Information management for linear infrastructure projects: conceptual model integrating Level Of Detail and Level Of Development

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Abstract

Despite the availability of several standards for modelling urban or infrastructure projects, interoperability is far from optimal. Following collaborative work process remains cumbersome to be implemented in production as it is currently organized. In this paper, we propose a conceptual data model to structure information based on requirements. After describing inconsistencies between actual standards and concepts such as Level Of Detail (LOD) and Level Of development (LODt), we will present our conceptual data model in two parts. The first part illustrates how an object is connected to the rest of the database through systems and spaces. The second part describes how the selection of relevant objects and relevant information is performed to meet required needs. These approaches use different concepts such as level of abstraction and BIM use. Our conceptual model is experimented on the A507 project in Marseille, Public Private Partnership for expressways currently in design and construction.

Keywords: infrastructure modelling, data model, data management, LOD

1 Introduction

1.1 Complex universe to design and model

The linear infrastructure projects include a significant number of complex structures such as roads, tunnels, channels, networks, buildings, earthworks… with multiple actors involved (design offices, manufacturers, builders, public administration). In addition, infrastructure is the convergence of several scales of representation (territory to building scale) and accuracy as stated in (Borrmann et al. 2012). Nowadays, Data Models (DM) that allow the modelling of these infrastructures in terms of information modelling and not only 3D modelling, are proprietary (technical specifications belong to the editor and are not available for users), barely collaborative and incapable till this date to handle the complexity of these infrastructure projects. Yet the construction engineering and civil engineering need interoperable Data Models (DM), supported by a large panel of tools. Collaborative tools based on proprietary formats, as efficient as they can be, are not sufficient for our industry and do not allow to manage information as we need at the present and future time.

1.2 How to better structure interoperability and collaborative work?

Managing a project in a concurrent engineering way improves productivity and the quality of the construction works to be executed: timelines are reduced and unforeseen problems are better managed (Gallaher et al. 2004). The use of open standards (technical specifications are public and not proprietary) is the most appropriate approach to achieve data exchange (Borrmann et al. 2012). The construction industry has been seeking for several years to integrate these concurrent engineering methods and collaborative works in its production processes: the most important challenges of this perspective are focused on the availability, the transmission and the manipulation of information (Gil & Duarte 2008). In the AEC Industry (Architecture, Engineering and Construction), this collaborative way of working is called Building Information Modelling (BIM), which is not only limited to 3D visual representation but to information management in its integrity. The benefits of BIM, although the valuation methods are debatable, have been demonstrated in many studies. So we need, specifically in our industry, **Conceptual Data Model (CDM)** on which the BIM process can be based on. Consequently, these must be stable over time, interoperable and they must consider all the data life cycle: acquisition, processing, storage, analysis and dissemination.

In this paper, we propose a CDM which should partially answer the following question: how to structure, information for an infrastructure project in compliance with the specific needs of actors and in operation infrastructure requirement? For that purpose, we have compared at first how two standardized data models; **Industry Foundation Classes (IFC)** and the **City Geography Markup Language (CityGML)** handle the information structuration concepts, respectively the **Level Of Detail (LOD)** and the **Level Of Development** (we will write it **LODt**). We have then proposed a CDM, integrating LOD and LODt, to manage information based on object and BIM use. We have ended up with an illustration of this proposed data model based on two specific BIM uses.

2 Analysis of existing concepts LOD and LODt

2.1 Evaluation of existing standards IFC and CityGML

Many comparative studies between IFC and CityGML exist. The most important parts either treat its differences regarding its object approach -for instance, the very well-known graphic of Nagel in (Nagel et al. 2009) that compares both approach feature (with CityGML) and product (with IFC approach) or describe the possible transformations and semantic correspondences between IFC and CityGML models. However, these comparisons do not allow us to resolve our problem of structuring and modelling information, based on the needs identified in the response to requirements.

