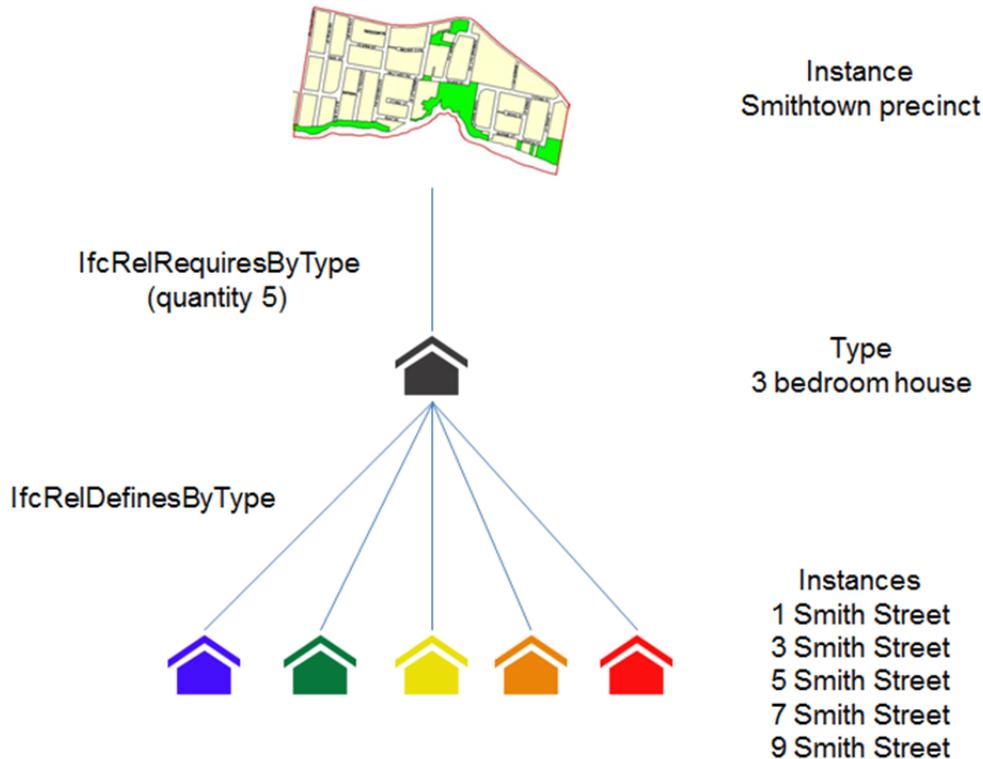


Fig. 2. Validating a requirement by type (quantity of 5 required, count of 5 achieved)

2.2. 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.

2.3. Requirement by property

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 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. The BPie [9] initiative has standardized some property sets for briefing using the property set naming methodology. 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.

2.4. 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”. The extension proposed in the PIM schema for this type of requirement is *IfcRelRequiresByDocument*.

3. Working implementation

Extending the IFC schema to become a PIM schema that includes the ability to edit and store requirements has implications for existing IFC-based software. Existing software tools only support the official published IFC standard. The PIM schema does not break any of the existing schema structure, but it does add additional class definitions for infrastructure and requirements, therefore in order to show how the extended PIM schema can add value for users, it has been necessary to create a new PIMViewer application. This software has built upon the open source xBIM Toolkit [10] by extending that software’s set of base classes. This allows the PIM extensions to be parsed, displayed graphically, and also detailed in an extended set of data panels. Figure 3 shows the PIMViewer software interface in which a user has selected a particular site (in the graphical view this site is highlighted in dark blue towards the back of the view, and it is also highlighted in the spatial view panel at top left). The requirements pane (bottom left) shows 3 example requirements for this site: by document; by properties; and by type. Using an interface such as this, the user is able to understand particular requirements for this site fully in the context of the existing, surrounding precinct.

