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# Chapter 7
# Process-based definition of model content

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**Abstract** The Industry Foundation Classes (IFC) data model provides a comprehensive, vendor-neutral standard for the description of digital building models. However, the IFC only concerns the data structure. To be truly useful in the context of planning processes, additional specifications are necessary that determine who provides which information when and to whom. To support this, the buildingSMART organization introduced the Information Delivery Manual (IDM) standard. This standard makes it possible to organize data exchange processes in a graphical notation, and to subsequently derive exchange requirements (ER) for data exchanges occurring in this process. The technical implementation of these exchange requirements takes the form of a Model View Definitions (MVD) that accurately specify which entities, attributes and properties may or should be used in a particular exchange. This chapter provides a detailed introduction to the IDM mechanisms. The chapter concludes with an introduction to the concepts of levels of development (LOD).

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## 7.1 Overview

The standard data model formats introduced in the preceding chapters, such as the Industry Foundation Classes (IFC) are targeted at capturing complete, all-encompassing information regarding all aspects of a building (all-in-one). This means they are both very complex but also never entirely complete due to the notion of 'reduction' (Stachoviak); see Chap. 1. For example, for structural calculations, statements about the color of the wall finish are as superfluous. Likewise, the detailed geometric description of a piece of furniture is irrelevant for the calculation of the energy consumption of a building. On the other hand, generic exchange models often lack the necessary information for specific use cases. For example, generic models rarely contain the fire resistance properties of crucial construction elements needed for fire safety calculations, or finite element meshes needed for structural simulations, or all the material properties required for cost estimation. Often, it is desirable, to focus and restrict the information captured in a model to particular aspects, processes or stakeholder views. This can be achieved by so-called partial or aspect models that apply restrictions and constraints to information models such as the IFC.

In this chapter, we examine different approaches that allow the process-specific applications of such mechanisms for building information models.

## 7.2 Information Delivery Manuals and Model View Definitions

As discussed in Chap. 6, the IFC data model is very extensive. The wealth of information that can be captured in attributes, properties and at a geometric level often exceeds the intended use at a particular stage in the life cycle of a building project. In addition, the flexibility of the IFC model, although on the whole desirable, can make it difficult to capture and retrieve information in an appropriate form for other scenarios. To avoid difficulties arising from this, it is necessary to agree on uniform and standardized means to further specify the contents expected from a building model instance. These specifications regulate *which* information is delivered by *whom*, *when*, and to *which* recipient. To address this, the buildingSMART organization developed IDM/MVD frameworks. This helps reduce room for interpretation and makes it easier to implement specific use cases and application areas. The framework distinguishes content-related requirements captured in *Information Delivery Manuals (IDM)* and technical implementations and mappings of these requirements in the form of *Model View Definitions (MVD)*. Information Delivery Manuals capture quality assurance agreements in a uniform, standardized way. Their creation and use are specified in the ISO 29481 (2016).

The technical implementation of these agreed requirements in the form of partial IFC Models is based on the Model View Definition standard. Figure 7.1 schematically depicts the phases with their respective intermediary results: First stakeholders, actors and their respective roles are determined (1). In a second step, processes are

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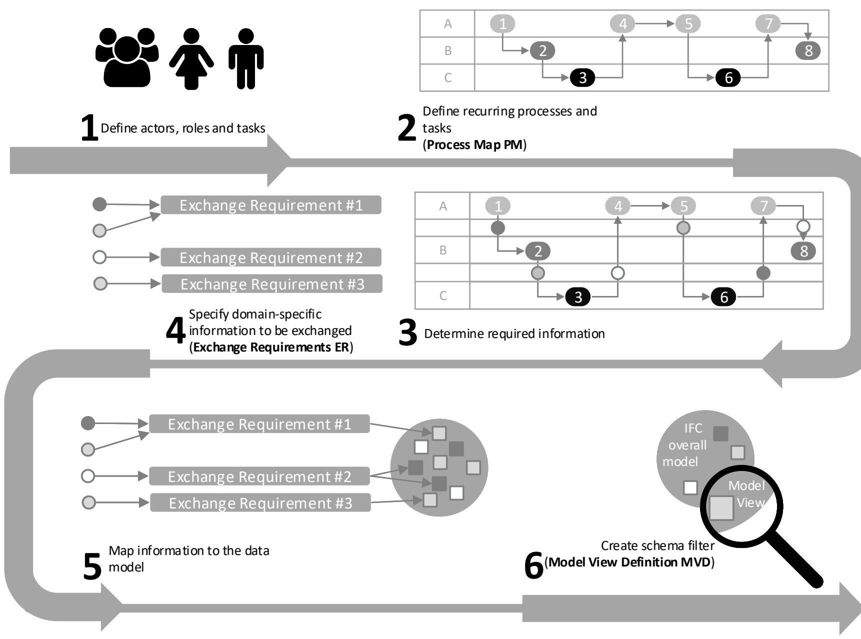