2.2 Information structuration with levels of detail and development

Levels of detail generally aim to model objects with the most relevant geometry and representation according to a specific objective of analysis, as described by Ruas in (Ruas 2004), and relating directly to the working scale. The **Level Of Detail (LOD)** defined in the CityGML standard facilitates the visualization and the analysis of data. For instance, an object can have different representations for each LOD which enables analysis and visualization of the same object with several degrees of resolution (Groger & Plumer 2012) (see Figure 1). The **Level Of Development (LODt)** transcribed the evolution of the design. However, it has not been standardized yet and is therefore subject to interpretation. In fact, some BIM guides, created by companies or institutes, considered different and in most cases conflicting LODt – sometimes also called Level Of Detail – that are specifically adapted to building project and not infrastructure project (AIA 2013; BIMForum 2014; BIMProtocol 2013; Kreider & Messner 2013) (see Figure 1). The LODt from BIM Protocol (PAS 1192-2 2013) based on PAS 1192-2:2013 considers the entire life cycle of a structure. Moreover, it is the only one to have a description for both buildings and infrastructure.

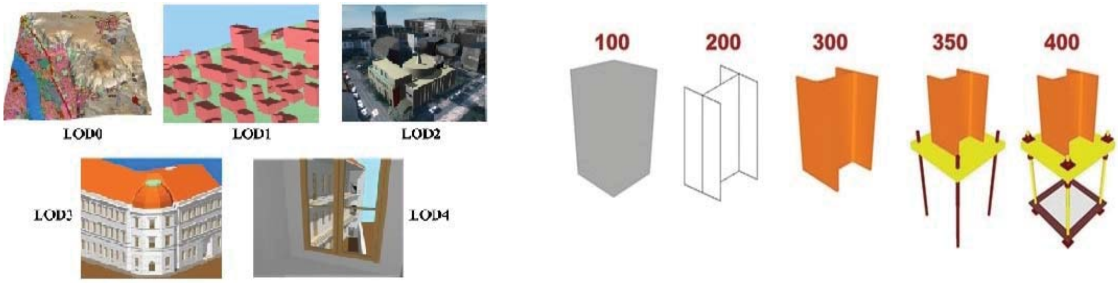

Figure 1 : Illustration of LOD on the left side (Groger & Plumer 2012) and LODt on the right side (BIMForum 2014).

The LODt integrates, such as LOD, several elements of the description of an object: some are explicit and others are implicit as outlined in Table 1. From a certain point of view, LODt are similar to the LOD in the sense that they embed the same sub-concepts (geometric complexity, semantic… see Table 1) through a unique concept (LOD or LODt) but with a different weighting of this sub-concepts. It has to be noted that LODt tend to be separated in two types of levels: level of information (which treat attribute and semantic part of an object) and level of detail (which deal exclusively with the geometry of the object). Again, these proposals are not standardized yet. In this paper we chose to use the LOD in the same direction as described in the CityGML standard (Groger et al. 2012) and the LODt as specifying only attribute and semantic data of an object: we work at this time with these definition. The designation of these concepts does not change anything in our discussion.

Table 1: Comparison of explicit concepts (+) and implicit concepts (-) who compose LOD and LODt (0 means that the concept is not included in the LOD or LODt). The decomposition in 6 topics is based on the work of (Biljecki et al. 2014).

Sub-concept	geometric complexity	dimension	appearance	semantic	presence	attributes
illustration				Generic or detailed object, link with System or Domain…	YES or NOT	Property, type, material…
LOD	+	-	+	0	+	0
LODt	+	0	-	+	-	+

CityGML LOD structure implicitly modelled objects in a single hierarchical tree: for a higher LOD, an object is split into multiple objects. However, this unique structuration approach is not sufficient as we will see in the example below. The object description and modelling depends on its context and the way it will be used and is not only related to the scale we observe it with, even though some scale depends on the analyses. In this way, this concept of LOD cannot be used alone in an infrastructure project as also stated in (Borrmann et al. 2012). A concept of higher abstraction level must be introduced to integrate the context of use of the objects and the requirements it has to meet.

Initially, the LODt strongly corresponds to the different phases of a building project. For infrastructure projects, the object LODt is not necessarily the same for all objects of a given phase. The LODt are actually defined in absolute, while according to the project and to the point of view of each actor, the uniqueness of LODt for each object is not relevant as shown in Figure 2. However, using relative LODt for each object involves partial or complete redefinition on each new project according to the contract, decision or actor consideration.

