Developing Modelling Skills to aligning a 'Real World': Data Specification to the TC211 Family of Draft Standards

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ABSTRACT

As the complex and comprehensive ISO TC211 family of standards for geographic information (GI) gradually moves towards ratification, there is increasing interest in identifying the skills needed to easily apply these standards during `real world' projects. In this paper is described our experiences of upskilling an experienced group of GI modellers while they apply relevant ISO TC211 standards to the task of producing a data specification. These modellers moved from the traditional modelling tools and techniques associated with GIS such as Entity Relationship Diagrams, to those tools and techniques fundamental to the TC211 family of standards, the Unified Modelling Language (UML), and new frameworks for quality evaluation and metadata. The overall conclusion reached by all concerned was that the substantial and on going investment in upskilling was beneficial in terms of producing a more complete, meaningful and rigorous data specification.

***Keywords and phrases*:** Standards, TC211, Modelling, UML, Application Schema, ESA Project.

1 INTRODUCTION

Recently, four experienced data modellers used the new ISO 19100 series of standards to guide and inform the modelling of a core data set to be shared among a variety of Crown agencies concerned with emergency services and administration. A brief description of the modellers, the ISO 19100 series of standards, and of the project in which they were involved is presented in Section 2. In this paper is discussed the modellers' experiences in coming to terms with the modelling methodology and constructs defined by the ISO 19100 series of standards and the Unifed Modeling Language (UML). Section 3 is a discussion of the modelling approach that evolved, and an evaluation of this approach in terms of what worked, what didn't work, and why. The next section, is a discussion of the ERD modelling skills that did or did not assist in the application of the ISO 19100 series of standards. This discussion includes a description of new skills that were developed as a consequence of using the ISO 19100 series of standards, and of skills that could have been developed that may have been beneficial to the project. Section 5 is a discussion of the relationship between the ISO 19100 series of standards and the modellers' existing understanding of CASE tools and Geograqphical Information Systems (GIS). Finally, in Section 6 is presented some insights into modelling with the ISO 19100 series of standards that may assist other modellers considering the application of these standards to other projects. Also presented are conclusions about the efficacy of the standards for this particular project and the modelling approach adopted.

2 BACKGROUND

2.1 The Emergency Services and Administration Core Data Specification Project

The National Topographic Hydrographic Authority (NTHA) is a regulatory business unit of Land Information New Zealand (LINZ). NTHA leads an inter-agency programme (sponsored by the Officials' Committee for Geospatial Information) to improve particular core Crown geospatial data which is used for Emergency Services responses and other core Crown Administrative functions; known as ESA data.

The modeling efforts discussed in this paper contribute to the project focused upon rationalization of core spatial data/systems within the e-Government programme by gaining a thorough understanding and complete specification of the set of the common core Crown data. These data included dwelling numbers or identifiers, road names and network and all types of named geographical features (natural and built). More specifically, the goal of the modelling efforts was to design a specification for core Crown data to be used principally for the functions of locate and verify in the contexts of emergency services and government administration. An important aspect of the project was to employ internationally recognized standards, such as the ISO 19100 series of standards, where ever possible to avoid reinventing the wheel and to be comparable to similar initiatives worldwide. The longer-term goal being to leverage on open standards to facilitate increased availability, access, integration, and sharing of core geographic information.

2.2 ISO 19100 Series of Standards for Geographical Information

The ISO 19100 series of standards were developed to standardize geographic information and services for processing this information. In doing so, the goals were to (ISO 19101, pg vi): increase the understanding and usage of geographic information; increase the availability, access, integration, and sharing of geographic information; promote the efficient, effective, and economic use of digital geographic information and associated hardware and software systems; contribute to a unified approach to addressing global ecological and humanitarian problem.

To achieve these goals, standardization of geographic information in the ISO 19100 series is based on the integration of the concepts of geographic information with those of information technology. The ISO19100 series of standards for geographic information comprises various elements, each having a separate standard within the series as shown in Table 1 (new work items have been created at the 13th Plenary in Adelaide).