**Fig. 7.1** Overview of the IDM/MVD method used for the IFC based exchange of information

captured in the form of diagrams according to the Business Process Modeling Notation (BPMN; see Chap. 4) referred to as Process Maps (PM) (2). The interfaces determining the exchange of information are defined in (3), after which they are formalized in (4) and mapped to the IFC model in a fifth step (5). The formal notation of capturing these exchanges using the dedicated mvdXML meta model concludes the process and results in (6) a use-case specific Model View Definition (MVD). Before starting this procedure, participants should agree on the scope of the effort and define clearly the intended improvements they intend to achieve. Consequently, the following requirements are essential:

1) Creation of an overview of the sub-processes of the planning process for the specific situation. Elaboration of these sub-processes using a standardized formalization notation referred to as *Process Maps (PM)*
2) Creation of a formal program of data exchange specifications referred to as *Exchange Requirements (ER)*
3) Mapping of these information aspects onto a data model like the Industry Foundation Classes, referred to as *Model View Definitions (MVD)*

The first two tasks (PM, ER) are undertaken by domain experts who have good knowledge and experience of past projects, general conventions, and best practices in the respective fields. The respective documents and information artifacts can be created using simple technical means such as general-purpose diagram editors, word processing applications and spreadsheets and do not require technical skills

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or knowledge of the underlying information models such as the IFCs. Already in these initial phases, the formalization and notation of processes and data exchange definitions at a low level can significantly improve the overall performance of a consortium by encouraging team members to reflect on and consider common business scenarios in a structured way. The requirements can be elaborated using natural language such as “all elements serving as boundaries for spaces should have a thermal coefficient” or “all spaces should have an indication of their intended use” and already make it possible to manually check the information passed between parties even without IT support. Depending on the project phase, the number of stakeholders involved, and the number of partial processes considered, the creation of such Exchange Requirements can be a laborious task that is best done as a collaborative effort, allowing all participants to share and re-use the documents in order to establish commonly agreed best practices. The buildingSMART organization provides extensive tutorial materials and templates for creating such documents, and a number of fully-fledged IDMs are publicly available in the archives of the BLIS initiative (BLIS, 2014).

However, to implement semi-automated model audits, for model-checking and quality assurance based on these requirements specifications, further formalization is required. For this, constraints defined by domain experts, for example in the form of spreadsheets, are mapped to data models such as the IFCs and documented in a form that can be implemented in computer tools. These exchange requirements are bundled into so-called Model View Definitions (MVD) that specify what parts of the large IFC meta-model (classes, attributes, properties and relationships) are required for a specific purpose. Whether the specified information should be included in an IFC partial model is determined by an additional rule set based on process-oriented domain-specific requirements. The overall goal of this step is to transfer user exchange requirements into a machine-readable form that can be processed by software tools such as modelers and model checkers implemented by software vendors. Specifying Exchange Requirements needs a good understanding of both the domain-specific requirements as well as technical knowledge of the underlying data model.

The relationship between domain-specific requirements independent of the IFC data model (Process Map + Exchange Requirements) to its technical implementation based on IFC is shown in Fig. 7.2. The information contained in the overall IFC model is narrowed down to what is required for a specific exchange using Model View Definitions. Through the application of additional restrictions, it is possible to define the precise information needed for particular exchange requirements.

