Creating the Dutch National BIM Levels of Development (extended)

L.A.H.M. van Berlo[1], F. Bomhof[1] and G. Korpershoek[2]

[1]Netherlands organisation for applied scientific research TNO, P.O. Box 40, 2600AA, Delft, +31 88 866 30 00; email: leon.vanberlo;freek.bomhof@tno.nl
[1]IOB, Struytse Hoeck 1, 3224 HA, Hellevoetsluis; g.korpershoek@iob.nl

This is an extended version of the original paper. This version elaborates more about the comparison between international LOD concepts and has more and larger pictures.

ABSTRACT

This paper describes the research and development of the Dutch national standard for information levels of BIM. The US developed "Levels of Development" LOD have become increasingly popular in the Netherlands. However, more and more projects felt the need to develop an additional LOD250 and LDO350. It became clear that the Dutch design- and engineering process needed different information levels to operate effectively. During an R&D project that involved 9 Dutch SME companies research was done focused on the levels needed in the Dutch AEC industry. During this project the team also looked at several other information levels like the Danish, and developments in the UK. The project team came up with 7 information levels. A matrix was developed on which construction objects where linked to the 7 levels. Several companies in different BIM projects tested this matrix in practice. Results from this test were concluded in a guideline for effective use of the information levels and the matrix. This paper will describe the test results and the resulting recommendations for practical use of the standard in the Netherlands. Furthermore an experiment was conducted to automatically identify the detail of the geometry of an IFC model. This was done by analyzing several characteristics like number of objects per m3, number of geometrical triangles per object, etc. The results of this geometrical test are also added in the paper.

INTRODUCTION AND PROBLEM STATEMENT

While the concept of "LOD" (different explanations for the abbreviation occur) is gaining popularity in the Netherlands, the confusion about the content of a model on a certain level is also growing. It is not clear to anyone what kind of information should be available in a model on a particular level. That doesn't stop people from asking for LODn00 models. In any serious BIM project the question is asked to all of the partners what kind of information they need to do their job. A common reply to that question is to name an LOD level. Some companies even tell the rest of the team that work only starts for them when the model is on a certain level. The Model Element Table to fill in the exact model requirements [AIA, 2008] is almost never

used so just mentioning an LOD number is still not clear to the team. However, everybody has his or her own idea of what a LODn00 model is, or should be.

Questionnaires in the form of quizzes were done in the Netherlands showing pictures of BIM and asking people what LOD level the model. Almost none of the responses were the same as the original opinion of the model creator. For some projects there were separate models for the construction, the architecture and the MEP according to the concept of aspect models [Berlo, et al 2012]. All of those models were classified as the same LOD, but the respondents estimated them differently.

The problem is that the industry has run of with the concept of LOD, without defining it properly. Every person has an individual opinion on what a LODn00 model is or should be.

The reason why the concept of LODs is so popular is because is gives an impression about a moment in the process. More developed models will likely be more stable and less subject to change. When a project partner, like the MEP engineer, receives a model from the architect it should be clear what the expected response should be. With BIM tools an architect can model very detailed models that seem to be almost ready to be build. An MEP engineer therefore starts to model very detailed MEP models and sends them back to the architect. However, the model from the architect was just a first draft and it still changes dramatically. Because is was not clear that the model was just a very early design phase sketch the modeling of the MEP engineer could be considered as failure costs. On the other hand some models from the architect don't always provide enough information for the MEP engineer to perform his task.

In the collaboration between multiple partners it should be required to know exactly:
- What the model can be used for;
- What data in the model is definite;
- What confidence level is appropriate for the model.

The main issue with the current specification of the LOD concept is that there is not a clear agreement and understanding of what the model can be used for. Therefore the Dutch Rijksgebouwendienst (the Dutch General Services Administration) has removed references to the LOD concept from their BIM Norm [RGD, 2013].