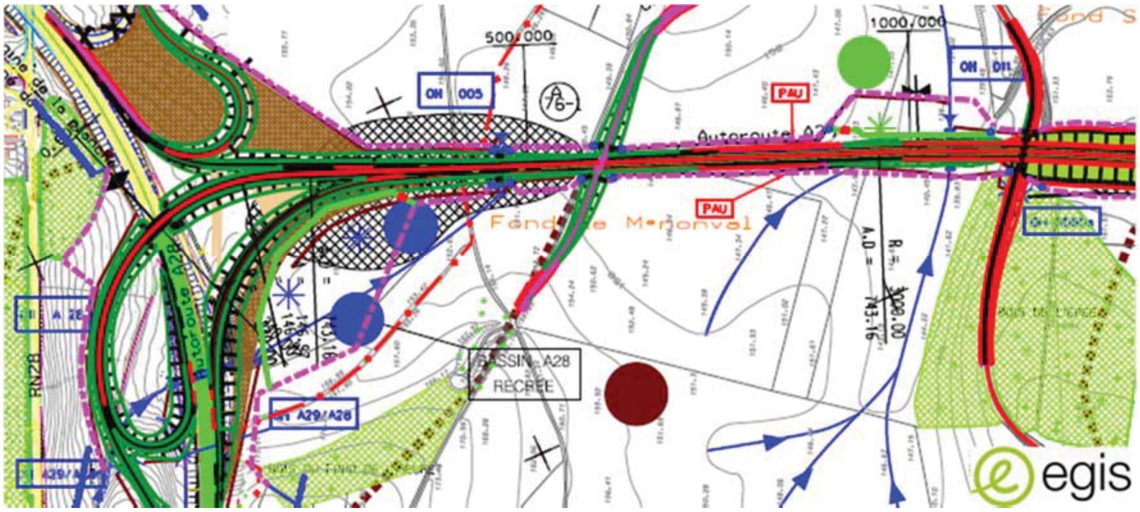

Figure 2 : Preliminary Design: (1) the road geometry and alignment are perfectly defined and detailed (high LOD and high LODt) ; (2) the settling pond (blue circles): the number, volume, spatial layout, geometry (mainly through the regulatory ratio between width and length) are defined and the technical feasibility is verified: only complexity of the geometrical form is not well defined (medium LOD and high LODt) ; (3) hydraulic flow studies of watershed are well defined at this phase but their representation is schematic (low LOD and high LODt).

2.3 Formalism to describe the CDM

Using an object-oriented language is essential for modelling the needed complex data models. Languages based on the entity–relationship model for example are not recommended because its concepts are too light to model the reality of infrastructure projects (Laplanche 2002). In addition, modelling an infrastructure project, which includes many disciplines, requires the modelling of heterogeneous phenomena and forces that handle multiple objects with various levels of abstraction. The bibliography that justifies object-oriented model in this type of context is abundant. As a consequence, we used the UML (Unified Modelling Language) to model our MCD.

3 Structuration of objects and properties through requirements and BIM uses

Although since 2007 tools and data models have evolved, it has been highlighted in (Plume & Mitchell 2007) that collaborative data models do not perfectly correspond to the disciplinary needs. An object must have several models and descriptions according to its context of use and should not loose links with the rest of the model. Therefore, it is necessary to consider interoperable models but also adaptable ones to the needs of object multiple representations in order to/ which meet several levels of abstraction.

An infrastructure depends on decisions throughout its life cycle. Each decision responds to one or more requirements (limited to technical or contractual requirements). But for each of it, only certain objects and properties are relevant among those available. To ensure that decisions are taken in the best conditions, it is essential to select only the relevant information to the decision.

Lastly, one last element is essential to properly identify and define the relevant information and objects for each decision and requirements. This is what we call BIM uses. BIM Use is a scenario that plays with roles and actors clearly identified to exchange data for specific project requirements (see Figure 3). In an infrastructure project, all BIM uses allow to meet all requirements. 25 BIM uses are identified among 3D coordination, programming, 4D modelling, asset management, etc. (Kreider & Messner 2013). It is fairly general, but the concept does not preclude defining more specific information related to the response to specific requirements as explained below. Note that an object can be subjected to several BIM uses, which may involve conflicting sizing and geometries.