### *7.2.1 Process Maps*

To obtain an overview of the partial processes under consideration for a particular exchange, and to organize different information exchange scenarios, process dia-

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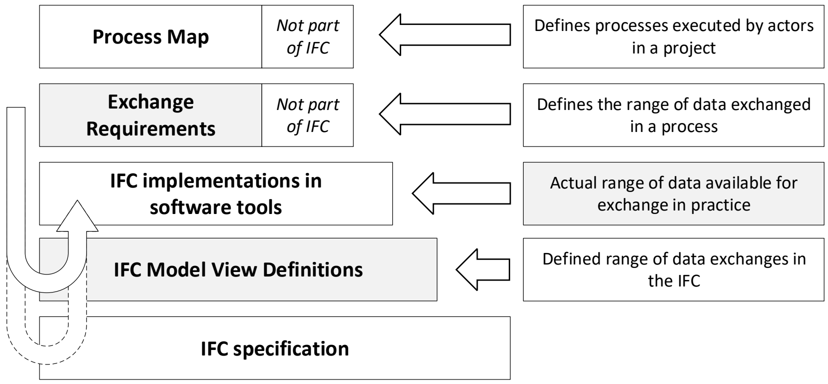


**Fig. 7.2** Mutual coverage of Process Maps, Exchange Requirements, Model Views and the IFC model

grams are created using the Business Process Model and Notation (BPMN) (see Chap. 4). These structure a number of process properties:

- Actors and their relationships (who transmits information to whom)
- Dependencies regarding the order of partial processes (when is information transmitted)
- Documents or partial models being used (what is transmitted)

For example, we can map the relationships between the actors "client", "architect", and "energy consultant" for the energy consumption use case based on an initial design created by the architect, the owner commissions an energy estimation from the energy consultant as illustrated in Fig. 7.3. The actors agree that in addition to external data sets such as climate data, energy costs and the relevant calculation methods (such as ISO 6946, or BREEAM (BREEAM, 2017) and LEED (LEED, 2017) in later stages), a building model in IFC format is also required. The resulting Process Map defines a clear structure for the requirements and the assignment of responsibilities for information exchange scenarios throughout all process steps. This detailed elaboration is necessary as the requirements for model content differ significantly in different situations.

### *7.2.2 Exchange Requirements*

Exchange Requirements set out the information needed for a handover in the data models in a semi-formal tabular form. The items are structured by building element and determine the necessary properties such as optional/required entry, data