Several efforts have been made to define the LOD levels more in depth. The next chapter evaluates the most mature, known efforts against the stated requirements.
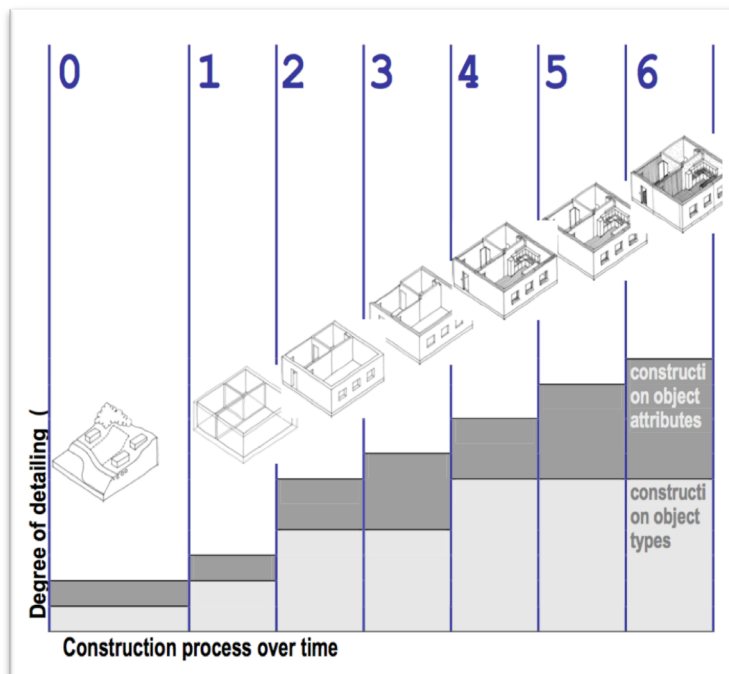
COMPARISON OF POPULAR LOD CONCEPTS

During this project the team also looked at several other information levels like the Danish levels, the AIA, BIMforum.org, and the UK RIBA information.

The Danish Information levels
In Denmark, a package of guidelines regarding 3D was developed in 2006. This was accomplished under the Digital Construction program initiated by the Danish Enterprise and Construction Authority. In June 2006 the Danish BIPS published the document "3D Working Method 2006" (Bips 2007).

The Danish method is built up on the principle of evolving detailing. Each party will add information to the discipline model at a higher and higher level successively through the process and thus work with rising information levels within its discipline. The modeled construction objects are refined geometrically and functionally and a number of object attributes are added and specified further during the process.

On transition from one agreed phase to the next, the discipline model is locked, with a status corresponding to the current information level. This information level is the starting point for modeling in the next phase. The Danish concept uses seven information levels. The method can be adapted to traditional phasing of construction, but does not exclude the option, on a specific project, of using another division of processes and responsibilities in terms of time and content. More or fewer information levels, and different constellations of information levels between the discipline models can be used (Berlo,et al 2012).

The seven levels correspond roughly to the traditional construction phases, but the levels can be customized to other phased processes and methods, and the allocation of roles can vary in accordance with the nature of the task (Bips 2007).

Vico Model Progression Specification
Vico Software (then a division of Graphisoft) began work in 2004 on a Model Progression Specification (MPS). The core of the MPS is the "Level of Detail" definitions—descriptions of the steps through which a BIM element can logically progress from the lowest level of conceptual approximation to the highest level of representational precision. The 5 levels are: Conceptual (100), Approximate geometry (200), Precise geometry (300), Fabrication (400), As-built (500). LOD identifies how much information is known about a model element at a given time.

AIA LOD

The AIA California Council IPD committee and the AIA Contract Documents Committee adopted the LOD concept as the core of its E202-2008 Building Information Modeling Protocol (AIA 2008). This committee evolved the LOD concept into "Level of Development". In 2008, the AIA developed its first set of Level of Development definitions in AIA Document E202™-2008 Building Information Modeling Protocol. Due to the rapidly evolving nature of the use of BIM, the AIA evaluated the E202–2008, including the LOD definitions. The result is the updated and reconfigured Digital Practice documents, AIA E203™–2013, Building Information Modeling and Digital Data Exhibit, AIA G201™–2013, Project Digital Data Protocol Form, and AIA G202™–2013, Project Building Information Modeling Protocol Form, which are accompanied by a detailed guide document entitled Guide and Instructions to the AIA Digital Practice Documents. The AIA's updated Digital Practice documents include revised LOD definitions.

