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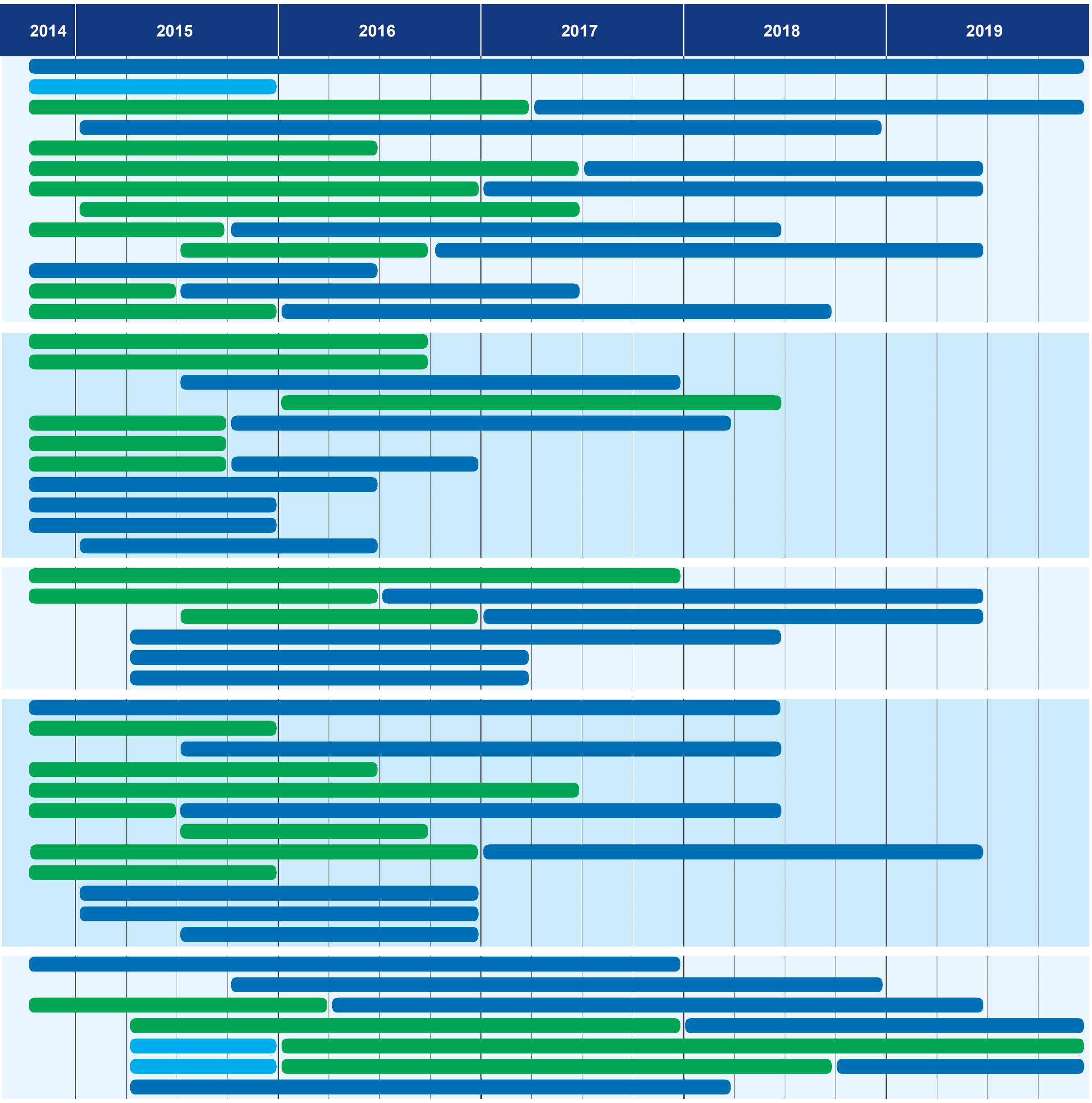
Project 2.33 New Project Management Structures: Position Paper 2

Network Asset Management Intervention:

Designing CONie
(Construction to Operations for Networks information exchange)
for Australian and New Zealand Roads



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Introduction

The computerisation of the workplace has been enabled by the development of digital systems for information exchange. Design, construction and operations of all types of infrastructure, especially road networks, utilise a variety of information communication technologies (ICT). Many of these technologies have been developed as open standards that provide a common digital environment for proprietary software and systems.