Code	Title of Standard
19101	Reference model
19102	(Retired at 13th Plenary in Adelaide)
19103	Conceptual schema language
19104	Terminology
19105	Conformance and testing
19106	Profiles
19107	Spatial schema
19108	Temporal schema
19109	Rules for application schema
19110	Feature cataloguing methodology
19111	Spatial referencing by coordinates
19112	Spatial referencing by geographic identifiers
19113	Quality principles
19114	Quality evaluation procedures
19115	Metadata
19117	Portrayal
19118	Encoding
19119	Services

Code	Title of Standard
19120	Functional standards + new revision started
19121	Imagery and gridded data
19122	Qualifications and certification of personnel
19123	Schema for coverage geometry and functions
19124	Imagery and gridded data components
19125-1	Simple feature access – Part 1 Common architecture
19125-2	Simple feature access – Part 2
19125-3	Simple feature access – Part 3
19126	Profile – FACC Data Dictionary
19127	Geodetic codes and parameters
19128	Web map server interface
19129	Imagery, gridded and coverage data framework
19130	Sensor and data models for imagery and gridded data

Table 1 ISO Codes and titles of standards in the ISO 19100 series for geographic information

The majority of these standards remain in a draft form. The underpinning concepts for these standards are defined in ISO19101. For example, conceptual modelling is defined to be 'the process of creating an abstract description of some portion of the real world and/or a set of related concepts' (ISO19101, clause 7.2). and is employed by the ISO 19100 series of standards for two purposes:

1) to provide a rigorous definition of geographic information and geographic information services.

2) To standardize the definition of geographic information and geographic information services so that software systems interoperate in distributed computing environments.

The general approach to using these standards is defined by ISO19101 (clause 7).

From a practical point of view, our goal was to define a conceptual schema for an application that supports the locate and verify functions associated with emergency services and Crown administration. Such an application schema is to be constructed in accordance to the rules defined by ISO 19109 and contains features, 'the fundamental unit of geographic information…an abstraction of real world phenomena' (ISO19101, 7.1) which are defined with 'respect to their representation in data structures defined by the application schema'. The application schema is expressed using the conceptual modelling language defined by ISO 19103. This language is based upon the Unified Modelling Language (UML) which is described in ISO 19103 and extended through the definition of, for example, stereotypes such as <<CodeList>>, and <<Leaf>> (ISO 10103, 6.8) . Only the class diagrams and the Object Constraint Language (OCL) components of the UML are used. ISO 19103 also contains naming conventions for UML elements, such as (ISO 19103, 6.10):

1) Combine multiple words needed to form precise and understandable names without using intervening characters (such as "_", "-",or space).

2) For attributes and operation names, association roles, and parameters capitalize only the first letter of each word after the first word that is combined in a name. Capitalize the first letter of the first word for each name of a class, package, type-specification and association names.

An important element to the development of an application schema is the use of modules (classes) defined by schemas in standards such as ISO 19107 (Spatial Schema), ISO 19108 (Temporal schema), ISO 19113 (Quality Principles), ISO 19114 (Quality evaluation procedures), and ISO 19115 (Metadata). Thus, application schemas contain a package diagram in which is documented the dependencies between the package containing the application schema and the packages containing the conceptual schemas defined by various ISO19100 standards.

2.3 The Modellers

The four modellers involved in the project came from Private Enterprise, Public Administration, and Academia. Collectively, they had significant experience in GIS, Entity Relationship (E-R) Modelling, and Spatially Extended E-R modelling. Only one had experience with object oriented modelling using UML. Anecdotal evidence would suggest that people engaged in and practising GIS vary greatly in their knowledge of data.

The modellers were aware of the simplicity of geographic data modelling that comes about through the discrete nature of the data. They were also experienced in the effective representation of the complexity of Geographic data modelling that comes about through the need to adequately express spatial relationships between these discrete data sets and the expression of the spatial derivation of new data sets from existing data.

The modellers were aware of difficulties in representing dependencies between spatial data in traditional ER models. These dependencies included specifying that the geometry of a particular feature must connect in a particular way to the geometry of another feature, the modification of a particular feature relative to the modification of another feature upon which it is dependant, and the ability for different features to share the same geometry. Such dependencies are typically documented as part of the narrative description associated business rules.