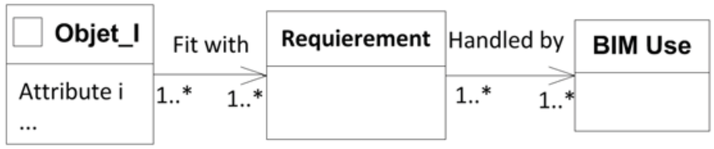

Figure 3 : Links between Infrastructure Object (Objet_I), requirement and BIM use.

This approach of BIM uses and requirements is part of project management and information management. Therefore, BIM uses should be described in the BIM Execution Plan (BEP). It should outline for each phase the information and object needed for each BIM use. We will now describe our proposition of CDM through the requirements, taking into account the concepts of LOD, LODt.

3.1 Description of the conceptual model

We present in this section the generic model that describes information structuration to facilitate the identification of BIM use relevant information and object. We have seen above that according to the requirement, relevant objects are different as well as its geometric representation and semantics. A BIM use can concern only some specific areas or some objects of a particular discipline and or function (called here System). It is therefore necessary to link every object to the spaces and the systems which includes it. As for IFC, spaces (and here systems) are structured and defined according to a level of abstraction, but this concept is not presented here (see Figure 4). BIM use specifications allow the selection of relevant objects, attributes and geometric representations (see Figure 5). The elements of these two Figures are detailed here below.

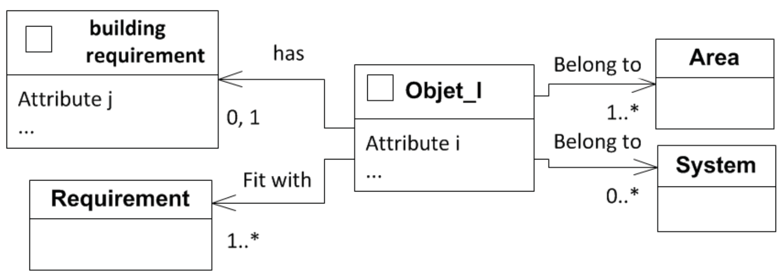

Figure 4: information structuration for infrastructure objects Objet_I: class diagrams (the little box on the left top box of Object_I and "building requirement" are used to describe object geometry (see **Figure 6** for more details).

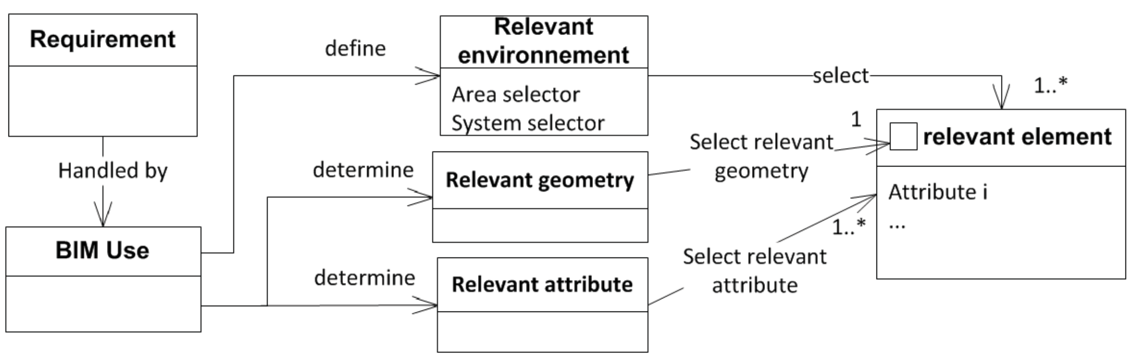

Figure 5 : How our BIM use works to select relevant information?

- Objet_I is any element of the infrastructure project. It could be a component, product, permanent or temporary construction elements. To describe element geometry we selected PERCEPTORY, usually used in GIS modelling spatial database (Bédard 1999; Larrivée et al. 2006) (see Figure 6 for more details).
- Environment is a set of one or more areas and one or more system. It allows selecting objects that belong to the concerned Area or System.
- Requirement is a statement reflecting (or expressing) need, constraints (technical, cost, time …) (Fanmuy et al. 2001). It might come from the client, standards, regulations…

- BIM use can be defined as "a method of applying Building Information Modelling during a facility's lifecycle to achieve one or more specific objectives." (Kreider & Messner 2013); some decisions are evaluated at different phases with different LOD and LODt: BIM use can be played in each phase but with different Environment for example.