BIMforum LOD

To help further the standardization and consistent use of the LOD concept, and to increase its usefulness as a foundation for collaboration, the AIA agreed to allow BIMForum.org to utilize its latest LOD definitions in this Specification. In early 2011, the LOD Working Group was formed under the auspices of the BIMForum and began developing the LOD framework into a consensus-based document. The LOD definitions that are used in this document are identical to those to be published in the AIA's updated Digital Practice Documents, with two exceptions.

First, the working group identified the need for an LOD that would define model elements sufficiently developed to facilitate coordination between disciplines—e.g., clash detection/avoidance, layout, etc. The requirements for this level are higher than those for 300, but not as high as those for 400, thus it was designated LOD 350. The AIA documents do not include LOD 350, but the associated Guide and Instructions references it.

Second, while LOD 500 is included in the AIA's LOD definitions, the working group did not feel it was necessary to further define and illustrate LOD 500 in this Specification because it relates to field verification. Accordingly the expanded descriptions and graphical illustrations in this Specification are limited to LOD 100-400 (BIMforum.org, 2013).

The first draft of the resulting Level of Development Specification was released for public comment at the Miami BIMForum on April 2013.

US veterans affairs and 2010 and Australia's NatSPEC 2011

To facilitate BIM development, in 2010 the US Veterans Affairs has provided the Object Element Matrix that defines object and element properties and attributes by Uniformat/OmniClass classification and Level of Development (LoD) (VA 2010). It is a spreadsheet to be used for identifying and tracking BIM information during the project. It depicts Building Information Typologies/Types, when they are relevant, and to what level of development (LOD) throughout a building lifecycle. It is an expansion of AIA Document E202 BIM Protocol Exhibit to support a greater level of

understanding of BIM information use. The initiative and spreadsheet were adopted by Australia's NatSPEC in its BIM Object/Element Matrix (Natspec 2013).

UK RIBA, BSI and NBS

In the UK BSI published PAS 1192-2 (Specification for information management for the capital/delivery phase of construction projects using building information modeling) in 2013. This document defines the following abbreviations:
- A.77 levels of model detail (LOD): Description of graphical content of models at each of the stages defined for example in the CIC Scope of Services.
- A.78 levels of model information (LOI): Description of non-graphical content of models at each of the stages defined for example in the CIC Scope of Services. The document shows the level of graphical and non-graphical information slowly developing throughout the project (alongside additional documentation).

The RIBA Plan of Work was published in 2013. As part of Stage 1 "Preparation and Brief", one key task that should take place before design begins is the production of a Design Responsibility Matrix. NBS has developed several tools to support the production of this document.

Private excel sheets
Several private BIM modeling companies have all created their own so called "demarcation" lists. This (mostly spreadsheet) lists define the border of what should be modeled in a particular phase of the process. These initiatives also show the necessity to define what information is needed to perform a specific given task. The current definition of LOD concepts is not explicit enough for this.

General/overall conclusion
There seems to be a consensus that a focus on geometry ("Level of Detail") isn't the key issue. Years ago already the LOD abbreviation was changed to "Level of Development" making geometry and non-geometric information equally important. Although the Danish had this covered already in 2006. The LOD concept gained traction with the AIA document. This initiative was focused on Integrated Project Delivery (IPD) and missed some tools to apply the LOD concept in other projects. With the comprehensive spreadsheet from the US Veterans affairs' minimum BIM requirements release, the concept was made applicable for practice. However, most practitioners lost themselves in filling out huge spreadsheets without actually thinking about why they were doing it. Today initiatives like BIMforum.org and the UK initiatives agree that the concept should be used as a guideline to define project responsibilities and expectations in a project.

SOLUTION APPROACH

Four sector representative organizations and nine Dutch SME companies asked TNO to start a research and development project to address the issues that arise with the LOD concept in Dutch practice. The main issue they face is about trust. There is a need to be able to rely on the presence of sufficient information in a model to perform a given task. It should be clear what a model could be used for.

