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Pragmatic Use of LOD – a Modular Approach

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ABSTRACT: The concept of Level of Development (LOD) is a simple approach to specifying the requirements for the content of object-oriented models in a Building Information Modelling process. The concept has been implemented in many national and organization-specific variations and, in recent years, several solutions have been proposed to address the challenge of the LOD concept being either too simple to fully describe the requirements for BIM deliverables or too complex to be operational in practice. This study reviews several existing LOD concepts and concludes that addressing the completeness and reliability of deliveries along with use-case-specific information requirements provides a pragmatic approach for a LOD concept. The proposed solution combines LOD requirement definitions with Information Delivery Manual-based use case requirements to match the specific needs identified for a LOD framework. This framework can act as a basis for future LOD solutions to harmonize the conceptual understanding of LOD definitions.

1 INTRODUCTION

1.1 *Study background*

Level of Development (LOD), Information Levels, and other similar concepts for defining requirements for Building Information Modelling (BIM) deliverables are widely used in the Architectural, Engineering and Construction (AEC) industry. LOD allows for a simple approach for specifying the requirements for the content of object-oriented models in a BIM process, but prior research (Hooper 2015; Berlo et al. 2014; Botton et al. 2015) has established that it is a considerable challenge throughout the AEC industry to define BIM deliveries accurately using existing LOD concepts.

Different design disciplines, project execution models and project organizations require different information to be available at project milestones, so there has to be a granularity within the framework of LOD. For this reason, several organizations have introduced further terms, such as Level of Detail (graphic-oriented), Level of Information (non-graphic-oriented), Level of Accuracy (tolerance-oriented), and Level of Coordination (collaboration-oriented) (BIM Acceleration Committee 2014).

Most solutions differentiate only graphical and non-graphical requirements to limit complexity.

For example, the BSI defines *graphical data* as “data conveyed using shape and arrangement in space” and *non-graphical data* as “data conveyed using alphanumeric characters” (BSI 2013).

As the range of options for specifying LOD requirements increases, so does the complexity of defining requirements and the challenge is to achieve actual added project value using such approaches (Hooper 2015). Berlo et al. 2014 also describes a considerable confusion of when a BIM model actually reaches a certain LOD level and it seems that one major challenge is still the misunderstanding of *detailing* as a definition for model progression (NATSPEC 2013).

There is a close correlation between the processes undertaken in AEC projects and the BIM model deliverables (Lee et al. 2007), and this means that any requirements stated will affect how the design is executed. Using LOD can, therefore, make it a complicated matter for clients and others to state requirements that will likely be of value for the entire project. The range of proposed LOD concepts available, however, indicates a need in the AEC industry to have an approach that addresses model deliveries. The challenge seems to be how such a solution can be both unambiguous and operational?

1.1 Study goals

The goal of this research was first to compare existing LOD concepts in the AEC industry to clarify their scope and the terminology they use. And then secondly to propose a solution that can harmonize the LOD concept to state unambiguous BIM delivery requirements yet still practical enough to ensure common ground for all the stakeholders in a project.

2 METHODOLOGY

The research started with a review comparing known and widely-used LOD concepts from organizations in several countries. Eight LOD concepts were selected for further analysis in this research based on their individual approach. The main goal was to explore how existing solutions handle the granularity of the LOD concept and to what extent they state unambiguous requirements. Secondly, the findings from work to develop a proposal for a set of new Danish Information Levels were used to define the operational requirements for a LOD concept. The authors have been actively involved in the development of both the prior Danish bips Information Levels and more recently of a new concept by Digital Convergence (DiKon), which is a working group of BIM experts from six of the largest AEC companies in Denmark. The findings from DiKon were identified during multiple workshops within this working group. Based on these findings, a solution is proposed here that builds on top of the DiKon concept in an attempt to harmonize the usage of LOD and also includes recent research on more modular approaches to delivery requirement definitions.