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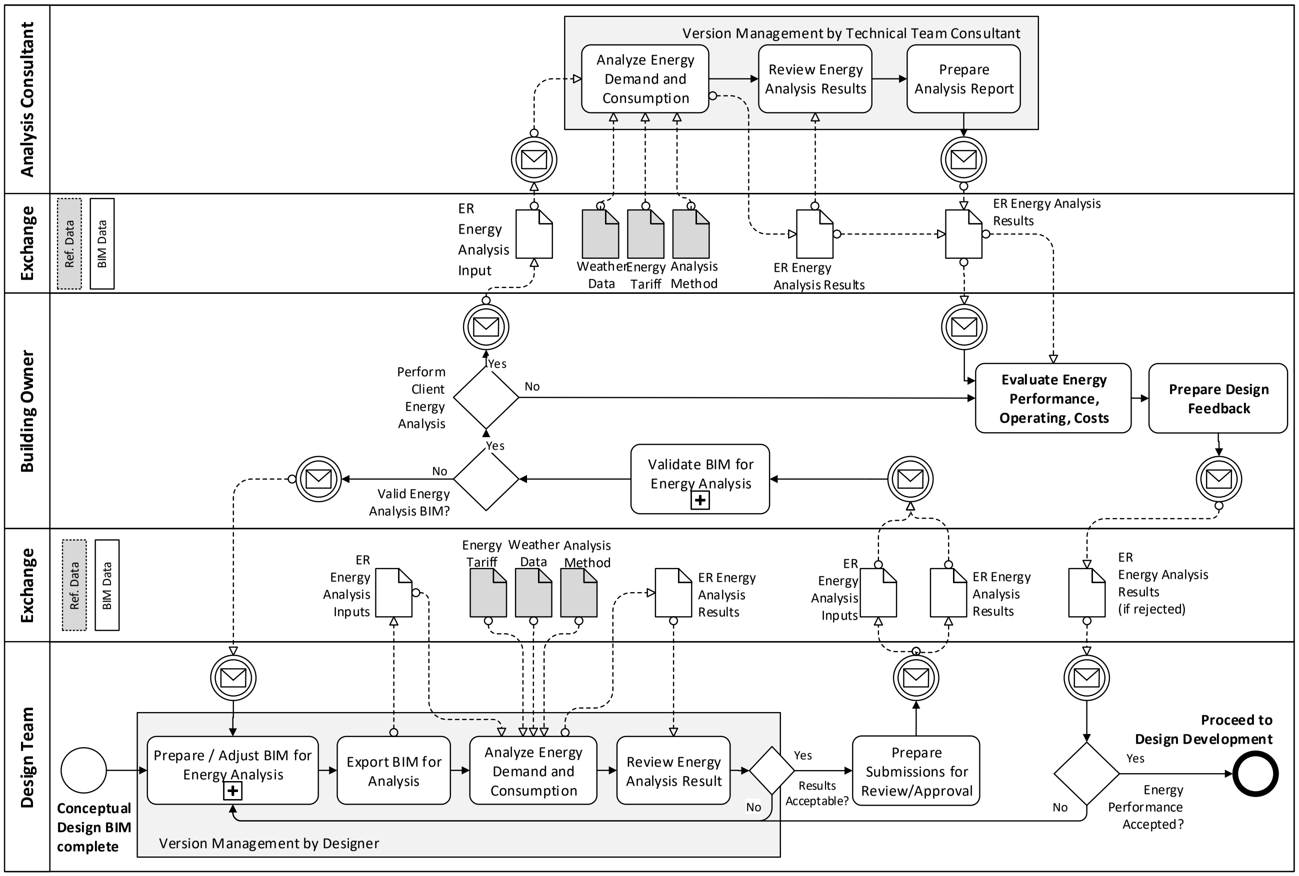


**Fig. 7.3** A Process Map captures the processes that are relevant in a given business use case and identifies data exchanges along with their relevant Exchange Requirements (ER). This serves as a basis for the corresponding MVDs. The Process Map shown here in abbreviated form is taken from the Concept Design Phase Energy Analysis IDM, developed jointly by GSA (USA), Byggforsk (Norway) and Senatii (Finland).)

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**Information Delivery Manual (IDM) -- BIM Based Energy Analysis** **Page 24 of 34**

| Type of Information | Information Needed | Required | Optional | Data Type | Units |
|---|---|---|---|---|---|
| | ○ Construction type (e.g. wall type, door type, window type, shading device type, etc.) Window constructions from Window 6, opaque constructions from ASHRAE Fundamentals. | X | | String | n/a |
| | ○ Classification - UniFormat (reference to a classification -- see below) | | X | String | n/a |
| | ○ 3D Geometry | X | | IFC Geometry | varies |
| | ○ Exterior or Interior Element (i.e. Is Exterior) | X | | Boolean | n/a |
| | ○ Link to Space Boundary | X | | Relationship | n/a |
| ***Building Elements*** *(Opaque- Wall, Roof, Floor, Ceiling, Door)* | Added to the list above, the following properties should be included for opaque building elements (e.g. walls, floors, ceilings, roofs, doors, etc.): | | | | |
| | ○ Link to Material Layer Set | X | | String | n/a |
| ***Building Elements*** *(Glazing- Curtain Wall, Glazed door, Skylight, Window)* | Added to the Building Elements list above, assigns thermal information to building elements to enable energy analysis. The following properties should be included for glazed building elements (e.g. windows, curtain walls, glazed doors, and skylights): | | | | |
| | ○ Window Assembly Exterior Surface Color of Glass (clear, bronze, silver, gold, copper, blue, | | X | Enum | n/a |

**Fig. 7.4** In an IDM, Exchange Requirements are captured in a user-friendly way. Here, required and optional information items are specified for each object type. In this excerpt from the IDM Concept Design Phase Energy Analysis, a particular construction type is specified. Such descriptions are formalized further in later stages, see Sect. 7.2.3

type, unit, value ranges, relationships to other elements etc. (Fig. 7.4). These Exchange Requirement documents facilitate both discussion between stakeholders and serve as a preparatory step for the formalized, machine-readable definition of model views.