2.4 The ESA Application Schema

The ESA application schema comprises over 80 distinct classes and occupies at least three A3 pages and is accompanied by a document over 200 pages. This is publicly available at the following URL:

http://www.linz.govt.nz/services/topo-hydro/pages/topo/documentation/documentation.html

From this page there are two links, one to the ESA Core Data Specification and another to the ESA Application Schema. To provide an austere overview of this model a couple of diagrams are presented in Figures 1 and 2. In Figure 1 is shown a simplified class diagram to illustrate the top of the class hierarchy used to define geographic features. All features are expected to have some properties in common and they are defined in the Feature class

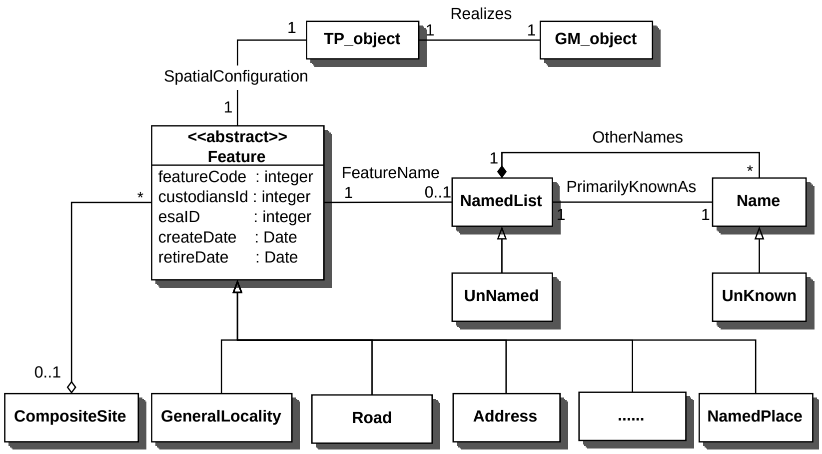

Figure 1: A simplified illustration of the feature class hierarchy used in the ESA Application Schema

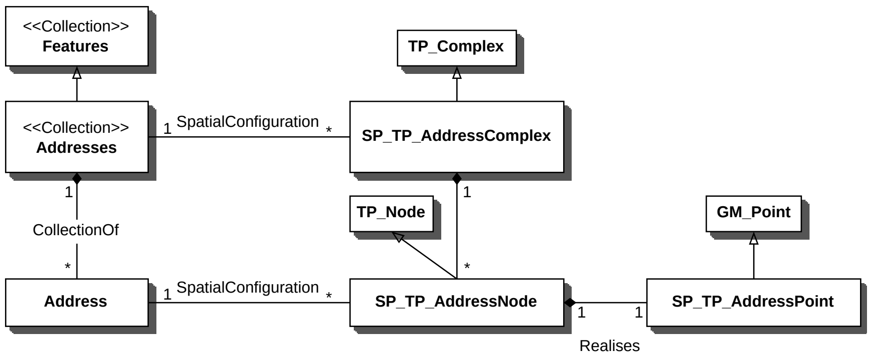

Figure 2: A simplified illustration of the spatial configuration for an Address in the ESA Application Schema

from which all other types of features are subclassed. The spatial aspect of any feature is specified by defining a spatial configuration. To illustrate, the spatial configuration for the Address feature is given in Figure 2 and includes both a topological and geometric definition. Note also the definition of collection objects in which features are stored. These collections provide access points by which features may be queried using a language such as the Object Query Language (OQL) (Cattell *et al*, 2000).

3 MODELLING APPROACH

In this section is described the approach recommended within the ISO19100 series of standards for developing an application schema (Section 3.1) and the approach that evolved as the ESA Application Schema was developed (Section 3.2). Some observations are described in Section 3.3 on the differences between the two approaches.

3.1 Approach recommended in ISO19100 Series of standards

In ISO 19103 there is a recommended sequece of phases for modelling. This sequence is (ISO 19103, clause C.2): **Phase 0**: Identify scope and context; **Phase 1** Identify basic classes; **Phase 1b:** Check that the modelling being done is consistent with the approach described in the rules for application schema document (ISO 19109); **Phase 2:** Specify relationships, attributes and operations; **Phase 3:** Completion of constraints using text/OCL.

Another explanation of the application modelling process is provided in ISO 19109 (8.1). This explanation is in terms of a stepwise process consisting of the following steps:

1) Surveying the requirements from the intended field of application (Universe of Discourse)

2) Making a conceptual model of the application wth concepts defined in the General Feature Model. This task consists of identifying feature types, their properties and constraints.

3) Describing the application schema in a formal modelling language (for example UML) according to rules defined in this International Standard [ISO 19109].

4) Integrating the formal application schema with other standardized schemas, for example spatial schema, quality schema, into a complete application schema.