3 REVIEW

3.1 Development of LOD concepts

Over the last decade, a number of LOD concepts have been proposed by industry and client organizations. In Denmark, the organization bips based its first proposal for a set of generic Information Levels (bips 2007) on work carried out by the Finish PRO IT organization. The Information levels were later revised (bips 2009) and recently completely reconfigured in a new set called CCS Information Levels (Cuneco 2014). The solutions define high-level and generic descriptions of the Information Levels at model level. There is an intention to define model-element-specific requirements based on the overall

levels, but so far this work is still in progress within bips.

In the US, the AIA released their first contracting documents describing LOD requirements in 2008 and revised them in 2013 (AIA 2013a). The documents only cover high-level and short generic descriptions of LOD, but in 2011 the AIA allowed the US organization BIMForum to put further detail into their LOD concept at model element type level. Their latest release (BIMForum 2015) includes more than 140 element-type-specific definitions, and supplementary Element Attribute Tables define requirements per level for non-graphical information for each element type.

Building on top of the work by the AIA, first the U.S. Department of Veterans Affairs and later the Australian NATSPEC organization in 2011 released a BIM Object/Element Matrix (NATSPEC 2013) with requirements for non-graphical object properties for 28 model element types. All the object properties are categorized in groups based on 15 defined use cases and mapped to the buildingSMART IFC specifications (buildingSMART 2007).

In the Netherlands, TNO has developed a proposal for a set of Information Levels focused primarily on the purposes a model can be used for (Berlo et al. 2014). A database is currently under development to define model-element-specific requirements for non-graphical information (TNO et al. 2014). In the UK, the BSI has defined a set of model stages in its PAS standard (BSI 2013) to define requirements at model level for both graphical and non-graphical content based on descriptions of themes and purposes. A BIM Toolkit solution by NBS (NBS 2015) aims to use the PAS model stages to define individual requirements for model element types at different design stages, but this solution also seems to be still under development.

Several other solutions, such as the Finish COBIM, the New Zealand BIM Handbook, and the US Army BIM Minimum Modeling Matrix, have also been introduced, but most other concepts are either limited in their range of model requirements or based on the principles of one of the solutions above.

3.2 Common Understanding of LOD

Originally introduced by the AIA as an abbreviation for *Level of Detail*, the term LOD was changed in 2013 to represent *Level of Development* (AIA 2013a) based on conclusions similar to those found elsewhere (NATSPEC 2013; BSI 2013) that

LOD represents the combination of requirements for the concretization of both graphical and non-graphical information during a project.

The ambitions for LOD are somewhat multifaceted, ranging from “the degree to which (...) information has been thought through” (BIMForum 2015) to “what the model can be used for” (Berlo et al. 2014).

The AIA defines the term *Model Element* as “a portion of the model representing a component, system or assembly within a building or building site” (AIA 2013a), and most recent LOD concepts define their requirements based on type-specific model element definitions. For the solutions that address model elements, a *LOD Table* like the Model Delivery Specification (DiKon 2015), the Model Element Table (AIA 2013b), or the BIM Object/Element Matrix (NATSPEC 2013) is needed to define delivery requirements for element types at the various project milestones. (Berlo et al. 2014) point out that the complexity of such LOD Tables quickly increases to such an extent that ordinary users lose all track of the relationship between desirable use cases and requirements. Current LOD concepts are therefore challenged by trying to address both a wide range of purposes and the need for simple and operational solutions.

3.3 Information Delivery Manual (IDM)

The concept of an IDM is an alternative solution to defining unambiguous exchange requirements for BIM deliveries for specific use cases and has been developed by buildingSMART (See et al. 2012). In an earlier paper, we proposed a solution using IDM Packages – each describing only a single-actor use case per IDM – to allow for a more modular approach to describing information flow in construction (Mondrup et al. 2014). IDM Packages can be rearranged more freely than traditional IDMs, which usually describe large-scale use cases involving several actors. The idea is to have the ability to define unambiguous information

requirements at model element level based on specific use cases.