### *7.2.3 Model View Definitions*

Process Maps and Exchange Requirements describe what is needed for data exchange in different scenarios. If the exchanged information is based on an IFC model, the respective partial models can be formalized as a Model View Definition (MVD). With the help of additional rules, one can determine which information is necessary and which is optional. The result is a description of requirements at the schema level that is applicable for the respective instance models in the concrete use case. A MVD is a technical means of checking the validity of instance models for a particular exchange scenario. Specifications in a Model View range from the definition of required Property Sets to restrictions on allowable forms of geometry representations. The latter is of particular importance in concrete data exchange scenarios as the Industry Foundation Classes model can accommodate a great variety of different geometrical representations (see Chap. 6) while real-world scenarios require only one or two. Limiting the availability of geometrical representations, e.g. to faceted meshes rather than parametric NURBS surfaces, can also reduce the functionality requirements for downstream software tools. Additionally, such MVDs form an excellent basis for the certification of IFC implementations in software tools (see Chap. 8).

Version 2x3 of the Industry Foundation Classes contains the following predefined MVDs (buildingSMART, 2014a):

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- Coordination View: contains all building information for the exchange between the three major disciplines architecture, structural engineering and MEP. Receiving software applications can modify the content.
- Quantity Take-Off Add-on: contains additional quantities for building elements and spaces that are only implicitly contained in the general model. For example, in the generic Coordination View model, the height of a wall is only captured in the geometric representation whereas the Quantity Take-Off Add-on also captures an explicit height attached to the element.
- Space Boundary Add-on: contains additional, explicit boundary descriptions for spaces that are required, for example, for MEP planning.
- 2D Annotation Add-on: contains additional elements for handing over 2D geometry, annotations, dimensioning and remarks.
- Structural Analysis View: contains information such as physical models and loads that are necessary for the structural analysis.
- Basic Facility Management Handover View.

These predefined views usually form the basis for the certification of software products and their ability to correctly import or export IFC data sets (see Chap. 8). Alongside these common predefined views, the new view definition models for IFC 4, based on the mvdXML standard, are going to play an increasingly important role. To basic forms, the Reference View and the Transfer View can be distinguished:

- The Reference View is mainly intended to support the coordination and merging of partial models and domain models for purposes such as collision detection based on geometric information. Changes are created in the respective authoring tools and made available through exports.
- In the Design Transfer View, the complete model is handed over and changes are made in the shared model.

The definition of a Model View is often done in a two-step process: First, special MVD-diagrams are created in which the required data items from the model are color coded. Here, "concepts" are used, that combine the use of attributes as well as relations across multiple instances. The concepts are defined in such a way that they are reusable across different MVDs. The combination of several simple concepts into more complex concepts is a further principle for the creation of Model Views. The introduction of concepts helps avoid the overly fine-grained production of views at an attribute level and supports the reuse of partial views and their implementation in software tools.

Typical examples for concepts are "GUID", "Name" and "Building Element Assignment". The use of corresponding concepts is shown in Fig. 7.5. An excerpt of an MVD diagram for the entity IfcBeam in the context of the MVD *Energy Analysis* is shown in Fig. 7.6. The diagram specifies for example how the fire resistance of each beam has to be provided. Furthermore, it defines that only the concepts *Brep*, *Swept Solid* and *Clipped Solid* may be used for its geometrical representation (see Chap. 6 for further information).