At the forefront of the ICT revolution is the ability to visualise built environment objects using building information modelling (BIM) and spatial standards based on Geographic Markup Language (GML).

ISO16739 the Open BIM Standard

The development of ISO16739 is accomplished through buildingSMART, an international organisation of representatives from AEC firms, Owners, Suppliers and Software providers. These stakeholders share a belief in open standards being developed by working together in a common community (bSi, 2015). BuildingSMART facilitates the development and deployment of open standards for the building industry via local international chapters.

After more than thirty years of work globally, in a number of different projects, the building industry has developed a robust ISO standard for the expression of detailed information across the entire project life-cycle. ISO16739 *Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries* was up-dated based on IFC4 in 2013 (ISO16739, 2013).

BuildingSMART has developed a suite of internationally accepted standards. Together, three essentials support a digital information exchange:

1. Industry Foundation Class (IFC) is a common language and an unique information standard that most software applications can use.
2. International Framework Dictionary (IFD) is an object dictionary.
3. Information Delivery Manual (IDM) is a framework that describes what information should be transferred.

IFC developed as an information exchange and interoperability standard for software in the building design, engineering, and construction sector.

IFC aims to maximize the semantic possibilities for representation of their model. To ensure that the schema does not lock in a limiting view of construction there are many highly flexible approaches built into the schema.

Three examples of this flexibility can be seen in geometric modelling, relationship objectification, and property set definition.

First, software systems used to view building information in two- or three-dimensions will have made a variety of internal decisions about their product's native geometric representation. Such decisions aim to optimise rendering speed, storage requirements, or other criteria. IFC allows any these native representations to be provided, however, this feature does not mean that such an IFC file can be easily used by a software system having an alternative native representation.

The second example is that of objectified relationships. The use of objectified relationships allows for great flexibility in the forms of relationship which can exist between and among objects at the cost of efficiency of navigation by passing through the objectified relationships rather than directly to a related object. Confusing the matter is that property inheritance through these relationships is not precisely defined in IFC.

The third example is that the development and exchange of Property Set extensions is critical for regional adoption of IFC in a given contractual context. Without *a priori* agreement about the use of these non-standard, "standard" extensions the information required is likely to be lost during a given exchange of information over the course of the project.

It is more complex for some Model View Definitions (MVD) since it is not necessarily the case that a MVD mandates mapping to a unified schema across all software systems. For example, the long-standard MVD supporting use-cases related to design coordination has as its purpose as the exchange of geometric information to minimize the potential for field change orders resulting from the physical collision of objects in three dimensions.

The Importance of Location: ISO 19100

Another set of ISO standards are those pertaining to geographic information systems. This family of standards falls under the ISO19100 umbrella. The major sections of this standard pertain to Geographic Information Services, Data Administration, and Data Models and Operators (Jakobsson & Giversen, 2007).

ISO19100 aims to define the semantics and structure of information and the computerized services needed to use these objects. These services are included in ISO19100: file formats and naming, procedure calls, search and query algorithms, visualization methods and software, and interoperability.

The Geographic Markup Language (GML) is the most applicable standard with the ISO19100 family. It delivers information about geographic information among project partners and development of this standard is extremely active with over 60 countries participating.

GML is an XML-based schema that aims to provide an open format for geographic information exchange. The principle purpose is to increase the ability of organizations to share geographic application information. The specification of GML defines a set of standard XML entities for spatial features, geometric types, and links to match features with geometry.

Similar to ISO16739, GML requires a domain-specific schema for use of GML in specific contexts. GML supports interoperability by allowing many different authors to overlay data, through linking, to the same defined set of geometric (i.e. physical) entities.

As a general purpose geographic modelling language there continues to be research into the applicability of GML for widespread use. The mutual work between buildingSMART and OGC is addressing three important issues when developing applications using GML.

The relative value of different data storage schemas including direct file storage, relational, or object-oriented databases. This means the use of different XML reading and searching algorithms, each of which may have a significant impact on performance. Visualization of GML data in native, browser-based, or phone-based tools may have an impact on the way in which the information is most easily (and quickly) viewed. Thus, specifications for system-to-system interactions, using the current technology *web services*, requires discussion of information exchange and automated conformance testing.

One application schema has achieved widespread international use for modelling infrastructure is CityGML. It provides semantics for the *basic entities, attributes, and relations of a 3D city model* (OGC, 2011). Sophisticated users of CityGML view the standard as a *data integration platform* for technical, social, and economic information. This is allowed since there is one geometric model that can be layered with information from domains as diverse as *tourism, navigation, mapping, real estate management, architecture, environmental, facility management, and training* (OGC, 2012b).