Both the IDM and LOD address delivery requirements, but the origin of the IDM was the need to define object-oriented and property-specific exchange requirements, whereas the origin of LOD was to define generic and high-level requirements. With a use-case-specific and information-intensive LOD concept like the NATSPEC, concepts originating from IDM and LOD get mixed together, illustrating the need for solutions to be both high-level and unambiguous at the same time.

The Norwegian bSN Guiden (buildingSMART Norway 2015) is a solution based on these principles. It provides individual users with a simple database interface for defining use-case-oriented and unambiguous delivery requirements at model element level. However, currently the solution only states limited delivery requirements, none of which relate to graphical information. It therefore needs supplementing with an existing LOD concept to make it fully useful.

3.4 Aspects of LOD concepts

To compare the somewhat different LOD concepts, five evaluation aspects were identified during the research:

- Content Aspect – How are completeness and/or detailing of deliveries defined?
- Format Aspect – Is graphical information separated from non-graphical information or are requirements combined?
- Context Aspect – Are levels related to phases and/or related to specific use cases?
- Structural Aspect – Does the concept target overall model requirements or model element requirements?
- Standardization Aspect – Does the concept make use of standardization solutions, like classification systems or exchange formats?

Table 1. Comparison of eight selected LOD concepts based on five defined aspects.

LOD Concepts		Content Aspect		Format Aspect		Context Aspect		Structural Aspect		Standardization Aspect	
Country and Organisation	Denomination	Completeness	Detailing	Combined	Separated	Phase related	Use case related	Focus on model	Focus on model element	Classification	Exchange format
DK bips 2007	Information Levels									DBK	IFC
DK CCS	Information Levels									CCS, intended	IFC, intended
DK DiKon	Information Levels										
US AIA 2013	Level of Development										
UK BSI	Level of Definition										
AUS NATSPEC	Level of Development									Uniformat	IFC + COBIE
US BIMForum	Level of Development									Uniformat	Partly IFC
NL TNO	Information Levels									NISfb	IFC, intended

Explicitly addressed
 Implicitly addressed
 Not included

The concepts address these aspects explicitly, implicitly or not at all. The comparison of LOD concepts is shown in Table 1.

3.5 Review findings

Notable from the comparison is that although there is still a considerable misunderstanding in the industry that LOD refers to the detailing of deliveries, none of the current LOD concepts address *detailing* explicitly in its definitions. Nevertheless, the concepts that include illustrations of the development stages, e.g. bips, DiKon and BIMForum, do implicitly address detailing to some extent, which can lead to misunderstandings about what is intended. Moreover, the UK BSI concept specifically mentions Level of Detail and includes some illustrations, but all definitions still relate to *completeness*.

No consensus has so far been reached in relation to whether graphical and non-graphical information should be defined separately or combined, whereas most recent solutions agree on defining use-case-related requirements at model element level. The relationship to classification systems and IFC/COBIE is increasing, yet still not implemented throughout the concepts, potentially leading to unclear requirement definitions in some cases.

According to Hooper, there is a lack of research on how useful LOD is in actually benefitting projects as well as a lack of research on the use of IDMs in practice (Hooper 2015). Berlo et al. report that the Dutch General Services Administration has removed all reference to LOD due to uncertainty of deliveries (Berlo et al. 2014), and although the Information Levels from bips are commonly used in public projects in Denmark (bips 2009), five out of the six AEC companies in the DiKon organization have developed supplementary definitions to improve the certainty of agreements. This illustrates the need for further definition of the success criteria for LOD concepts if they are to be unambiguous and operational.

4 FINDINGS FROM DANISH DEVELOPMENT EFFORT

4.1 Initial work by bips

During the development of the first set of Information Levels (bips 2007), it was concluded that the levels must be detached from phases because different project constellations require information to be utilized at different stages. However, the solution should 1) have levels

representing deliveries in all main phases, and 2) allow for different parts of a delivery to be represented by different levels.