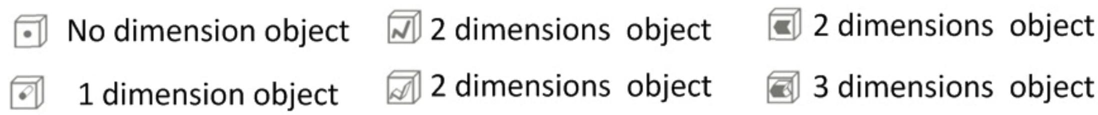

Figure 6: Objects dimensions representation in a 3D environment, based on (Bédard 1999; Larrivée et al. 2006).

4 Experimentation: case of noise analysis

This example will help us to illustrate our proposed CDM. We will deal with two specific BIM uses called *Sizing noise barriers* and *Clashes detection in complex area* in preliminary design and in a simplified manner. Only three significant objects are studied here: platforms because they are the source of noise, noise barriers and drainage network. This experiment is based on the expressway A507 project, in Marseille, France. Thus, we will instantiate the CDM of Figure 4, i.e. identifying objects information that has to be handled for this two BIM use. The formalism of these figures is explained as follows: when the elements are emphasized, it means that they are an instance of a class defined in the Figure 4. So we have <u>instance name: class name</u> at the top of the boxes. Note that "#" means that the instance does not necessarily have a specific name.

4.1 Case of BIM use *Sizing noise barriers*

These explanations make reference to Figure 7. This BIM use meets a rather general requirement of respect acoustic regulation. It concerns the current section of the project, the noise sources (platform) and acoustic protection to be sized. The relevant attributes of that BIM use are relevant for noise impact calculations. The platforms are surfaces and noise barriers also are 2D object but a little bit different as we can see in Figure 7 with PERCEPTORY pictures. Each system has a relevant geometry (LOD system-related). Authorized attributes are determined for all the BIM use. Noise barriers are outputs for the first analysis and inputs for the next iterations. Versioning and workflow are not discussed here but they can complete Figure 4. The interest of the CDM becomes significant when several BIM uses are treated all together, as we represented here below.

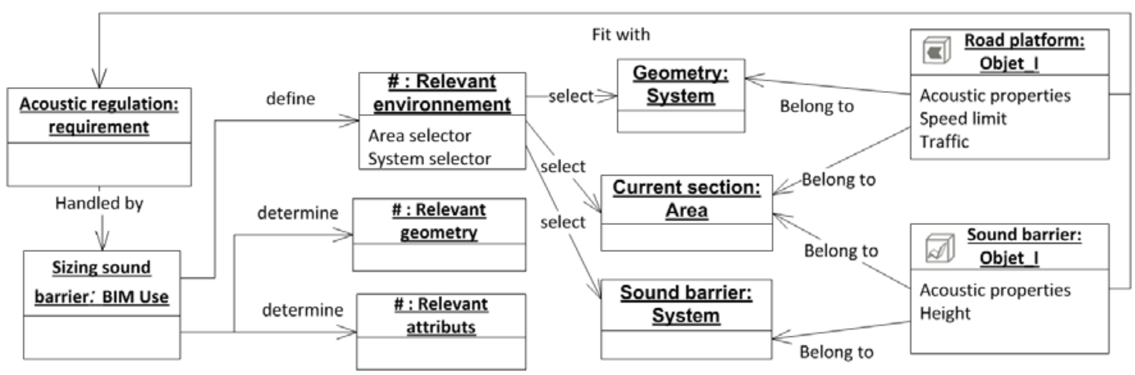

Figure 7 : CDM instantiation for application to Sizing acoustic walls BIM use only for Road platform and acoustic wall. All connections are not shown not to burden the Figure, especially about relevant geometry and relevant attributes.

4.2 Case of *Clashes detection in complexes area*

In preliminary design, it is not appropriate to assess potential clashes on the whole project, but only specific areas covering many networks and civil works. The environment selector selects this type of areas and critical systems to perform the analysis, for instance drainage, noise barriers and, not presented here, civil works. Furthermore, building requirements are not defined for all networks at the preliminary design stage. But BIM ensures that all building requirements are defined for all objects belonging to Risked section for clashes Area, Drainage System and sound barriers System. In this way, we also can control LODt, in compliance with each BIM use.