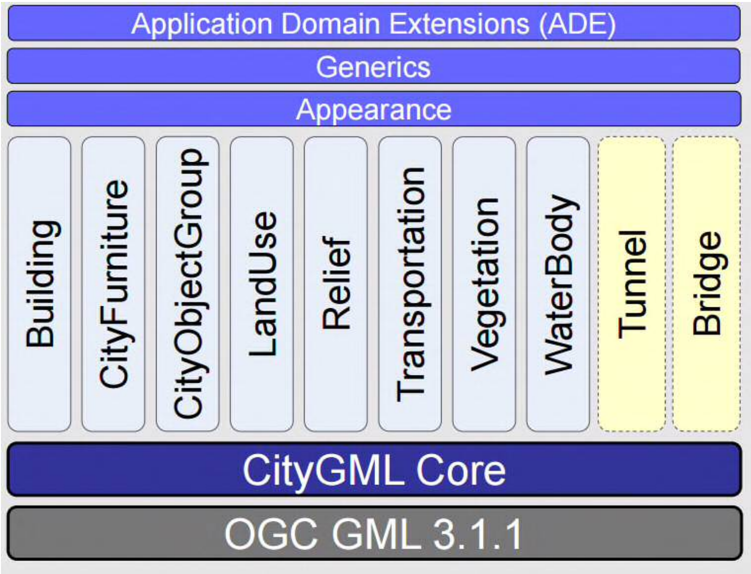

Figure 1. Modular Structure of CityGML (Kolbe & Nagel, 2011)

Figure 1 illustrates the modular structure of CityGML. Based on the GML standard, CityGML adds specific semantics for many of the objects found in city infrastructure. An important feature of CityGML is its ability to define the Level of Detail (LOD) associated with a given portion of a model (Valencia *et al.,* 2015). There are five Levels of Detail (LOD) in CItyGML (Kolbe & Nagel, 2011):

LOD 0 – Regional Model: Digital Terrain Model
LOD 1 – Block Model: bounding boxes for city objects only
LOD 2 - Textured Block Model: external gross shapes with relevant textures
LOD 3 – Exterior Architectural Model: shows doors, windows, exterior structure
LOD 4 – Interior Model: A “walkable” interior model.

The BIM models also use the nomenclature of Level of Detail (LOD), however, the series 100-400 is used for the design of all elements of buildings (BIM Forum, 2013). Comparing the quality of the information IFC and CityGML provides relative value information of each approach in different situations. While the IFC model provides detailed geometry as well as engineering and construction information about a facility (including occluded objects), the CityGML model is focused only on observable surfaces (van Berlo & de Laat 2010). So IFC shows the constructive solid geometry: volumetric, parametric primitives representing the components of buildings. Whereas CityGML shows the boundary representation: an accumulation of observable surfaces of topographic features.

These distinctions are illustrated in Figure 2. For example, engineering properties of an IFC object in a BIM model have a place to require and store such information. One the other hand, if location is the only concern, then the surfaces of the wall only need to be provided.

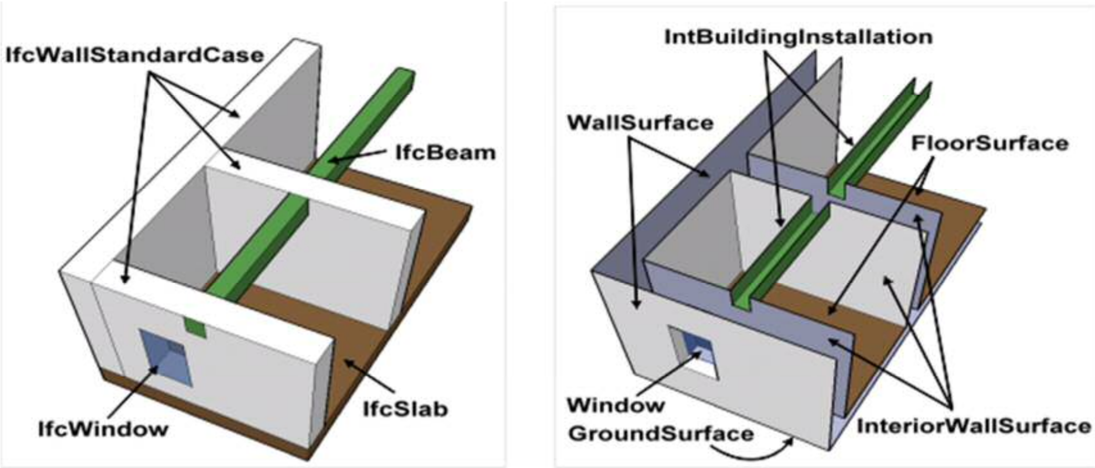

Figure 2. Comparison between IFC (left) and 3D GIS (right) geometry modelling paradigms (van Berlo & de Laat, 2010)