In the latest version from bips (Cuneco 2014) the levels have lost explicit connection to phases and are now defined as generic steps in the concretization of building projects ranging from 1 to 7. The challenge with this approach is that the levels are now defined so generically that it can be complicated to relate the levels to desired use cases in an unambiguous way.

4.2 DiKon Information Levels

So in 2015, the Danish organization DiKon decided to expand the latest set of Information Levels with a range of model element type-specific definitions and create a LOD table to link requirements to phases. The solution includes specific descriptions for 22 commonly used model element types (DiKon 2015).

More than 15 workshops were conducted by DiKon first to define the scope and then to review the content of the proposed model element definitions. The following findings summarize the conclusions from the workshops and define the scope of the proposed solution:

- The LOD levels from AIA/BIMForum do not match the delivery requirements common in the Danish AEC industry.
- The main goal is a tool for agreeing on the scope of deliverables that must be operational for clients and project managers with limited BIM experience
- The solution must make it possible to state unambiguous delivery requirements throughout a project without obstructing the processes and being too workload intensive.
- A LOD Table is required to allow for individual element types to be assigned different LODs at specific deliveries depending on 1) their type (prefab/build-on-site, etc.) and 2) their location in the building (e.g. differentiating HVAC components in plant rooms and shafts from similar components in other room types).
- Requirements for graphical and non-graphical information must be defined separately in the LOD table.
- The requirements for non-graphical information must be based only on high-level use cases and must be part of the information currently available in BIM models.

Based on the above findings, a solution was developed (DiKon 2015), as illustrated in Table 3.

Only graphical requirements are illustrated in the table. Additional requirements for non-graphical information are also part of the solution, defined per level for each selected model element type.

The graphical requirements are defined based on three criteria:

- The reliability of the elements, ranging from *Expected, Specified to Final*.
- The shape of elements related to reliability, e.g. the max. outer contours for the expected level of reliability or contours reflecting the final dimensions for the final level of reliability.
- The completeness of the elements, referring to the element representation (e.g. generic, assembly or element-divided) and the scope of components to include along with the main element.

5 DESIRED LOD TERMINOLOGY

5.1 Comparison of DiKon and BIMForum

The DiKon concept is very similar to the BIMForum concept because they share common goals. In Table 2 and Table 3, a comparison is made of definitions for graphical requirements of comparable building services based on the DiKon and BIMForum concepts. Three interpretations of each definition described below have been added to the tables to make it possible to compare the similarities and differences of the two concepts.

5.2 Level of Completeness (LOC)

The review in section 3 concluded that LOD definitions describe completeness and not detailing, so we introduce the concept of Level of Completeness (LOC) to address this need directly. LOC is defined on the basis of the concretization of the model element and the scope of included components. The combination of a description and an illustration defines each LOC. The comparison in Tables 2 and 3 illustrates why the BIMForum solution is not directly applicable in a Danish

Table 2. BIMForum 2015 LOD definition for D2010.20 – Domestic Water Equipment supplemented with an interpretation of corresponding detailing, Level of Reliability (LOR) and Level of Completeness (LOC).






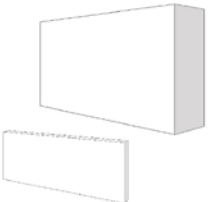
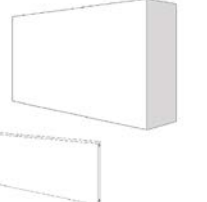
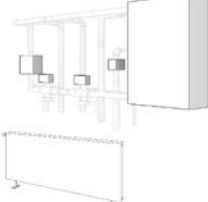
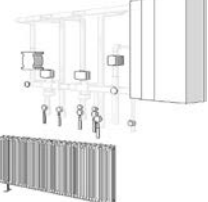
LOD 100	LOD 200	LOD 300	LOD 350	LOD 400
				