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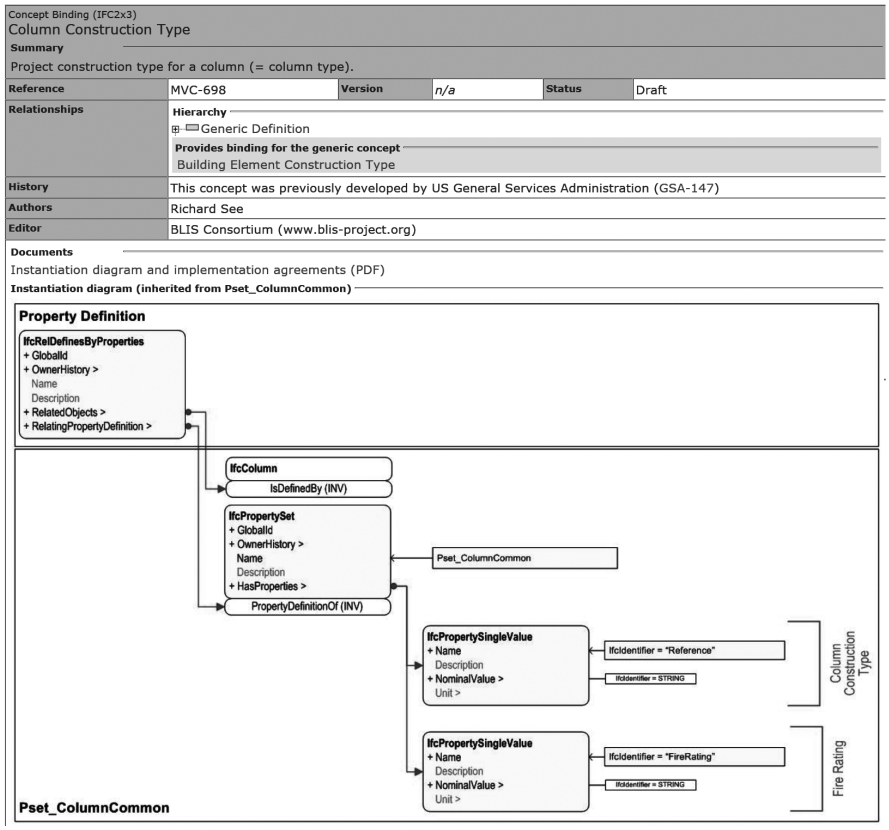


**Fig. 7.5** The definition of the concept "Column Construction Type" describes the assignment of a construction type and a fire rating to an IfcColumn. This concept is used, for example, in the Energy Analysis View Definition.

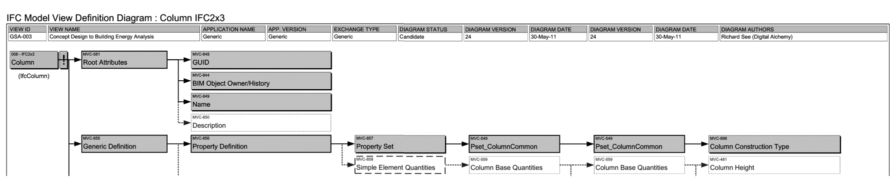


**Fig. 7.6** An MVD diagram defines for an ENTITY which concepts are an required par of a particular MVD. This figure shows the diagram of the IfcBeam in the Concept Design to Energy Analysis MVD. The definition of corresponding Column Construction Type is provided in Fig. 7.5

In a second step such MVD diagrams are transferred into the machine-readable format mvdXML, which describes Model Views using an XML Schema (Chipman et al., 2012). In addition to the graphical description described earlier, further concepts such as links, if-then-else relations and conditions as well as arithmetic calculations can be captured as formal rules. Software tools for the creation of mvdXML

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definitions are presently comparatively rare, but will in future be more widespread. Increasing awareness of the necessity of such formalizations, along with an increase in specifications and the standardization of enabling technologies, will lead to an increase in the use of quality assurance tools for building information data sets. The creation of ad-hoc, project-specific Exchange Requirements would pave the way for semi-automated checks of information exchanges alongside existing semi-formal agreements and manual model checks. An important step is the creation and maintenance of re-usable concepts that can be used by end users and modified for the specific organization or project needs.