3.2 Approach evolved during development of the ESA Application Schema

The ESA application schema was developed in an iterative manner with each loop comprising

1) A group of data specialists from the Emergency Services and participating governmental administration agencies meeting on a regular basis in order to (a) review the additions and refinements made to existing elements of the schema in light of previous working group meetings, and (b) to discuss and define the requirements to be captured in a new aspect of the schema.

2) A period of modelling during which the modellers:

   a. Creating the classes that represented instances of the real world business phenomena and for each defining properties that described the important real world characteristics that were needed for the locate and verify functions within the ESA context of the project as discussed by the working group. There were two aspects to creating these classes

      - Identifying the required features and their non spatial characteristics that are necessary for supporting the locate and verify functions.
      - Examining each feature and determining the most appropriate spatial representation. Initially each feature having a spatial representation was associated with the classes GM_Primitive and TP_Primitive from the spatial schema (ISO 19107) to represent both the geometric (GM) and topological (TP) aspects of the spatial representation respectively. These primitive classes were replaced in time with one or more, more specific, subclasses as the ESA spatial schema evolved. Furthermore, the spatial representation of each feature was linked to other spatial representations of related features.

   b. reviewed and modified the schema in light of feedback from the working group, and to generalise and specialise the constituent elements to unify and simplify the schema. Consideration was given to properties, especially enumerations where representing each value of the enumeration as a subclass may be a better option. The desired contents of the feature catalogue will be a guide to good decisions. The schema was reviewed and modified constantly in light of their increasing appreciation of the ISO 19100 series of standards and how best to apply them to specific issues addressed within the schema.

   c. testing of the application schema by ensuring that real use case scenarios reflectng the locate and verify functions could be achieved using the structures defined by the application schema being developed.

Some activities of our aproach are discussed in more detail below.

3.2.1 Insights gained from developing an application schema

Predictably, the development of the application schema involved developing both the spatial and non spatial aspects of the features required to support the locate and verify functions. An effort was made to concentrate on the non spatial aspect of the schema in order to think beyond polygons, lines, and points and to consider what features were needed and how they were related. This more holistic perspective seemed to be more in keeping with ensuring that user requirements were met by the application schema being developed, the ISO 19100 series of standards, and in particular was seen as being important to facilitate the development of a feature catalogue.

Once the features had been identified, describing the spatial schema became the focus of attention. There are two approaches, bottom up and top down, that could be taken and the modellers tried them both. The Bottom Up approach starts by working with the "protons and neutrons" and working upward to eventually construct the Geometry required to record the graphical representation of the class (e.g. how primitive points combine to eventually for, say, a surface containing holes). This causes the modeller to think more carefully and examine all the options available to them. It is likely that this is the most robust style of the two. The top down approach starts by working with the geometry or topology that the modeller intuitively knows will best suit the graphical representation of the class and working downward to construct the components that they are comprised of. Both methods were shown to work and it may just come down to a matter of style, choice and experience.

The modellers were also able to model structures that allowed different graphical representations to optionally share the same geometry. The standard prescribes classes for geometry but does not let you instantiate them. Instead you must create your own similar class and realise the GM or TP class in the standard (e.g. MyGM_Polygon realises GM_Polygon). If MyGM_Polygon was created as an abstract class with a number of subclasses ChurchGM_Polygon, HistoricBuildingGM_Polygon etc., the that would allow for one instance of the geometry to be a church or an historic building or both. An example from the project would be a meshblock which is a polygon consisting of lines, some of which share the geometry of road centrelines. Should the geometry of road centrelines be spatially updated then the meshblocks should move with them.

While many conformance tests are defined by the ISO 19100 series of standards, these test are concerned with ensuring that the application schema conforms with the standards, rather than ensuring that the application schema satisfied the users' requirements. Thus, the modelliers applied another construct provided by UML, Use Cases and Use Case Scenarios, to achieve the latter goal.

3.2.2 Testing using Use Case Scenarios

The application schema was tested through the creation of Use Case Scenarios using real data (both supplied by the users). The austere Use Case Diagram created for testing purposes had a single Use Case representing the locate and verify functions to be supported by the application schema. This lack of a comprehensive use case analysis was, in hindsight, a recognised weakness of the earlier phase in which user requirements were gathered. Members of the working group provided historical examples of specific locate and verify functions that they required to be supported by the application schema and these historical examples formed the basis for a variety of use case scenarios that were used to test the application schema.

