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GIS (geospatial) / BIM interoperability

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 59, *Buildings and civil engineering works*, Subcommittee SC 13, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The complexity of information needed to support decisions relating to built assets by the public and private sectors as well as by citizens, require digitally enabled practices based upon interoperable systems. Indeed, the decisions that are needed over a built asset's life cycle and across its different stages rely on these complex sets of information. Moreover, these decisions are made by a multitude of actors that perform information-processing activities such as data creation, capture, transformation, and analysis, and are embodied in project and asset management practices as defined in existing and emerging standards.

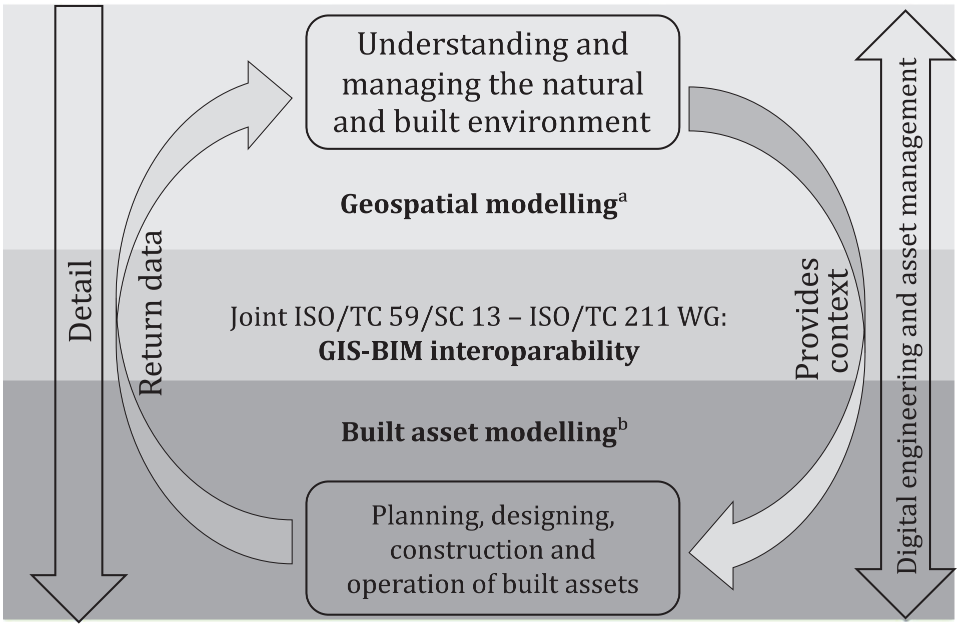
Consequently, several initiatives aimed at the digitalization of built assets at regional, national and international levels have spurred considerable investments around the globe. A key component of these initiatives concerns the need for collaboration and interoperability between information processing systems. These systems rely on digital practices that support digital engineering and asset life cycle management, which rely heavily on different domains of information modelling. These domains include both the observed natural environment and built structures. They also span many scales, from the fabricated asset to its territorial and contextual setting. In this case, the domain of geographic information, "maps", and geomatics, is encompassed with the concept of geographic information systems (GIS), whereas the built asset and its parts is encompassed by the concept of building information modelling (BIM). Traditionally these two information systems have been viewed as separate domains. From a digital engineering and asset management perspective however, there is an increasing overlap and need for interoperability between the two, as illustrated in Figure 1.

The two domains can also be viewed as two different sets of tools, used by several disciplines/domains.

The geospatial domain with its many professions (e.g. land management, engineering surveying, geodata management, remote sensing and cartography) uses GIS tools to acquire, manage, analyse, distribute and present geospatial information.

The geospatial domain handles (most of the time) descriptive models that are designed for many purposes and long-term use and were formerly presented on maps in scale 1:100 to 1:100 000 000. But as the need for geospatial applications varies greatly between actors, the main standardization committee for geomatics, ISO/TC 211, focuses on enabling the development of application schema. The main focus has been on a set of common rules for the development of application schemas (ISO 19109). However, there are applications schemas provided in other organisations, like OGC's CityGML standard for urban environments (including buildings). Buildings (and their urban environment) and the data specification for buildings in the European INSPIRE directive, both based upon ISO/TC 211 standards, including ISO 19109.