The solution approach in this research project is to develop a standard or specification that defines the information that should be in a model to perform a specific task. A model on a certain level should be trusted to "be useful for" a goal. There are specific tasks and goals models are used for during different stages of a modeling process. For example cost calculation, energy simulation, checking design requirements, etc. are all tasks that are performed based on a BIM model during every stage of the process. When a model holds more detailed information (properties and geometry) these simulations will be more precise during the process.

The ideal situation would be to define Model View Definitions (MVDs) for every specific task. These MVDs mostly hold the minimum information for a simulation. During a typical project process there are several simulations that have to be performed to make a decision to continue the project. The concept of LOD and, the goal of this project, were to define a more generic set of minimum required data to

support decisions during GO/No-GO moments in the process. To define these tasks the team analyzed GO/No-GO moments during several BIM projects.

Side step: Backwards engineering: As a sidestep during this research project the team was interested if there would be a de-facto standard for the LOD 100-500 levels. Therefore 35 models with different assigned LOD levels from 100 to 350 were analyzed on 10 different aspects. The aspects were number of objects, M³ Volume, number of Spaces, M³ of Spaces, number of geometric triangles, Objects/ M³, Triangles/ Volume, Objects/ Space M³, Triangles/ Space Volume, Average number of properties / Object. The complete models where analyzed, the models without proxy element and the models without proxy and furniture elements. This was done with the bimserver.org framework (Beetz, et al, 2011). If there would be a de-facto standard for the LOD levels, the numbers should reveal a pattern of increasing complexity. This was not the case, concluding that there is no de-facto standard to be defined from the given models and characteristics.

LOD	Objects	M³ Volume	#Spaces	M³ Spaces	Triangles	Objects/ M³	Triangles/ Volume	Objects/ Space M³	Triangles/ Space Volume	Gem. Aant. eigenschappen/ Object
100	917	26090	0	0	7995	0,04	0,31	Infinity	Infinity	31,33
100	754	40705	0	0	12036	0,02	0,3	Infinity	Infinity	34,36
100	637	35161	0	0	9077	0,02	0,26	Infinity	Infinity	34,77
100	1957	590306	1403	330603	5582	0	0,01	0,01	0,02	22,27
300	164	1973	0	0	296	0,08	0,15	Infinity	Infinity	28,18
300	222	2160	0	0	567	0,1	0,26	Infinity	Infinity	27,79
300	228	1950	0	0	378	0,12	0,19	Infinity	Infinity	29,75
300	257	2196	0	0	604	0,12	0,28	Infinity	Infinity	29,18
300	158	1136	0	0	271	0,14	0,24	Infinity	Infinity	30,24
300	165	1269	0	0	463	0,13	0,36	Infinity	Infinity	28,97
300	160	1304	0	0	468	0,12	0,36	Infinity	Infinity	30,64
300	196	1446	0	0	656	0,14	0,45	Infinity	Infinity	31,04
300	312	214121	0	0	17129	0	0,08	Infinity	Infinity	37,52
300	1358	154468	0	0	36720	0,01	0,24	Infinity	Infinity	28,04
300	680	23218	0	0	1216	0,03	0,05	Infinity	Infinity	4,64
350	12849	1065017	1403	330603	138282	0,01	0,13	0,04	0,42	24,07
350	12767	576340	1403	330603	137223	0,02	0,24	0,04	0,42	24,01
350	2329	73464	9	211	28581	0,03	0,39	11,06	135,71	33,05
350	1321	283091	0	0	8790	0	0,03	Infinity	Infinity	36,29
350	3070	371962	0	0	54219	0,01	0,15	Infinity	Infinity	29,89
350	3070	33187	0	0	54188	0,09	1,63	Infinity	Infinity	29,86
350	3393	146782	0	0	60027	0,02	0,41	Infinity	Infinity	28,85
350	482	31468	0	0	4196	0,02	0,13	Infinity	Infinity	35,35
350	591	15217	0	0	4244	0,04	0,28	Infinity	Infinity	35,92
350	734	13894	0	0	4484	0,05	0,32	Infinity	Infinity	35,94
350	729	10686	0	0	4255	0,07	0,4	Infinity	Infinity	36,17
350	446	16896	0	0	2258	0,03	0,13	Infinity	Infinity	36,95
350	512	15476	0	0	2697	0,03	0,17	Infinity	Infinity	36,31
350	462	21663	0	0	2401	0,02	0,11	Infinity	Infinity	35,96
350	568	10716	0	0	2711	0,05	0,25	Infinity	Infinity	36,5
350	5165	973460	1403	330603	15777	0,01	0,02	0,02	0,05	12,29
350	680	23218	0	0	1216	0,03	0,05	Infinity	Infinity	4,64
350	1115	23197	0	0	1792	0,05	0,08	Infinity	Infinity	4,6
350	1134	23711	0	0	1833	0,05	0,08	Infinity	Infinity	4,57
350	12601	998381	1403	330603	137121	0,01	0,14	0,04	0,41	23,78