Diagrammatic or schematic model elements; conceptual and/or schematic layout/flow diagram; design performance parameters as defined in the BIMXP to be associated with model elements as non-graphic information.	Schematic layout with approximate size, shape, and location of equipment; approximate access/code clearance requirements modeled; design performance parameters as defined in the BIMXP to be associated with model elements as non-graphic information.	Modeled as design-specified size, shape, spacing, and location of equipment; approximate allowances for spacing and clearances required for all specified anchors, supports, vibration and seismic control that are utilized in the layout of equipment; actual access/code clearance requirements modeled.	Modeled as actual construction elements size, shape, spacing, and location/connections of equipment; actual size, shape, spacing, and clearances required for all specified anchors, supports, vibration and seismic control that are utilized in the layout of equipment.	Supplementary components added to the model required for fabrication and field installation.
Interpretation: Detailing = Diagrammatic LOR = Conceptual LOC = Diagrammatic	Interpretation: Detailing = Medium LOR = Approximate LOC = Generic Level	Interpretation: Detailing = Fine LOR = Design-specified LOC = Type Level	Interpretation: Detailing = Fine LOR = Actual LOC = Component Level, Design	Interpretation: Detailing = Fine LOR = Actual LOC = Component Level, Fabrication

Table 3. DiKon 2015 Information Level definition for Heating and Sanitation Components supplemented with an interpretation of corresponding detailing, Level of Reliability (LOR) and Level of Completeness (LOC).

Information Level 2	Information Level 3	Information Level 4	Information Level 5	Information Level 6
Not defined				
	Components are modelled as generic volume objects in expected max. outer contour. Expected location and orientation of components.	Components are modelled in specified max. outer dimensions incl. Specified location and orientation of components.	Components are modelled in final outer dimensions. Final location and orientation of components.	Components are modelled in final dimensions based on actual choice of product. Final location and orientation of components.
	Interpretation: Detailing = Coarse LOR = Expected LOC = Generic Level	Interpretation: Detailing = Coarse LOR = Specified LOC = Type Level	Interpretation: Detailing = Medium LOR = Final LOC = Component Level, Design	Interpretation: Detailing = Fine LOR = Final LOC = Component Level, Fabrication

context: as similar levels, LOD 350 and Information Level 5, might both be at component level, but whereas e.g. hangers are included in LOD 350, this is not the case in Information Level 5 because this is not Danish practice. This indicates that while the concept of LOC could be used to harmonize the definitions of graphical requirements at a generic level, national or organisation-specific definitions are needed to match the content required for local practices or needs.

5.3 Level of Reliability (LOR)

The DiKon workshops concluded that reliability is a useful factor to include so that the concept can be used as part of a contractual agreement. It is clear that BIMForum reached similar conclusions because the terms *Conceptual*, *Approximate*, *Design-specified* and *Actual* are used throughout their definitions. A harmonization of such terms would further add to the common ground on expectations for deliverables.

5.4 Detailing

Believed to be of less relevance to the deliverables is the detailing or coarseness of the model elements. Detailing describes how objects are presented visually, but does not address the content. BIM authoring tools like Autodesk Revit have a functionality for easily changing the detailing of objects from *Coarse* to *Medium* or *Fine*. However, this does not necessarily imply that the LOD level has increased. The above tables indicate the interpreted detailing level on the basis of the illustrations available and this clearly shows that only limited consensus has been reached because the detailing is not aligned in the concepts. A review of illustrations for other model element types – particularly in the BIMForum concept – further adds to the conclusion that there is limited consensus about the detailing level at different LOD levels.

This partly explains the concern expressed by Berlo et al. that if people are asked to review different models, they reach very limited common agreement about what LOD level a particular model has reached (Berlo et al. 2014). Most likely this is because they focus on the detailing level of the model elements as opposed to the completeness and reliability of the elements.