The AECO (architecture, engineering, construction and operations) domain with its many professions (e.g. project development, architecture, civil engineering, contractor, facility management) related to planning, designing, building and operating built assets (buildings, infrastructure, etc.) uses the evolving BIM method for collaborative and digital processes in construction projects and for asset management. The models are (most of the time) prescriptive models, designed for a specific purpose and project phase and were formerly presented on drawings in scale 10:1 to 1:1 000, including landscape drawings, rail and road geometrics. These AECO disciplines have at least one thing in common: the building.



[a] ISO/TC 211: ISO 19101 (all parts), ISO 19103, ISO 19104, ISO 19105, ISO 19106, ISO 19107, ISO 19108, ISO 19109, ISO 19110, ISO 19111, ISO 19136 (all parts), ISO 19150 (all parts).

[b] ISO/TC 59/SC 13: ISO 16739-1, ISO 29481 (all parts), ISO 19650 (all parts), ISO 12006 (all parts).

Figure 1 — Standards that relate to the cycle of information flow between geospatial and BIM domains (adapted from a diagram developed by the Joint OGC / bSI IDBE Working Group)

To date, the interaction between the BIM and the GIS domains has not been intuitive or seamless. In its simplified form the GIS, or geospatial modelling, domain has traditionally focused on modelling at the territorial scale and has adopted a large perspective of the observed environment which includes a multitude of distributed assets. The BIM domain has focused more on modelling the components of a single built asset. With the move towards integrated information environments, the differences in focus and scale between the two domains are diminishing. Arguably, use cases and perspectives in both domains are converging and overlapping. Indeed, and as mentioned, decisions pertaining to built assets typically require data and information that span both domains. Therefore, information models from both domains are becoming increasingly bound to each other: every built asset has a location and is situated within a context relative to the existing environment. Conversely, the existing environment incorporates all built assets.

With this move towards integrated information environments, use cases will increasingly require seamless transitions between both domains and their information models, from the bird's eye perspective to the manufactured component found within a built asset, to support the various asset life cycle practices and requirements within a specified context as illustrated in Figure 1. A key challenge in achieving this seamless transition or movement between both domains is ensuring the interoperability in systems used for geospatial information modelling and built asset information modelling. Currently, state-of-the-art modelling of geospatial information is based upon international standards developed and maintained by ISO/TC 211 and Open Geospatial Consortium, Inc. (OGC), whereas state-of-the-art modelling of built assets is based upon standards developed and maintained by ISO/TC 59/SC 13 and buildingSMART International (bSI).

This document aims to identify measures to enable interoperability between the two domains. These measures are expected be developed in either ISO/TC 211, ISO/TC 59/SC 13 or as a joint work between the two committees. To achieve this the enterprise interoperability framework (EIF) defined in ISO 11354 (all parts) has been used, focusing on the need for interoperability in data, services and processes to ensure seamless exchanges and transitions between both domains. First this document focuses on identifying standards within the two aforementioned interoperability levels. Barriers, or incompatibilities, between the two domains are then exposed and discussed. Lastly, specific work packages aimed at eliminating these barriers are identified and suggestions for future work aimed at streamlining interoperability between the two domains are made.

GIS (geospatial) / BIM interoperability

1 Scope

This document investigates barriers and proposes measures to improve interoperability between geospatial and BIM domains, namely, to align GIS standards developed by ISO/TC 211 and BIM standards developed by ISO/TC 59/SC 13.

Where relevant this document takes into account work and documents from other organizations and committees, such as buildingSMART, International (bSI), Open Geospatial Consortium (OGC) and Comité Européen de Normalisation (CEN). The focus is to identify future topics for standardization and possible revision needs of existing standards.

This document investigates conceptual and technological barriers between GIS and BIM domains at the data, service and process levels, as defined by ISO 11354 (all parts).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
application schema
conceptual *schema* (3.13) for *data* (3.5) required by one or more applications

[SOURCE: ISO 19101-1:2014, 4.1.2]

3.2
conceptual model
data (3.5) model that represents an abstract view of the real world

Note 1 to entry: A conceptual model represents the human understanding of a system.

[SOURCE: ISO/IEC 11179-1:2015, 3.2.5, modified — The preferred term "conceptual data model" has been removed.]

3.3
conceptual schema
formal description of a *conceptual model* (3.2)

[SOURCE: ISO 19101-1:2014, 4.1.6]

3.4
conceptual schema language
formal language based on a conceptual formalism for the purpose of representing *conceptual schemas* (3.3)

EXAMPLE UML, EXPRESS, IDEFX1.

Note 1 to entry: A conceptual schema language may be lexical or graphical. Several conceptual schema languages can be based on the same conceptual formalism.