METHODOLOGY

The team analyzed GO/No-GO moments during several BIM projects. Depending on the company, the discipline of work and personal opinions the project phases that were found had different names. Research and interviews showed that there is a consensus about 7 stages with GO/No-GO moments in between. BIM models should be suited to support these discussion moments. The result is presented in the following table:

BIM Information Levels		0	1	2	3	4	5	6
Information / deliverable of a model on this level:		Functional program requirements (no solutions yet); Room specifications; Location (if known); Desired performance; Ambitions; Budget.	Spatial program requirements; Mass study; Basic quantities; Risks; Estimate; Variants;	Spaces; Objects/elements; Representation of façade; Floor plans; Routings; Technical description; Zoning; Construction principle.	Basic detailing; Energy properties; Definitive measurements; Building method; Principle planning.	Supplier independent; Bill of Materials; Products; Technical specification; Materialization; Detailing; Separation between aspectmodels/disciplines.	Shop drawings; Reliable dimensioning; Product specific detailing; Schedules; Production drawings; Planning; Estimates; Product certificates; Definite detailing, materialization, tolerances, etc.	Revisions of information; User instructions; Maintenance regulations; Warranty and delivery receipts; Key plan; Construction journal and reports.
Application: "Model can be used for"		Demand specification (+ context); Program requirements	Feasibility test (Scenarios/design variants) against requirements.	Test against local policies. Energy simulations.	Permit application; Definitive agreement with client for detailed engineering; Base for collaboration between parties.	Separation between aspectmodels/disciplines. Contract document; Procurement; Base to define contract price.	Site management; Construction preparation; Production and construction; Product purchasing.	Facility management and maintenance. Creating a level 0 BIM for renovation projects.
Comparable with:	NL commons names:	Programma van Eisen	Schetsontwerp / structuurontwerp	Voorlopig ontwerp	Definitief ontwerp	Bestek	Werkvoorbereiding / werktekeningen	Uitvoering
	RIBA:	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
	Denmark:	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
	US:	-	LOD 100	LOD 200	LOD 250 / 300	LOD 350 / 400	LOD 400 / 450	LOD 500
	CityGML:	LOD 0 / 1	LOD 2	LOD 3	LOD 4	LOD 4 (evt. met ADE)	-	-
	NEN EUR	NEN 2699 niveau 1,2,3	NEN 2699 niveau 3-4	NEN 2699 niveau 4-5	NEN 2699 niveau 4-5	NEN 2699 niveau 5-6		NEN 2699 Niveau 5-6
	Drawings	NEN 2574, fase 1,2 en 3, Inititatie, Haalbaarheidsstudie en Projectdefinitie	NEN 2574, fase 4, Structuurontwerp	NEN 2574, fase 5, Voorlopig Ontwerp	NEN 2574, fase 6, Definitief Ontwerp	NEN 2574, fase 7, Bestek	NEN 2574, fase 9, Werkvoorbereiding	NEN 2574, fase 11, Oplevering

(more detailed table is available on nationaalbimhandboek.nl)

In the last row of the table a comparison is made between the levels from RIBA, Denmark, US AIA, CityGML and typical Dutch norms and currently common names. Although this effort was defined independently from the current LOD conceptual frameworks, the similarity with the Danish information levels and the UK RIBA levels was very high. This lead us to the question if more European construction processes might require a different approach to the LOD concept than the current US levels.