Capturing Road Location Data: InfraGML

The rich semantics of IFC supporting the planning, design, construction, and facility management domains is not found in the native GML or the application-specific CityGML, however, another project InfraGML aims to bridge this gap.

LandXML was initially the basis of development of spatial data. However, since 2009, it has not been formally supported by an organization that develops standards (van Berlo & de Laat, 2010). This is because LandXML has been reported to have several problematic issues with respect to consistent schema design (Scarponcini, 2014).

Inadequate Object Specification; Non-Standard Schema Documentation; Incorrect Choice Specifications; Inconsistent Data Typing (for Stations); Weak Data Typing (for Points); Nation Optionality Inconsistency; Case Inconsistencies; Use of Plural names; Inadequate Identifier Specification; Inconsistent Schema Extensions Guidance.
In addition, due to concerns by OGC about LandXML ownership, the Open Geospatial Consortium has proposed a new specification InfraGML that will supersede LandXML.

Accordingly, a joint BuildingSMART/OGC project commenced in September 2014, to bring together the two worlds of IFC object libraries and OGC standards into a common Unified Modelling Language (West & Kenley, 2014).

The plan means developing a new standard. The OGC InfraGML Encoding Standard provides a subset of LandXML functionality, but will be implemented with the OGC Geography Markup Language (GML) and supported by a UML (Unified Modelling Language) conceptual model.

InfraGML is being explicitly designed to be compatible with the more detailed engineering information standards, ISO16739 specification, developed by buildingSMART international (van Berlo & de Laat, 2010). Thus, the rich semantics of IFC (supporting the planning, design, construction, and facility management domains) not found in the native GML or the application-specific CityGML, will be integral to infraGML.