[SOURCE: ISO 19101-1:2014, 4.1.7]

3.5
data
reinterpretable representation of *information* (3.9) in a formalized manner suitable for communication, interpretation, or processing

Note 1 to entry: Data can be processed by humans or by automatic means.

[SOURCE: ISO/IEC 2382:2015, 2121272, modified — Notes 2 and 3 to entry have been removed.]

3.6
dataset
named collection of *data* (3.5)

3.7
data template
schema (3.13) providing a standardized *data* (3.5) structure used to describe the characteristics of objects

3.8
implementation
realization of a specification

[SOURCE: ISO 19105:2000, 3.18, modified — Note 1 to entry has been removed.]

3.9
information
meaningful *data* (3.5)

[SOURCE: ISO 9000:2015, 3.8.2]

3.10
interoperability
capability of two or more functional units to process *data* (3.5) cooperatively

[SOURCE: ISO 2382:2015, 2120585, modified — The domain "<distributed data processing>" and notes to entry have been removed.]

3.11
metamodel
model that specifies one or more other models

[SOURCE: ISO/IEC 11179-3:2013, 3.2.80]

3.12
ontology
formal, explicit specification of a shared conceptualization

Note 1 to entry: An ontology typically includes definitions of concepts and specified relationships between them, set out in a formal way so that a machine can use them for reasoning.

Note 2 to entry: See also ISO/TR 13054:2012, 2.6; ISO/TS 13399-4:2014, 3.20; ISO 19101-1-2014, 4.1.26; ISO 18435-3:2015, 3.1; ISO/IEC 19763-3:2020, 3.1.1.1.

[SOURCE: ISO 5127:2017, 3.1.2.03, modified — References in note 2 to entry have been editorially updated.]

3.13
schema
formal description of a model

[SOURCE: ISO 19101-1:2014, 4.1.34]

3.14
semantic interoperability
capability of two or more systems to communicate and exchange *data* (3.5) through specified data formats and communication protocols

[SOURCE: ISO 18308:2011, 3.48]

3.15
service
distinct part of the functionality that is provided by an entity through interfaces

[SOURCE: ISO 19119:2016, 4.1.12]

4 Abbreviated terms

API	application programming interface
AECO	architecture, engineering, construction, and operations
AIM	asset information model
ARM	application reference model
BAT	BIM authoring tools
BIM	building information modelling
BOM	business object model
CDE	common data environment
CEN	Comité Européen de Normalisation
CRS	coordinate reference system
GIS	geographic information system
GFM	general feature model (in ISO 19109)
GML	Geography Markup Language
ICT	information and communications technology
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
IDM	information delivery manuals
MDA	model driven architecture

OMG	Object Management Group
OWL	Web Ontology Language
OGC	Open Geospatial Consortium
PDT	product data templates
STEP	standard for the exchange of product model data
SQL	Structured Query Language
UML	Unified Modeling Language
XML	Extensible Markup Language

5 Specification of BIM and GIS interoperability issues

5.1 General

According to ISO 11354 (all parts), enterprise interoperability can be implemented at 4 different levels, going from the simplest to the most complex e.g. data level, service level, process level and business level. In addition, the framework identifies three categories of interoperability, conceptual, technological and organizational.

Business and operational processes can give rise to interoperability barriers between enterprises, and this is also the case between enterprises across the geospatial and BIM domains. Figure 1 highlights the fact that while both domains share a focus on digital engineering processes and asset management, they inherently rely on different approaches to the management of information to support those processes at the service and data levels. This is the key consideration addressed in this document.

It is this common focus on information modelling in the built environment, albeit from differing perspectives, that creates both the requirement and opportunity to integrate information flows across both domains. While the processes do introduce interoperability challenges, it is the specific use cases or services where those processes intersect that introduce the biggest interoperability barriers. These barriers manifest themselves principally at the service and data levels. Hence, the focus is put on the data and service levels in this document from a conceptual and technological perspective, as listed in Table 1.

ISO 11354 (all parts) is designed for analysing enterprises. As explained above, GIS and BIM can be viewed as different domains, alternatively as different set of tools. Due to this difference between the enterprise approach and the domain/tool approach, not all the perspectives of ISO 11354 (all parts) are relevant, ending up with focusing on the need for interoperability in data, services and processes to interoperate between the domains. The concept of “process” is understood differently in the BIM domain and in the GIS domain. While several BIM processes have been specified using languages such as BPMN (business process modelling notation), there are no equivalents in GIS.