We came to the conclusion that the Dutch industry needed 7 levels of information in BIM models. We labeled them 0 to 6. For users to be able to trust that a model holds enough information to be useful for a task, additional specifications were needed. The team decided to create a matrix with objects and properties listed per information level. In total there will be three deliverables: the matrix as the 'standard' specification of objects and properties that have to be in a model on a certain level; a practical guide how to use the concept of information levels explaining background, examples, etc. with references to the matrix; and a project template to be used in a specific BIM project to define the use of the concept. This template uses references to the practical guide and the matrix

RESULTS

The matrix: To define what objects and properties should be in a model that is modeled on a certain level, a matrix is created. The matrix looks like:
The objects and properties are listed on the left column. For each Information Level a column is available. With 'x' signs the team defined which objects + properties had to be in a model on a certain level. Each decision was done with the question in mind: 'What information should be in the model to perform the task defined for that level?'. The team recognized the potential to use a predefined list of objects and properties. Like the Danish concept a reference to an object library (or BSDD concept library) would make sense. Therefore this project extracted all the Dutch concepts and properties from the BSDD. This gave us a list of >12.000 concepts with a total of >60.000 properties. This was impractical to use to fill out the matrix. An alternative was to list all IFC objects and properties but the same issues came up with impracticalities. Finally the team decided to use the Dutch classification system NL-SFB as a base to start the definition in the matrix. Eventually the matrix holds over 2.000 properties of objects in 8 categories. The matrix is published in an online database on nationalbimguidelines.nl. The database is accessible to anyone and there are multiple options to query and filter it.

Practical guide: The goal of the practical guide is to explain the proposed usage of the Information Levels. Most important contents of this guide are: a position statement about the concept (background, disclaimer, definitions,); a description of the Information Levels and their proposed use; example pictures; use case examples.

The project template: The project template is a tool, ideally to be used at the beginning of a project phase. It helps project teams to define how they are going to use the information levels in their specific project. It is used as a spreadsheet/table that holds a demarcation of the project. A project could be demarcated in building parts, building elements, etc. The team is free to choose this. For each section the team should agree on who will model that section (i.e. who is responsible); what the status of that model will be; what classification system is used in the model; what information level the model will have (minimal); and there is the ability to list some exceptions. A typical project template could look like table 1.
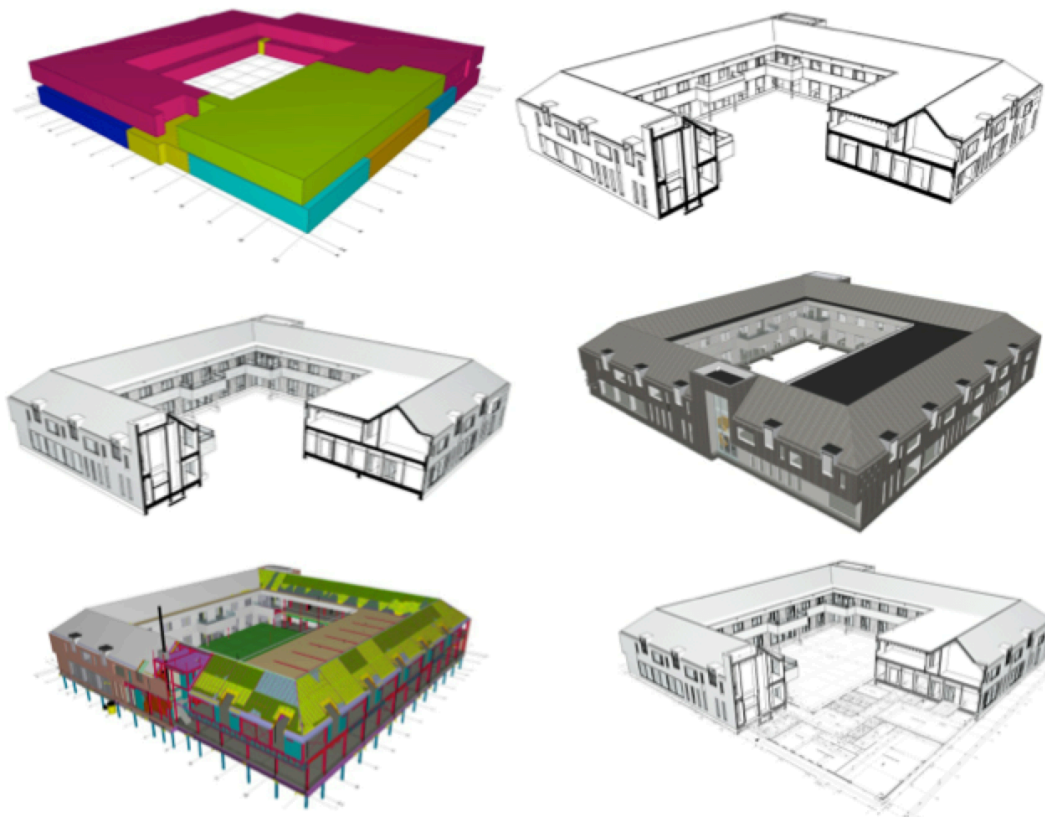
Table 1. example project template for a specific project phase.