### *7.2.4 Level of Development*

An alternative and complementary approach to specifying design and planning requirements using IDM/MVD is the concept of "Level of Development" (LOD) or "Level of Model Definition" (LOMD) for determining which information has to be delivered by whom at which stage. This concept is analogous to scale drawings: A scale such as 1:200 contains only approximate information and the information it contains is therefore inherently uncertain; a detail drawing at a scale 1:10 contains information suitable for the production of building components with a high degree of precision and accuracy. The assignment of a LOD to a model or building components allows the recipient of the information to assess its reliability. To achieve this, standards for the levels of detail of building components have been created in various countries. The American Institute of Architects (AIA) in collaboration with the American BIMforum, for example, has defined the following six LODs (AIA, 2013; BIMforum, 2013):

- LOD 100: The model element is represented graphically by a symbol or a generic representation. Information specific to the element such as costs per square meter can be derived from other model elements.
- LOD 200: The model element is represented graphically in the model by a *generic* element with approximate dimensions, position and orientation.
- LOD 300: The model element is represented graphically by a *specific* object that defines its size, dimension, form, position and orientation.
- LOD 350: The model element is represented graphically by a *specific* object that defines its size, dimension, form, position and orientation as well as its interfaces to other building systems.
- LOD 400: The model element is represented graphically by a *specific* object that defines its size, dimension, form, position and orientation along with information regarding its production, assembly and installation.
- LOD 500: The model element has been validated on the construction site including its size, dimension, form, position and orientation.

Figure 7.7 the different levels of development of a steel column and its interfaces. LOD definitions are not related primarily to IFC models but can also be im-

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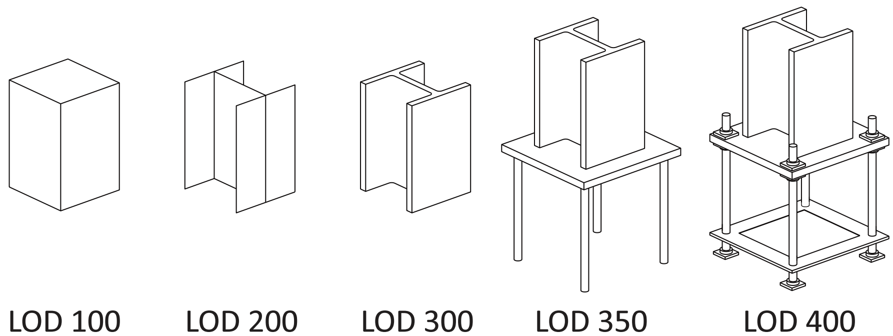


**Fig. 7.7** Different Levels of Development as defined by the American Institute of Architects (AIA). In this example a steel column including its connection to the lower building elements is shown. LOD 500 is left out.