Table 1 — Interoperability levels considered for this document

	Conceptual	**Technological**
Service	Refers to the expressions, definitions and understanding of exchange information, and how that affects the ability to request, provide and utilize each other’s services.	Refers to the use of ICT to communicate and exchange information, and how that affects the ability to request, provide and utilize each other’s services.
NOTE Reproduced from ISO 11354-1.		

Table 1 *(continued)*

	Conceptual	Technological
Data	Refers to the expressions, definitions and understanding of exchange information, and how it affects the ability to exchange data items between the (GIS-BIM) domains.	Refers to the use of ICT to communicate and exchange information, and how it affects the ability to exchange data items between the (GIS-BIM) domains.
NOTE Reproduced from ISO 11354-1.		

5.2 BIM and GIS interoperability levels

5.2.1 General

In this subclause the service and data interoperability levels are explored and compared through analysing the relevant standards targeting these categories in both domains e.g. ISO/TC 59/SC 13 for BIM and ISO/TC 211 for GIS.

5.2.2 Data level

5.2.2.1 General considerations

This subclause aims at describing existing schemas in standards used in BIM and in GIS.

The overview of GIS schemas is based on the model driven architecture (MDA) approach as defined in ISO 19103:2015, 5.2.2.3. Open BIM schemas follow the STEP architecture, defined in ISO 10303 (all parts) and are presented in 5.2.2.4. The only common concept to both approaches is the concept of "conceptual schema language". Therefore, the languages as used in BIM and in GIS for describing conceptual schemas are listed in 5.2.2.2.

5.2.2.2 BIM and GIS Conceptual Schema Languages

Conceptual schema languages are commonly used for formal representations of conceptual models. Table 2 lists the different languages used for schemas in GIS and BIM standards.

Table 2 — Conceptual schema languages

Domains	Name	Reference
GIS	UML Unified Modeling Language	ISO/IEC 19505-2
BIM	EXPRESS modelling language.	ISO 10303-11
Note 1: ISO/IEC 19505-2 has been developed by the Object Management Group (OMG) and standardised by ISO. Note 2: The EXPRESS data modelling language is specified in ISO 10303-11, a standard for the computer-interpretable representation and exchange of product manufacturing information. Note 3: ISO 10303-11 also specifies a graphical representation for a subset of the constructs in the EXPRESS language. This graphical representation is called EXPRESS-G.		

5.2.2.3 GIS data schemas

5.2.2.3.1 General

GIS schemas are structured according to a model driven architecture (MDA) as defined in ISO 19103. The founding principle in MDA requires schemas to be defined for different levels of abstraction. ISO 19103 defines four levels of abstraction, as illustrated in Figure 2:

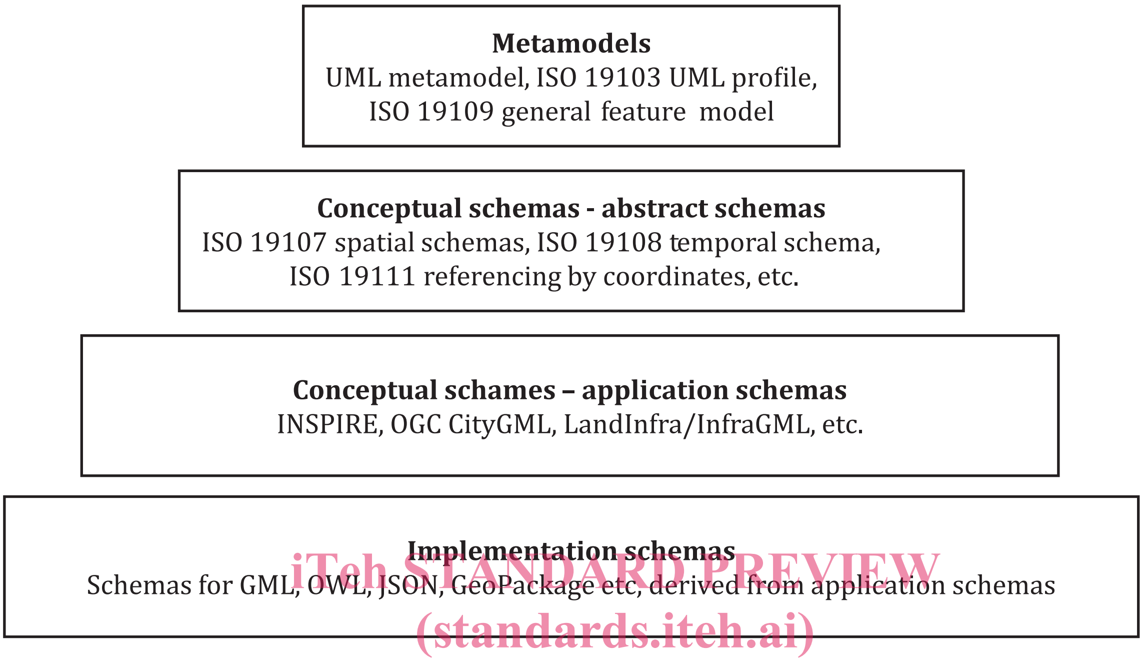
— metamodels: the fundament for defining other models;