5.5 Focus on use cases

Berlo et al. conclude that this confusion should lead to LOD levels focusing purely on use cases. The more use cases included to define a LOD level, the narrower the reuse of similar LOD levels

can be in different project constellations. The review and findings in this paper indicate that there is a need to be able to define the level of concretization of model elements in a generic, simple and unambiguous way and this is why the use of LOC and LOR seems more valid as the foundation of a LOD framework. BIMForum acknowledges the need to link requirements to use cases and select 1) Quantity take-off, 2) 3D coordination, and 3) 3D control and planning as the high-level use cases which graphical and non-graphical delivery requirements should address as a minimum. Supplementing the above with drawing production as a use case still seems necessary, but leaving out requirements for additional use cases keeps the concept generic and still unambiguous.

5.6 Level of Information (LOI)

To define the requirements for non-graphical information accurately, we make use of the Level of Information (LOI). Such requirements are stated explicitly as object properties in some LOD concepts and in others described implicitly just as information needed to fulfil specific use cases, such as energy simulation or cost calculation. Koskela et al. conclude that the use of relevant software tools has limited impact if the AEC process is confused at the outset, so unambiguous information requirements are needed (Koskela et al. 2002). For this reason, LOI requirements should be defined explicitly and a solution like IDM Packages could be included to define requirements for additional use cases, adding a more modular approach to the LOD concept.

6 PROPOSAL FOR A PRAGMATIC LOD APPROACH

6.1 Generic Framework

Based on the above conclusions, we propose a solution for a generic set of LOD levels as shown in Table 2. This framework is intended to act as a basis for future LOD solutions to harmonize the conceptual understanding of LOD content. As previously indicated, there is a need to customise the LOC definitions to match local practices, while the framework is still seen as generic.

6.2 Scope

BIMForum uses LOD 100 to define requirements for diagrammatic or schematic layouts of model elements. As argued also by NATSPEC, 2D drawings and other informational representations

Table 2. Framework for a generic LOD solution – must be detailed on model element level based on national or organizational needs.

	LOD 0	LOD 1	LOD 2	LOD 3	LOD 4	LOD 5	LOD 6
Scope	Specification	Idea	Outline	Proposal	Design	Construction	Handover
Level of Reliability	Final (requirements)	Expected	Expected	Specified	Final	Final	As-build
Level of Completeness	Descriptive Level	Volume Level	Generic Level	Type Level	Component Level, Design	Component Level, Fabrication	Component Level, Handover
Level of Information (based on the four high-level use cases)	- Identification - Scope	- Identification - Size	- Identification - Type - Size	- Identification - Type - Size - Material - Performance requirements	- Identification - Type - Size - Material - Performance requirements	- Identification - Type - Size - Product-specific values	- Identification - Type - Size - Product-specific values

could just as well be defined by different LOD levels (NATSPEC 2013). Accordingly we argue, based on the original findings from DK bips 2007, that LOD levels should be available to represent all the main phases of the AEC industry, focusing on delivery milestones. This is why we propose a total of seven levels spanning from LOD 0 to 6. The hundred-concept used by BIMForum to allow for custom LODs like 120 or 340 has also been dropped because we argue that such in-between levels are not desirable. Instead, local variations of the LOC of the seven levels must be accepted. Some LOD concepts assign *Operation* as the last level, but we argue that operation, maintenance, renovation, etc. are all use cases which use data from the milestone *Handover*.

6.3 LOD table and use case connection

To make it possible for additional use cases to be addressed, we propose to use the concept of IDM Packages to define use-case-specific information requirements. Including use cases in a Delivery Specification (LOD Table) based on such IDM Packages would allow for a configuration system

to point directly to the information required by the additional use cases, as illustrated in Figure 1. The sum of information required as standard based on LOD 4 and the additional information required by the two selected use cases constitute the total requirements of what is to be delivered at (in this case) the Detailed Design phase.

6.4 Pragmatic and modular

The proposed framework and practical solution will allow clients and project managers with limited BIM knowledge to use the Delivery Specification to agree on the scope of deliveries.

Since the Delivery Specification is backed up by unambiguous information requirements, the BIM modellers will know what content should be included in the BIM models later, how it should be modelled, and what non-graphical information should be included.

The concept is only tied to a few high-level use cases and the modular approach allows for any additional requirements to be included as long as they are derived from a use case.