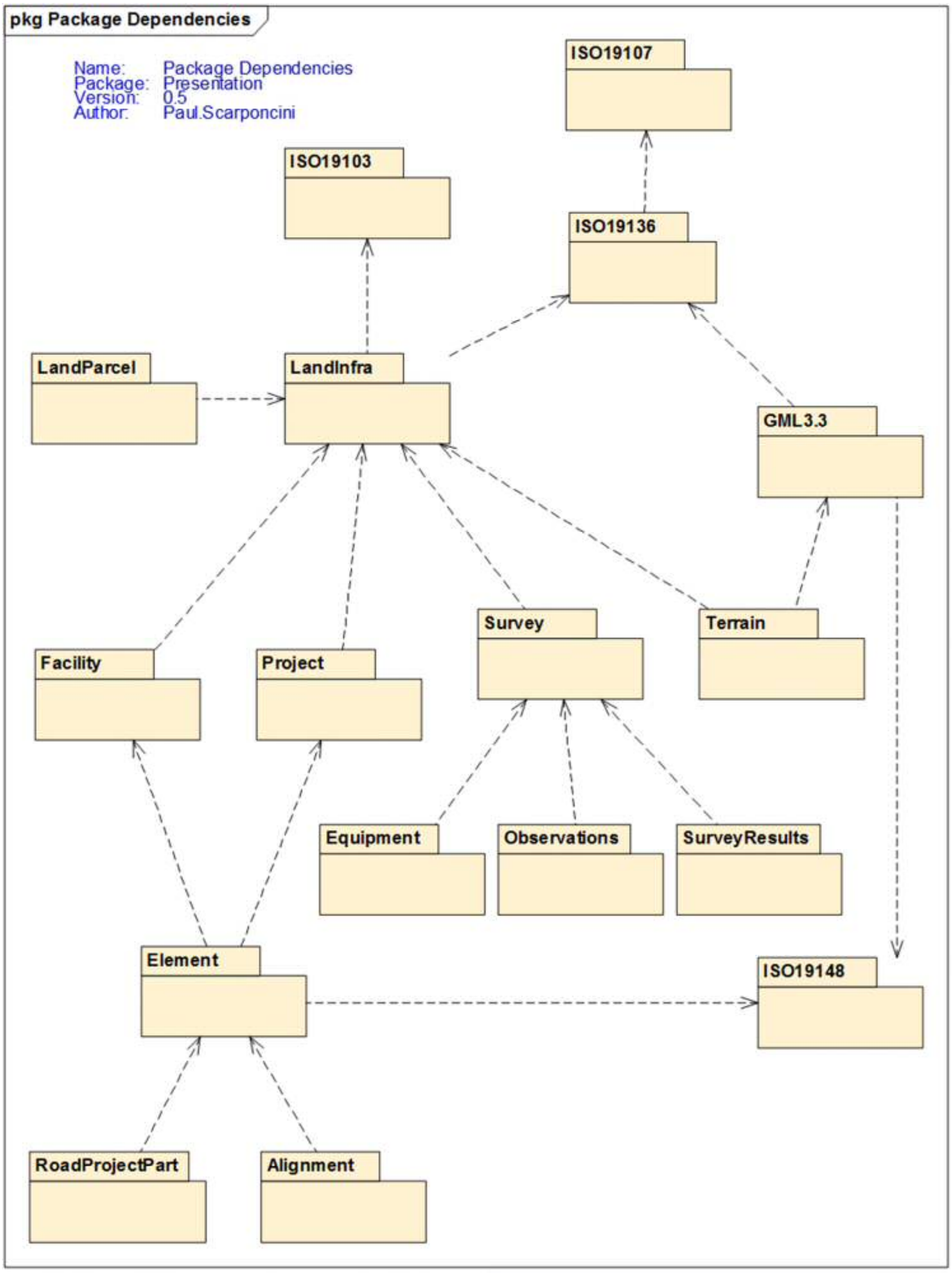

Figure 3. Top-Level InfraGML Objects (Scarponcini, 2014)

The foundations for InfraGML are based on the Unified Modeling Language (UML) diagrams that provide a standard-neutral view of the domain. Having a high-level description of the domain is critical since a meta-model will support the precise comparison of the representational choices made by previous standards (Amann *et al.,* 2015a).

InfraGML is comprised of four top level objects: Facilities, Projects, Surveys, and Terrain as shown in Figure 3. Within these classes of objects are a given set of attributes and subclasses that help to understand the scope of the InfraGML project. Figure 4 provides a list of these high level object class attributes.

The work is proceeding through combined efforts of participating global committee members (Bormann & Liebich, 2016). The first InfraGML is for road alignment includes the development of a specification for the exact geometric positioning of cross sections (Amann *et al*., 2015b). Given that both the IFC-INFRA and InfraGML projects are being developed to support 100% of the data specified in the UML diagrams, 100% interoperability is expected between STEP-based and GML-based data standards to represent infrastructure project information. LandInfra has horizontal infrastructure Rail development input.