	Aspect- model	Status	Classification	Information Level
Buildingpart A	Architect	Definitief	Omniclass	3
Buildingpart B	Architect	Definitief	EAN	3
Buildingpart C	Constr.	Voorstel	NlSfb	4
Etc…				

The project template is part of the BIM protocol generator and available on bimprotocolgenerator.com.

USAGE / IMPLEMENTATION

The concept of the 7 levels, the definitions and the project template where validated in Dutch projects. These pilots were the source for the information in the practical guide.

The evaluation delivered example pictures and valuable feedback that is integrated in the practical guide. Unfortunately there are not enough projects available yet that used the Dutch Information Level during multiple phases of a project, to do validated statements about the usability of the concept. However, all users respond that the specification (the matrix) is a solution to the current lack of definitions for LOD.
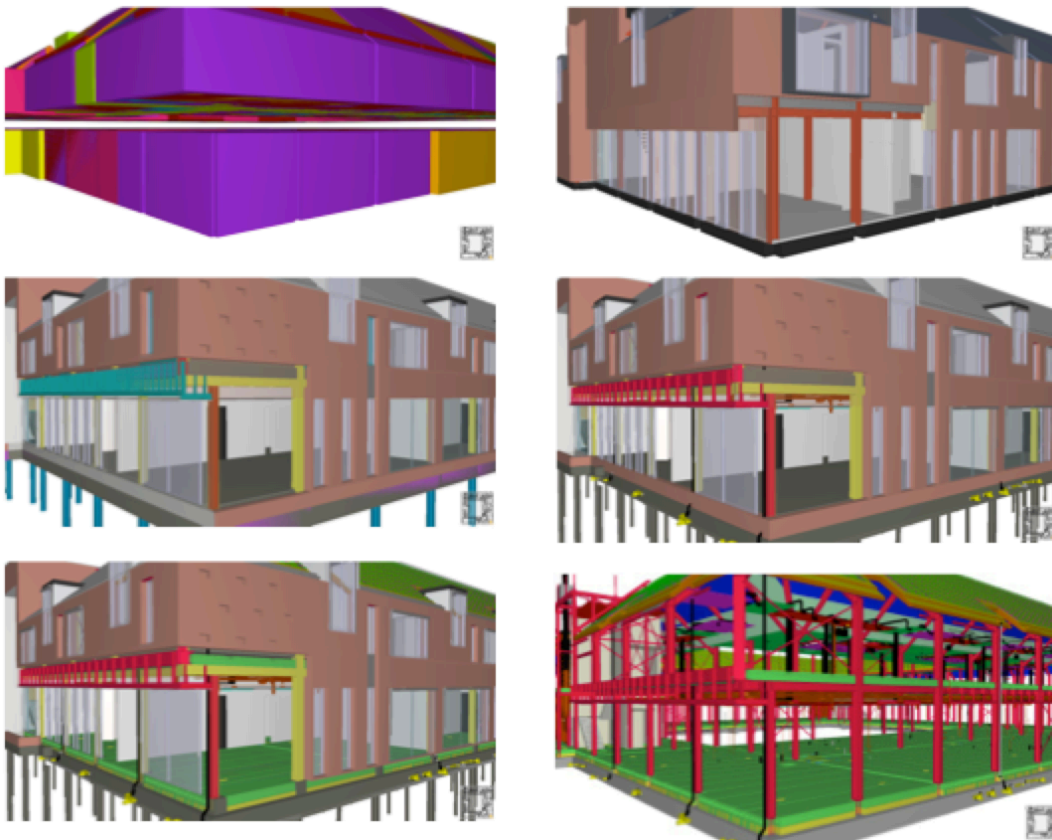
The most important feedbacks from practical use that are integrated in the practical guide are:

- There is no strict correspondence between the Dutch Information Levels and design phases. The use of the Dutch Information Levels in a project doesn't have to be in the same sequence as the levels. Different projects have different needs and parts of models might be more or less developed during a project. Creating a working standard for each project could improve productivity of BIM modelers.

- The Dutch Information Levels define a base for the minimum level of information that has to be in the model to be used for a defined task. The project members still

have to think about what they need before the start of each project (phase). The information in a model can be (much) more detailed than the assigned Information Level to the model. The assigned information level says something about the trustworthiness of the data in a model, not about the amount of information in it.

- There is no such thing as a model on a certain Dutch Information Level. As previously stated, project models at any stage of delivery will invariably contain elements and assemblies at various levels. The use of the project template is therefore a key issue to successfully use this concept.

- There is a returning request for an automated tool to validate IFC models to the Dutch Information Levels. In addition to the previous two bullets is does not make sense to evaluate a model to assign a level to it. It would make sense to check if the minimum required information is in a model that is already labeled with a Dutch Information Level. However, because information can be hosted in the model on several different locations and manifestations it would be impossible to automate this. Using an open data standard like IFC is not enough to solve this issue. Additional MVDs could be created to facilitate this.

CONCLUSION

The main issue during the discussion about the LOD concept is, or at least should be, about trust. Project members need to be able to know what the level of trust is from

the information. With increasing capabilities of BIM modeling software most BIM models will hold much more information than the assigned information level. Exchanging data and the use of Information Levels is not about the amount of information in a model, but about the level of trust that can be assigned to a model. The original approach "*Where can I use this model for*" fits perfect in this conclusion. There needs to be a minimum amount of information in a model to be able to use it for a task, but the real message modelers give to team members is about the level of reliance of the data.

In the end a BIM model is used to make decisions in a process. Using the Dutch Information Levels as a definition project members are sure to have enough information to base their decision on.

The most surprising conclusion we found during this project was that the level of detail of the geometry of a model was not important at all.

REFLECTION AND FUTURE WORK

This research was just a first step into the development of a stable standard for Dutch Information Levels. There are still some issues to resolve and future work to be done:
- Level 0 is still underexposed. There is not a lot of experience with BIM information in the requirements stage of projects.
- One of the main problems that project members don't define (or don't know) what they need from other team members is still not addressed with this project. Therefore we started a BIM protocol generator. The BIM protocol generator also holds the project template for the Dutch Information Levels.
- The current Dutch Information Levels only define objects and properties. Each object and each level should also contain modeling agreements.
- The link with BSDD or other concept/object libraries could be of great value. This still has to be researched. At this moment there is no reference from objects and properties to their equivalent in the IFC standard.
- The standard definition (the matrix) is available online and will be referenced in contracts. When revisions or additions will be made to this standard it should be clear that there is a new version. References in contracts should therefore also name the version number of the Dutch Information Level standard.

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