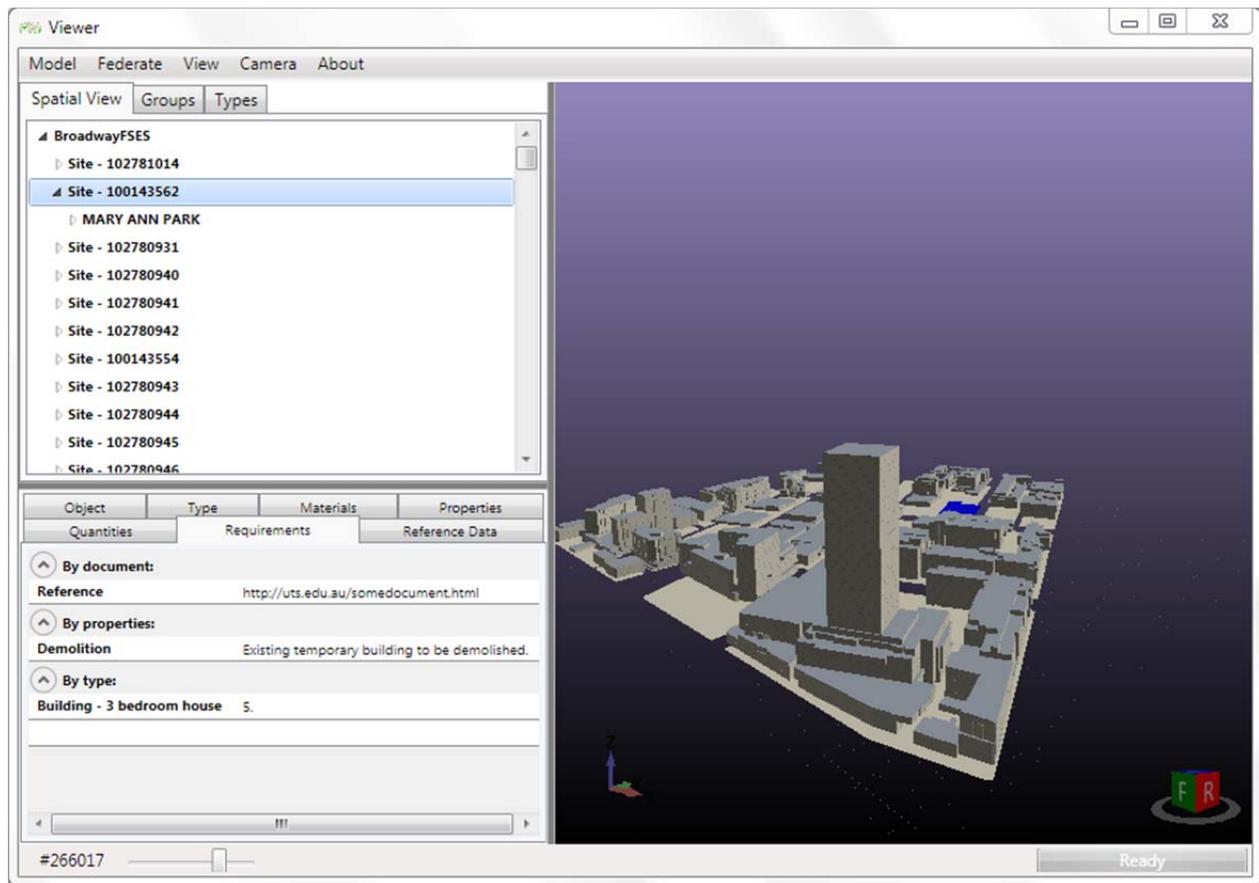


Fig. 3. PIMViewer application showing example requirements for a site

4. Conclusion

The design, construction, and occupancy of buildings (and even more so, of precincts) occur over long periods of time relative to the human participants in that lifecycle who have involvement only at particular stages of development. Intermittent involvement of this kind in any process has the potential to lose knowledge along the way, especially at handovers between predominant interest groups at each stage - for example briefing-to-design, design-to-construction, construction-to-occupancy. The stated intention of product-related standards like IFC is that they are standards which address the whole lifecycle of the product. However, Burry et al [11] point to the 'silomenality inherent to the construction industry' and as a consequence to perceived problems with the disaggregated datasets that are currently in use. In particular, they list 'limited functionality for validation across a range of related (yet often not yet interconnected) datasets'. The inclusion of requirement relationships into the PIM schema is one suggested way in which to interconnect two disparate sets of information that have traditionally been kept in such separate silos.

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