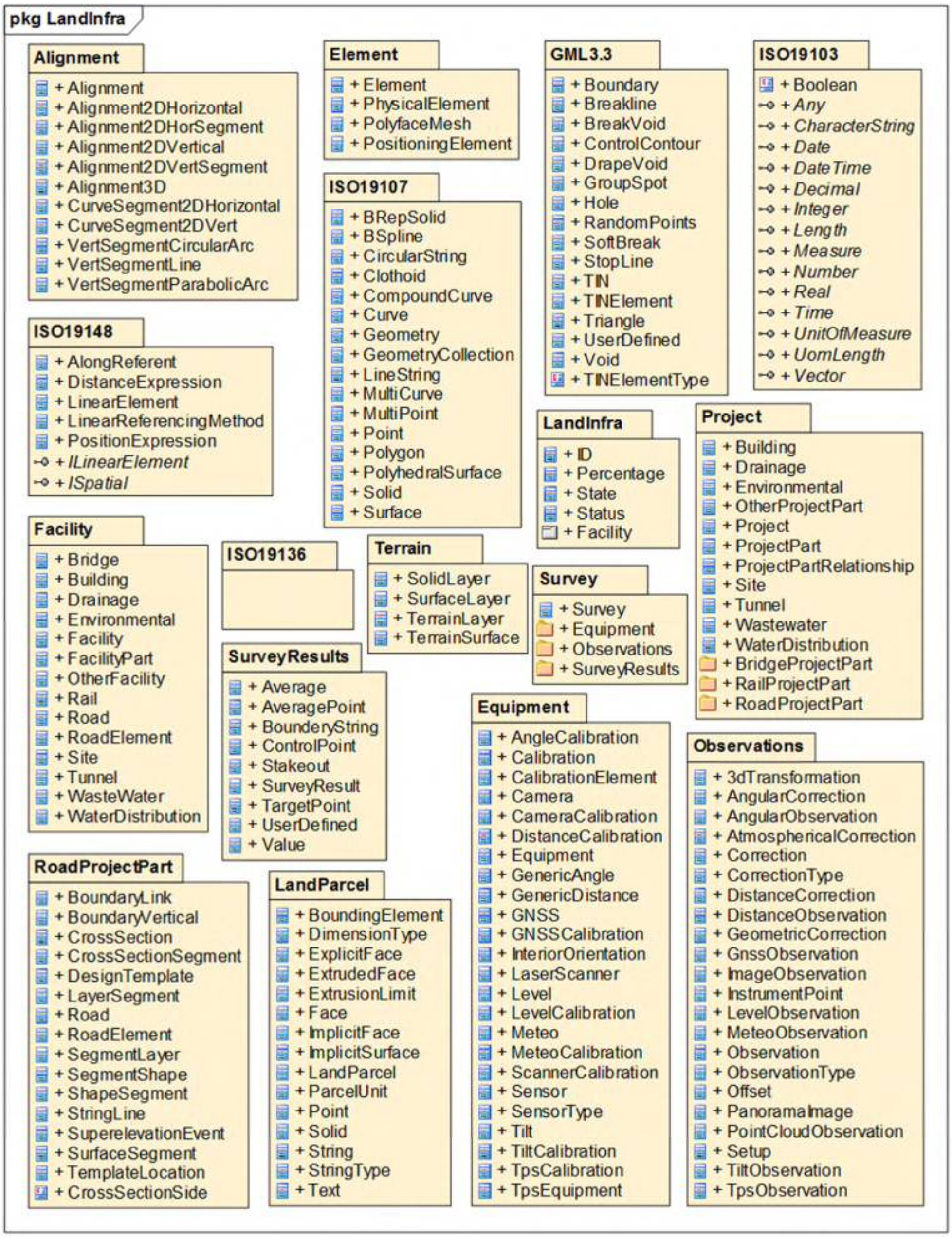

Figure 4. InfraGML Object Attributes (Scarponcini, 2014)

As noted in Figure 4, construction and operations of roads are included in the packages. The ongoing IFC/OGC projects will provide road agencies with current international standards.

IFC-Alignment: An Incremental Approach to the Large Problem

Currently buildingSmart chapters globally are continuing the development of a related set of specifications for horizontal infrastructure projects (Liebich, 2013).

The first of these specifications Alignment has been developed and was approved as a Building Smart International extension to IFC-4. The first step towards a standard that is more inclusive of horizontal infrastructure was made publicly available in August 2015 as a bSi Final Standard (http://www.buildingsmart-tech.org/infrastructure/projects/alignment).

The Alignment extension of IFC4 thus becomes an important building-block for the second group level of horizontal IFC extensions; roads, rail, bridges, and tunnels. They all share a common central set of information related to the layout of those assets as shown in Figure 5.