— abstract conceptual schemas: abstract schemas describing concepts for reuse in other schemas;

— conceptual application schemas: conceptual schemas defined for specific applications;

— implementation schemas: schemas for implementation in databases and exchange formats.

The conceptual schemas are required to be independent of specific implementation technologies.



NOTE Adapted from Reference [62].

Figure 2 — Levels of abstraction

5.2.2.3.2 to 5.2.2.3.5 further detail the specific elements and items as specified by the standards for each of the levels of abstraction.

5.2.2.3.2 GIS metamodel standards

Table 3 lists metamodels defined in GIS standards.

Table 3 — GIS metamodel standards

Name	Reference	Description
Geographic information - Reference model	ISO 19101	Model that defines concepts of a universe of discourse.
Core UML profile	ISO 19103	Formalised UML profile and rules for the use of UML for modelling geospatial information.
UML profile for application schemas	ISO 19109	Rules for the use of UML for modelling geospatial information in an application schema.
General feature model	ISO 19109	The general feature model is the metamodel for ISO/TC 211 GIS standards, with concepts for FeatureType, PropertyType (AttributeType, Operation and FeatureAssociationRole) and FeatureAssociatonType.

5.2.2.3.3 GIS abstract conceptual schemas

Table 4 lists abstract conceptual schemas defined in GIS standards.

Table 4 — GIS abstract conceptual schemas

Schema name	Reference	Description
Core data types	ISO 19103	Specifies core data types for use in UML models of geographic information.
Spatial schema	ISO 19107	Specifies UML classes for representing the spatial characteristics of features as composites of geometric and/or topological primitives.
Core profile of the spatial schema	ISO 19137	Provides a profile of ISO 19107 that is limited to describing features as simple geometric primitives of 0, 1, or 2 dimensions.
Schema for coordinate referencing	ISO 19111	Concepts for coordinate references systems, coordinate systems, datums and operations.
Temporal schema	ISO 19108	Concepts for temporal characteristics of features and classes for describing relevant temporal reference systems.
Schema for referencing by identifiers	ISO 19112	Concepts for describing spatial locations by reference to identifiers.
Schema for moving features	ISO 19141	Extends ISO 19107 to support the description of moving spatial objects.
Schema for linear referencing	ISO 19148	Concepts for describing spatial locations by referring to locations in a linear network.
Schema for data quality	ISO 19157	Concepts for describing data quality.
Feature cataloguing	ISO 19110	Concepts for feature cataloguing.
Metadata	ISO 19115-1	Concepts for metadata.
Schema for coverage geometry and functions	ISO 19123	Schema for an alternative representation of spatial information as a coverage, in which non-spatial attributes are assigned directly to geometric objects rather than to features composed of such objects.

5.2.2.3.4 GIS Conceptual application schemas

Table 5 lists conceptual application schemas defined in GIS standards.

Table 5 — GIS Conceptual application schemas

Standard	Reference	Description
OGC Land and Infrastructure Conceptual Model Standard (LandInfra)	http://docs.opengeospatial.org/is/15-111r1/15-111r1.html	OGC® Land and Infrastructure Conceptual Model Standard (LandInfra) presents the implementation-independent, concepts supporting land and civil engineering infrastructure facilities, projects, alignment, road, railway, survey (including equipment, observations, and survey results), land division, and condominiums.
OGC CityGML Application schema	https://www.ogc.org/standards/citygml	OGC® CityGML is an open data model and XML-based format for the storage and exchange of virtual 3D city models. It is an application schema for the Geography Markup Language version 3.1.1 (GML3), the extendible international standard for spatial data exchange issued by the Open Geospatial Consortium (OGC) and the ISO/TC 211. The aim of the development of CityGML is to reach a common definition of the basic entities, attributes, and relations of a 3D city model.