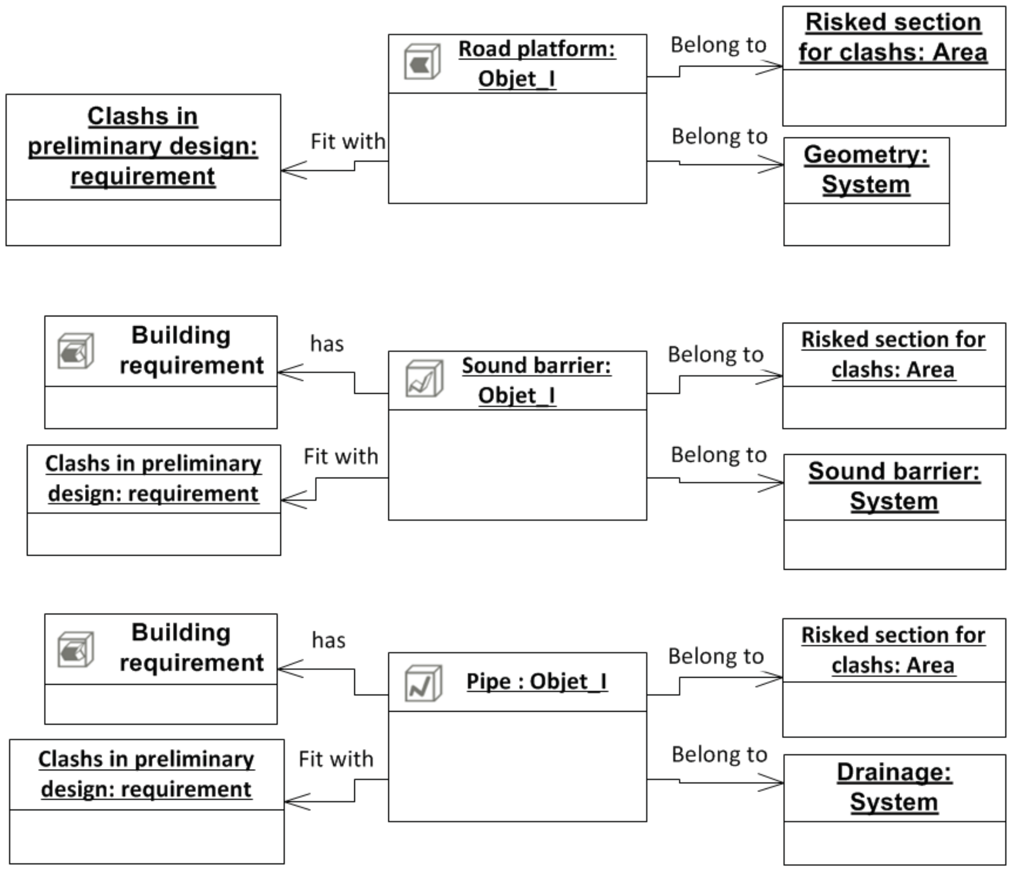

Figure 8 : Object_I instantiation of Figure 4 for drainage pipes, sound barriers and platform.

4.3 Summary of this cases

Here is an analysis of these two BIM uses. For a particular phase, LOD and LODt related to each object vary according to the requirement (see Figure 9). It is also disconnected, the representation is not necessary the exact representation of design progress. Consequently, both concepts cannot be used in absolute as they are now applied but it is relative to each object, or to each composition of System and Area. Then, the spatial project decomposition varies depending on each stakeholder. It is worthwhile mentioning that those are the requirements that determine modelling needs and not contractual deliverables. The CDM proposed here allows the selection of objects, attributes and relevant geometric representations for each stakeholder or BIM use. However, defining each BIM use with its corresponding Environment and Context (geometry and attributes) remains a major part of the work. This is a tedious and complex work that requires perfect knowledge of each domain. Although a standardized European project is under development on this subject (specifically on MVD), these specifications are subject to permanent change for each new project. Defining BIM uses and associated LOD and LODt is an important part of the project BIM Execution Plan.