For each use case scenario, the application schema was tested by determining whether an appropriate object diagram could be created to show how the data structures within the application schema could (a) represent the data used in the scenario and (b) how this data would be linked. This allowed the formulation of queries to illustrate how the required data could be extracted from an imaginary database having a structure defined by the application schema.

3.3 Insights and reflections upon adopted approach

When establishing associations in general, the modeller needs to decide whether the associations established between classes are done so through a derivation or are established on an instance by instance basis by an operator using a keyboard or mouse. It is important to understand this and communicate it clearly in the conceptual model so that the correct intention is implemented later. Derivations are clearly identified using the standard by prefixing the derivation name with a "/". At a conceptual level the modeller will generally need to decide whether the derivation is transient or persistent. If persistent, then a new class needs to be defined. Persistent derivations are likely to be needed for a variety of reasons. Examples would include performance (eg the suburbs containing an address), where the derivation is likely to be used for further derivations (eg a derivation of soil strength zones requires further overlay with buildings or planning zones), where the derivation is a complex sequence of spatial overlays and formulae needed to be run in a set sequence (eg a derivation that identifies Road Owners), or as frequently happens in the spatial arena where the derivation needs some ad-hoc intervention after the derivation to tidy up the data.

Prior to this the classes that represent the collections of the instances will need to be added to the model along with a TP_Primitive class for each. This is needed to ensure that the appropriate associations are attached to the correct classes and are navigable in the required direction. Testing the scenarios certainly assisted in defining the required spatial derivations between topological classes.

The modellers found that testing the application schema using object diagrams can also lead to discovering some unstated requirements (in this case one related to character set issues). Discussions with the reviewer during the peer review showed that the use case had had a marked effect on the conceptual design when this model was compared to a model of similar business objects for an Australian project.

Testing the application schema by applying various use case scenarios was found to be effective in highlighting errors in the application schema. At times, testing needed to be tempered by the realization that the application schema was intended to act as a conduit through which the necessary data would be merged and was not intended to define a high performance data structure by which locate and verify queries could be answered. Use of object diagrams was found to be beneficial beyond the testing process as they were also an effective mechanism for explaining how the class diagrams of the application schema related to real data values. Illustrating this relationship often clarified discussions associated with deciding upon the structure of the application schema.

As an application schema develops into a reasonably complex specification, issues associated with change control become important. Simple matters of version control and ensuring all changes were consistently applied throughout the schema required care and was greatly assisted through the use of a case tool.

4 MODELLING SKILLS

The modellers involved with the development had a long history (at least 35+ years collectively) in modelling with Entity Relationship Diagrams and with relational databases. This experience needed to be extended to encompass the different perspective needed to model with objects and more specifically with the UML used by the ISO 19100 series of standards.

A number of skills that are used in E-R modelling did transfer well into the OOM environment. One area of note is the acute attention to the language of the Users. An awareness of the Nouns, Adjectives and Verbs that get thrown around in the conversation can be of enormous insight to the modeller in sorting out the classes, properties and associations. In OOM these skills seems now even more important. In the E-R world the verbs indicated a relationship and gave it a name - nothing more was required. In the OO world the verbs used can give an indication of the type of association, whether it is derived, spatial, an aggregation or composition, the direction of navigability and so forth. Attention must also be paid much more closely to the adjectives used, as they can become a property, a subtype or an enumeration class (limited list).

Conversely, skills that don't migrate as well include persistent identifiers, primary-foreign key links, tables (instead of instances and collections), and normalisation. While the rules and procedures of normalisation in the relational world are difficult to apply, those modellers who use techniques that ensure their conceptual E-R design is normalised as they go, will find those techniques just as valuable in the Object world.

Our experience suggests that data modelling works best when carried out in group sessions where users with expert knowledge of their domain can contribute to the design and buy into the change. This was evident during working group meetings where members, some of whom were E-R data modellers in their own right, also critically commented on the parts of data model that had been created outside of these sessions. To comment effectively these people needed to understand UML notation and conventions: therefore, a session was presented to the working group to introduce the basic constructs within UML. Predictably, people without an understanding of UML had more trouble comprehending the model expressed in UML than they might have had if the model had of been expressed as an E-R diagram.