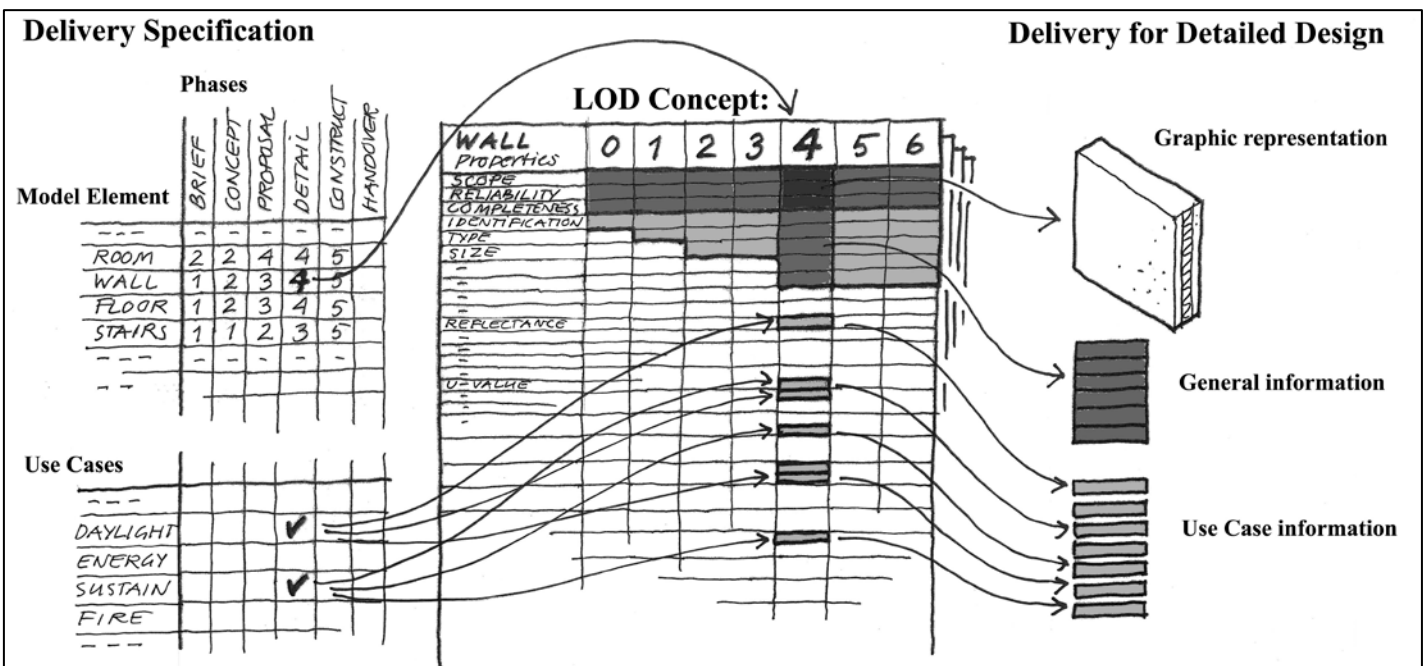


Figure 1. Modular approach of defining delivery requirements based on LOD selection for model elements and supplementing requirements with desired use cases.

7 CONCLUSIONS

In this study, we review several existing LOD concepts and conclude that addressing the completeness and reliability of deliveries along with use-case-specific requirements can provide a pragmatic approach for a LOD framework. This framework can act as a basis for future LOD solutions to harmonize the conceptual understanding of LOD definitions and, because it combines LOD definition requirements with IDM-based use case requirements, the solution is also highly modular.

The use of LOD is linked to the need for a pragmatic approach to agreeing on model deliveries, but the concept still requires human interpretation of graphical requirements to be translated into individual model-specific requirements. As the AEC industry matures further in relation to BIM modelling, it would be appropriate to focus more on IDM requirements – potentially fully integrating the LOD concept into IDM.

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