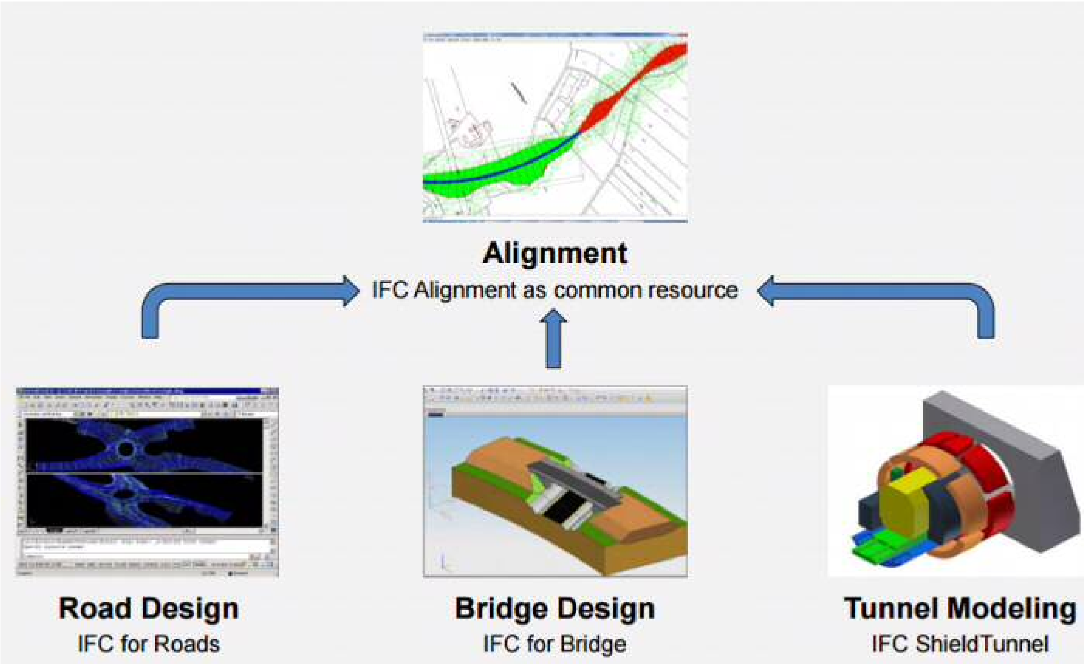

Figure 5. Alignment as Common Resource (Liebich, 2015)

The IFC-Alignment project combines the traditional horizontal and vertical curves and cross-section profiles used to define the layout of these assets. It is taking some time to develop and define the schema for roads and bridges. One of the main issues to be faced with these infrastructure open standards development projects is the merging of data based on different scales of measurement.

For example, at the project engineering and construction level of detail, precise information about cut and fill calculation, pavement volumes and properties for each batch of material provided are all needed. For managing a project, the level of detail required is only general information. And at the planning stage information is only needed about network properties.

Thus, authoritative information at the required level of details is needed before Model View Definitions will enable a growth in digital environments for horizontal infrastructure information exchanges (Liebich, 2013). However, the model view is only part of the picture. The utility of any model is based on the ability to exchange information.

Information Exchange for Horizontal Infrastructure

In recent years, efforts for construction productivity driven by smarter information use have focused on the development of Building Information Modelling (BIM) (Love *et al.,* 2015) and integrated design processes as the digital solution (Steel *et al.,* 2012; Gu & London, 2010). This effort has resulted in digitally enabled structures, standards and tools, led by a number of not-for-profit groups working to design and develop open source standards such as buildingSMART and the Open Geospatial Consortium (OGC). These are captured within discrete international standards under the auspices of the International Standards Organization (ISO).

BIM represents one of the key innovations in the Built Environment discipline. Pressure is being brought to bear on the construction industry to adopt BIM, and the associated open standards, on all public infrastructure projects (Guo *et al.,* 2010). Consequently, our road agency partners are under pressure to seek ways to improve the use of digital information from their design models under the symbol of “BIM”.

BIM advocates often fail to understand the ontological (Agarwal, 2005; Smith & Mark, 2001) design differences between vertical infrastructure and horizontal infrastructure, (Utiome, 2015; Drogemuller, 2009) thereby placing the adoption of BIM by road agencies at risk. Building Information Models are important for smarter use of data, so it is critical not to merely adopting existing tools – for example COBie for buildings – but to develop tools appropriate for their type of infrastructure – for example CONie (*Construction to Operations for Networks information exchange*) for roads.

Identification of the intervention point at <u>handover</u> will give both clients and providers the opportunity to reduce waste for asset management and maintenance. Handover is the least considered construction phase, but it can be considered as the most important with the growing emphasis on Asset Management for road networks. The new data management model, CONie, will be designed to remove process waste from both individual projects and portfolios of projects.

Handover: The Need for New Information Exchange Specification

A review of historical construction project pdf files found that:

1. they were unreadable with storage devices currently installed on computers
2. they were unreadable due to errors in creating the media
3. unsearchable files comprised of thousands of image-based pages
4. unfiltered information containing unneeded chain of authorship information
5. the information contained in the pdf files was inconsistently organized.

These findings clearly show that delivering electronic data without properly addressing the context of that exchange makes them unusable. If it is more difficult to retrieve information either, through browse or dedicated searching, then keeping information in paper format still remains the best option.

Innovative technologies such as BIM hold the promise to eliminate the paper from all construction phases, including Asset Management. Yet, all solutions for infrastructure asset networks must, for at least a generation, maintain the link to paper documents for which designers and contractors are paid according to contracts (Larson & Golden, 2007).