During the modelling process, modellers made a small number of UML convention "mistakes". One of these was the informal use of colour. The standard separates out the use of various different types of class through the use of naming conventions. An example of this is the Geometry classes, which are prefixed with 'GM_'. Interestingly, naming conventions are one area where the standard does not always comply with UML convention The standard does not suggest the use of colour. The past experience of the modellers is that colour can be very effective in clarifying and communicating the design. The modellers were in the habit of identifying geometric and topological classes or distinguishing version control changes with an informal use of colour. This is one area where the standard could improve. In UML, however, semantic meaning can be attached to the use of colour in a class diagram.

Another area was the conscious decision not to use the Object Constraint Language (OCL) for expressing business rules and other constraints among classes within the application schema. In a spatial database, the discrete nature of spatial objects means that many of the associations will be spatially derived. Such derivations should be specified in OCL. It was the opinion of the modellers, that had OCL been learnt and used, very few people in the country would in fact have been able to read it. It would have failed as a communication tool. The modellers instead chose to describe the derivation as narrative text in the notes of an operation. It does raise the issue of how prescriptive a conceptual model should be. Do you simply say that this class or association is derivable or do you prescribe how it is derived, bearing in mind that there may be other, perhaps better ways of performing the derivation. The structure of the model is in itself very prescriptive. To simply say that an association is derivable without saying how is somewhat glib. A narrative that indicates how it might, rather than must, be derived is a nice compromise.

5 MODELLING WITH THE ISO 19100 SERIES

The application of UML and the spatial schema specified by the standards proved to the data modellers that the more demanding and complex aspects detailed above could be meaningfully modelled and specified in a more comprehensive way than existing tools and skills permitted. The modellers were unable to determine if the mediocre fit between the CASE tool used in the project was due to not having a full knowledge of the capabilities of the CASE Tool or whether the CASE tool did not fully comply with the requirements of UML and the Standard. It is likely that both of these cases are true and there is an opportunity for more research in this area.

The key principles embodied in their current approaches are embedded in the standard. However the standard is a document that requires a great deal of interpretation. The quality of any data model will depend on the quality of the interpretation of the standard. A difficulty the modellers faced was how to measure whether their interpretation was a good one and of knowing what the implications were of a not-so-good interpretation. This is an area that would benefit from further research.

In coming to terms with the standard the modellers went through a number of iterations in the way ideas were being expressed. As different parts of the model were developed at different times this meant inconsistencies in the way the ideas were expressed occurred across the model despite efforts of the modellers to apply such changes across the model. It also meant that ideas were often tried, discarded and then resurrected weeks later as another aspect of the standard was discovered. The complexity of the standards meant that the representation of the spatial schema required considerable thought and investigation before deciding upon an appropriate approach very late into the time available. No doubt the model produced could be further refined as a consequence of further time in which to reflect.

The modellers to various degrees, took time to come to terms with envisaging the implications of the standard. Their existing GIS paradigms were tested to various degrees when it came to conceptually relating the standard to the use of their day-to-day tools, how and whether models created in a UML Case Tool central repository could be translated to a Relational or Object-Relational database. It is not altogether obvious how vendors will bridge the gaps between the existing products and the standard, or how they will integrate their products with UML case tools. It is less obvious how GIS practitioners will bridge the gaps between their current knowledge and paradigms and the 'alien' requirements of the new standard, particularly where they have not had contact with any academic environment. How the vendors bridge the gaps between their products once they meet the new standards and their customers (without alienating them) will be interesting to watch.

6 CONCLUSIONS

In our opinion to create an application schema that conforms with the ISO 19100 series of standards would be extremely difficult without a comprehensive understanding of UML and object oriented modelling and design. Likewise, understanding the semantics encoded within the ISO 19100 series of standards would be difficult without considerable experience and expertise in geographical information science. A very close collaboration between these different disciplines will be required to facilitate future development of meaningful real world application schemas.

In hindsight, the slowness that the team experienced in coming to terms with satisfactorily expressing the spatial schema and its associations was influenced by a lack of communication between the GIS and OO modellers (in both directions). Both groups experienced frustration in the joint exercise of not adequately using UML opportunities and not adequately expressing spatial ideas. It is very clear that this is an area that needs to be bridged early if using this standard for a conceptual model is to be contemplated. Once bridged, the outcome was that all modellers were very pleased with the performance of UML as a notation, the standard as a robust specification, and most importantly, the model as an accurate expression of their abstraction of the real world. It was in the end a very satisfying experience.

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