| Column | BIM Object or Element | | General Information Use |
|---|---|---|---|
| | Item Catergory - **Column** | | **Building System** |
| | **Description: A 2D and 3D element.** An relatively vertical element most commonly attributed to the structural support system for a building. Columns may be located on the exterior or interior of a building . A column may be a non-structural decorative element only. | | Item System Category - Uniformat |
| **Level of Development** **AIA Document E202 - 2008** Developed by Graphisoft 2001 | **Information Category for Information Item (See Master Information Tab)** | **Information Item (information about the specific object or element)** | **IFC Support** |
| **LOD 100 - Conceptual** | | | |
| Overall Building Massing Indicative of Area, Height, Volume, Location, and Orientation. | Building Program & Project Meta Data | Facility ID | IfcColumn->IfcBuilding.Name |
| | Building Program & Project Meta Data | Facility Name | IfcColumn->IfcBuilding.LongName |
| | Building Program & Project Meta Data | Facility Description | IfcColumn->IfcBuilding.Description |
| | Physical Properties of BIM Objects & Elements | Overall Length | IfcColumn->IfcQuantityLength.Name="Length" |
| | Physical Properties of BIM Objects & Elements | Overall Width | IfcColumn->IfcQuantityLength.Name="Width" |
| | Physical Properties of BIM Objects & Elements | Overall Height | IfcColumn->IfcQuantityLength.Name="Depth" |
| | Physical Properties of BIM Objects & Elements | Overall Area | IfcColumn->IfcQuantityArea.Name="GrossSurfaceArea" |
| | Physical Properties of BIM Objects & Elements | Overall Volume | IfcColumn->IfcQuantityVolume.Name="GrossVolume" |
| | GeoSpatial and Spatial Location of Objects & | Position Type | IfcColumn.ObjectPlacement |
| **LOD 200-Approximate Geometry** | | | |
| Generalized Systems or Assemblies with Approximate Quantities, Size, Shape, Location, , and Orientation. | GeoSpatial and Spatial Location of Objects & | Zone/Space Name | IfcColumn->IfcZone.LongName (new in IFC2x4) |
| | Manufacturer Specific Information Requirements | General Type | IfcColumnType.Name + IfcClassificationReference |
| | Costing Requirements | Value Based Costing (i.e. Cost SqFtg) | IfcColumn->IfcCostValue.CostType="Estimated" + UnitBasis |
| | Sustainable Material LEED or Other | LEED Items per Quantity Values | IfcColumn->IfcEnvironmentalImpactValue or ifcPropertySet with local LEED agreement |
| | Program/Space Compliance or Validation | Program Room Requirements | IfcColumn->IfcSpace - IfcSpace has IfcConstraint |
| | Code Compliance/ Occupant Safety | Egress Requirement | IfcColumn->IfcSpace - IfcSpace has IfcConstraint |
| | Code Compliance/ Occupant Safety | Circulation Requirement | IfcColumn->IfcSpace - IfcSpace has IfcConstraint |
| | Phases Time Sequencing & Schedule | Order of Project Milestones | IfcProject->IfcTask.IsMilestone->IfcRelSequence + assign IfcColumn->IfcRelAssignsToP |
| **LOD 300-Precise Geometry** | | | |
| Specific Assemblies that are Accurate in Terms of Size, Shape, Location, Quantity, and Orientation . | Physical Properties of BIM Objects & Elements | Nominal Size | |
| | Physical Properties of BIM Objects & Elements | Mass | IfcColumn->IfcQuantityWeigth.Name="GrossWeigth" |
| | Physical Properties of BIM Objects & Elements | Connections | - physical fasteners - |
| | Physical Properties of BIM Objects & Elements | Capacity | IfcColumn->Pset_ColumnCommon with Property.Name="LoadBearing" |
| | Physical Properties of BIM Objects & Elements | Perimeter | fcColumn->IfcQuantityLength.Name="GrossPerimeter" |
| | Manufacturer Specific Information Requirements | Type | IfcColumnType |
| | Manufacturer Specific Information Requirements | Material | IfcColumnType->IfcMaterial.Name |
| | Manufacturer Specific Information Requirements | Availability | |

**Fig. 7.8** The reduced excerpt from the BIM Object/Element Matrix of the Australian NATSPEC standard shows the different levels of development of a building element along with its required parameters and maps these into the IFC model

plemented with proprietary models by software vendors. Combinations of the LOD concept with the vendor-independent IFC model include the Australian NATSPEC National BIM Guide (NATSPEC, 2011). In this standard, extensive spreadsheets are provided by the so-called NATSPEC BIM Object/Element matrix that provide specifications for IFC model contents for each respective LOD (Fig. 7.8). In current business practice, contractual agreements between stakeholders include information on which LOD has to be delivered. Depending on the local standard, this matrix is referred to as a "Model Progress Specification", "Model Element Table" or "LOD Table". The LOD concept is of particular value for model-based collaboration across

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organizational boundaries and for contractual agreements concerning model content and quality. In future, we can expect to see further formalizations of LOD and their inclusion in norms and standards.

## 7.3 Summary

For the organization of model-based collaboration it is essential to determine which stakeholders should receive which information at what level of detail at a certain moment in the planning process. The Information Delivery Manual (IDM) method requires that underlying business processes be structured in a Process Map (PM) and that the necessary information for handovers between project participants is identified. Specifications are created for these information transmissions in the form of Exchange Requirements that define the kind of information that has to be delivered to the recipient in order to continue with the process. If IFC model instances are used as an information carrier, Model View Definitions (MVDs) can be specified in a subsequent step to capture the Exchange Requirements in a formalized way. Such MVDs make it possible to ensure that the required information contained in IFC models is handed over and help reduce the model complexity. In addition to MVD developments, the American Institute of Architects (AIA) has specified “Levels of Development” (LOD) that represent the maturity and accuracy of a model. Such LODs can also be employed with other models than the IFC.

Current semi-formal graphical methods for the creation of IDM/MVD will soon be augmented by more formal and expressive formats, such as mvdXML, that are completely machine-processable. As such, we can expect to see more widespread use of IDMs for recurring scenarios as well as their standardization at national and international levels in the coming years.

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