Construction Contracts: Imposing BIM Interoperability Issues

In the BIM enabled world, the term “interoperability” has gained favour as one way to describe information exchange. Some examples of what interoperability could provide are:

1. Protection of Investments
    a. Data documentation, data quality
    b. Avoidance of duplication
    c. Independence from industry standards

2. Improved collaboration
    a. Within large organizations with many departments
    b. Easier to share, exchange, and integrate data
    c. Relationships with clients becomes easier
3. Customer requirements
4. Legislative requirements
5. Best practices, learn from others
6. Support of research.

Unfortunately, the selection of the term "interoperability" carries significant connotations that cannot actually be met by simply defining a standard data exchange format. At present, the major constraint to interoperability is the legal basis for contractual deliverables of design, engineering, and construction information.

Although the legal issues constrain BIM as a global construction industry standard, there are still many reasons to establish **common information exchange standards**. What is currently possible to provide is a performance-based specification to replace current document-centred contract deliverables (East, 2010).

A Small Contract-Based Intervention: A Relational Database

At the core of virtually all maintenance management systems is a relational database that allows multiple-service and work orders to be assigned to different resources, and tracked over time.

Relational database technology is the mainstay of all corporate information management due to its standardization, reliability, and ubiquity.

Relational database systems are often designed in a three-layer architecture with an underlying "model" of the world that is stored and maintained in the database. Currently maintenance management systems for building projects rely on databases, regardless of the way the information is visually presented to the user.

A study in the use of databases for infrastructure management found that the information is easy to maintain, flexible to up-date, and practicable for data collection both via computer imagery and in the field (Proulx *et al.,* 2014). The basic requirement for all project or portfolio management is systematic data storage to keep information up-to-date to support decision-making.

An important feature of an integrated asset management databases is the ability to integrate legacy data with objectively-measured asset information (Aktan & Moon, 2006). Legacy data is particularly important for the growing use of life-cycle costing for infrastructure assets. Thus the quality of the original data needs to be considered for:

1. suitability of data for purpose
2. scale
3. accuracy of information that is able to be objectively measured.

An essential consequence of developing a database is to deliver a **simple model that can be understood by many people with different occupations, levels of knowledge and desired outcomes**. Such databases are currently the mainstay of Asset Management for road networks (Austroads AP-204, 2002). Indeed, the asset management of roads databases have been and continue to be a resource that is the focus of continuous improvement. For example, the Austroads *Harmonisation of Location Referencing for Related Data Collection* study suggests that the cost of collecting infrastructure asset information via computerized data collection methods may be able to eliminate the need for manual data collection (Austroads AP-T190-11, 2011).

However, the commonly suggested solution to computerised data collection, BIM, is itself the focus of continuous improvement, as it attempts to become a global standard for vertical infrastructure asset management (Kenley & Harfield 2014).

CONie Enables Actual Information Exchange

A major driver of the development of information technology is the move away from single, centrally defined and managed data systems. The development of cheap and reliable computing power provides the foundation for distributed systems of information that manage an entire organization. This in turn supports purpose-built applications that may be plugged into the organizational infrastructure.

To enable these applications to function there must be specific instructions about the data/information flows between systems. Such rules allow specific information to be maintained as the "data of record" in one system and used, and augmented in other systems that contain additional authoritative information.

Some systems support such exchanges, others may not. For any exchange, two types of specifications are required:

1. content of the information to be exchanged
2. how information is to be addressed, formatted, and sent through the Internet.

There are several competing and complementary current and under development standards, related to highway networks. Understanding the requirements for horizontal infrastructure (Kenley & Harfield, 2014) means that lessons learned in the development of open standards that enable life-cycle road asset management (Guo *et al*., 2010) provide the foundation for Creating a CONie (*construction to operations for networks information exchange*).

CONie: Turning Hand-Over into an Information Exchange

Handover is the least considered construction phase, but it can be considered as the most important with the growing emphasis on Asset Management for road networks. Thus, identification of the intervention point at hand-over will give both clients and providers the opportunity to reduce waste for asset and maintenance management processes.

As a new data management tool, CONie, will be designed to exchange information for both individual projects and portfolios of projects. CONie specification format is based on the need for members of the construction community to interact with as-built construction information in a way that they would accept, i.e. spreadsheets. Thus any type of network asset management system will be able to read some of the provided information.

CONie will be a model-view specification that can be used for exporting digital asset information from the design phase, together with further information regarding installed assets and provided to the network owner in a purely electronic form. The export format is to be independent of the design platform or technology in use. Similarly, the specification provides a schema for importing asset information into the clients' asset management system for operational utilization turning handover into **Information Exchange**.

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Project Partners

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