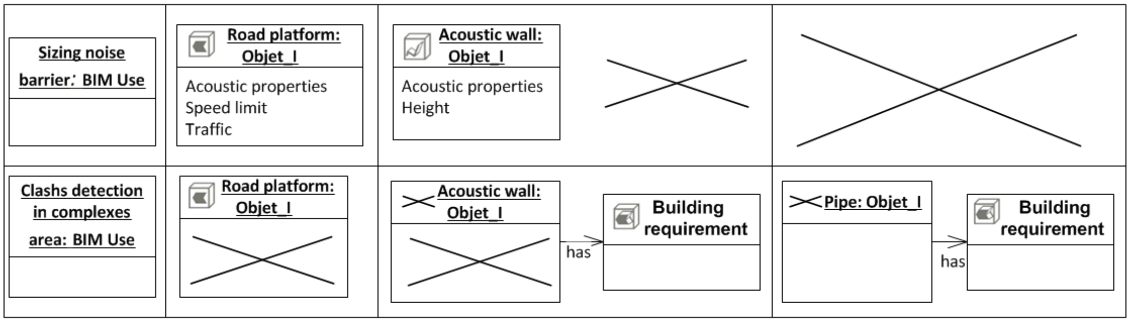

Figure 9 : relevant geometry and attributes for two different BIM uses. The crosses show the differences.

Defining BIM uses based on contract and requirements encourages the selection of relevant information to make decisions based on optimal information. . Based on our knowledge of the design progress of relevant objects only, the measurement of the design progress (LODt and LOD) for each of these relevant objects might also be an indicator to identify the possibility to play the BIM use and to make a decision for a single BIM use

As we have just seen aboveFigure 9, it is necessary to separate the different concepts included in LOD and LODt since there are some redundancies as shown in Table 1.Thus, the simultaneous use of these two concepts as defined today is not possible. It should be redefined. We note that some communities that use LODt, especially in United Kingdom, are tending to give up on the LODt. They separate LOD (Level Of model Detail: "Description of graphical content of models at each of the stages") and LOI (Level Of model Information: "Description of non-graphical content of models at each of the stages") (PAS 1192-2 2013). This kind of LOD becomes different from CityGML LOD and must introduce/share certain concepts of its content. Otherwise, this would create inconsistencies during the assembly of geographic and environmental data with design data (CAD), which is inevitable in an infrastructure project. In the same line, in Table 2, we propose a first simplification of LOD and LODt. These LOD, LODt and LOI concepts are all essential for infrastructure modelling and information management. It should also be used simultaneously and therefore it might not use the same information structuring concepts. As a result, the proposition presented in Table 2 does not have any more redundancies with concepts. However, this does not mean that appearance is dependent of attributes for certain BIM uses for example.

Table 2: distribution of concepts among LOD and LOI (explicit concepts (+) and implicit concepts (-); 0 means that the concept is not included).

Sub-concept	geometric complexity	dimension	appearance	semantic	presence	attributes
illustration				*Generic or detailed object, link with System or Domain…*	*YES or NOT*	*Property, type, material…*
LOD CityGML	+	-	+	0	+	0
Proposed LOD	+	+ / -	+	0	+	0
LODt (IFC complient)	+	0	-	+	-	+
Proposed LOI	0	0	0	+	0	+

5 Discussion and conclusion

We detailed our proposed CDM on a single practical case by treating some objects of two BIM uses. We must now show that this proposal works in a more complex case that includes various objects and runs several BIM uses. For example, we will have to handle the fact that some object properties, defined by a BIM uses and determined by certain requirements, become requirements to define other properties for other infrastructure objects. We are working on the establishment of an experiment in this direction. This experiment should allow us to add the concept of level of abstraction and to describe the multi-structuration of areas and systems.

In the perspective of a wider implementation of this work, many elements remain to be defined, such as how to model the workflow (process and validation stages) of each object. Moreover, such major upheaval in how to design cannot be integrated by design teams immediately, especially because the available tools are currently lacking this kind of information management. Although collaborative work and BIM have been very popular for many years now and many studies have lean to take it forward, both on the academic side as on the industrial side, it seems that current approaches to information management do not allow to correctly answer the needs of our construction trades. We believe that the work done in other industries, for example around PLM (Product Lifecycle Management) or PLCS (Product LifeCycle Support), is relevant and has to be taken in consideration. Our CDM proposition presented here integrates some concepts existing in PLCS but that are still missing today in the information management for infrastructures projects.

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