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LOD standardization for construction site elements

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Abstract

In the last years an increasing attention to the information management in construction is visible. The advent and the continuous development of BIM applications permitted to focus more on this issue and to transform the way of design and manage construction. As known the management of a project is divided in different phases from the early draft to the management of the maintenance. Each of this phase need a different level of information development and also a different graphic detail according to the need of each project. International standards developed different scales for these two issues such as the LOD scale of the American Institute of Architects, taken as guideline in different standards. Since the need of developing a proper construction site plan during each phase of the design process, the level of development of construction elements need to be standardized as well. The paper presents then the development of a LOD scale for construction site elements such as equipment, temporary structures, etc. In particular it considers the phases between the draft design and the detailed design, developed by a client designer. In addition to this it considers the construction phase developed by contractors for the installation design. This according to the systematic approach proposed in an earlier report of research. In fact the research consisted in the analysis of each design phase in order to evaluate the exigencies in terms of information and graphic detail. The postulated LOD scale has been then developed also modelling a reasonable number of elements and tested in the design of real case studies. As a result the findings of this research are inserted in the Italian Standard UNI 11337-4 about the digital management of construction processes and the information development of models, deliverables and objects

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Keywords: BIM; Construction Site; CoSIM; Design phases.

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1. Introduction

It is known that construction field has been subject during the last years to an evolution due to the advent of digital models and, in general, IT developments. The design phase of a building projects acquires more and more importance, with the aim to reduce uncertainty during construction phase. Projects are characterized by an high quantity of information that are collected, thanks to the developments of digitalization, and then are available into graphical and computerized models. In this context acquire more and more importance the way to collect, store and express, in a digital format, information about construction elements. The presented research continues the study made by the task group on construction planning, focusing on the need of information expression, also for what concerns the construction phase of the process: the design of site logistics and layouts [1]. A previous report of the research [2] showed how the possibility of using Building information models for construction site design (i.e. Construction Site Information Models) allows designers to have at disposal a series of construction elements graphically developed and provided of the information necessary for the choice of the correct solution. The study of the development of a Construction Site Information Model during the different phases of a building project expressed the need to model also construction elements in different levels of detail according to the phase in which the model is used. In fact, together with the graphical detail, the kind of information needed for each phase are quite different from another phase. Then each model has to represent in each phase a specific kind of information related to the aims of the phase itself and becomes gradually more developed moving head through the project. This research is inserted then in the context of international standards that specifies levels of development for building elements. The aim is to define the criteria of modelling construction elements according to a precise LOD scale specifically developed in order to realize the different phases of a construction plan [3].

Levels of development are defined in BIMForum website, that publish continuous developments about LODs specifications as a "a reference that enables practitioners […] to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process [4]. Different studies have been carried out on the topic. Hopper specifies that "LOD is an example of a newly standardized concept, measure of an object's reliability and specificity [5]. Level of Development (LOD) codification is the mean to assess to what extent modelling has progressed throughout the design process, and for which purposes information can be extrapolated reliably. The aim is to define a discerned and indisputable "quantity" of useful information to fulfil BIM operators' expectations at a certain design stage. It is then a common benchmark for design stages planning and for delineating project requirements to be communicated among stakeholders [6].

Starting from this background the research aims to define a LOD specification for construction elements able to fit the existent LOD standards and to produce a library of construction elements based on this specification. This to realize a tool able to satisfy the needs of production of a Construction Site information Model [7] in each phase of the design process.

2. Construction information and LODs definition

The expressed need of producing a library of BIM elements representing construction components brought to the study of the panel of information related to the construction process. These information, to be related to each modelled element, was the starting point of this part of the research in order to produce a reasonable number of construction elements able to collect the main requirements of a construction plan.

The development of the library consisted then in the modelling of a reasonable number of construction elements. In fact, the number of machines and temporary structures available on market make impossible to complete the panel of elements present in the construction panorama. The aim of this research, therefore, is not to provide a complete library of elements but to introduce the general criteria for developing construction site BIM elements. To do this, a partial modelling work was needed since the necessity of evaluating the applicability on field of the stated criteria.

The modelling process started together with some case studies carried on by the task group, in order to satisfy one of the need on CoSIM design that is the representation of site facilities in a BIM environment.

Some difficulties were encountered during the modelling phase, mainly based on the time consumed not compatible with the time of the design. These difficulties brought to the thought that a proper library of elements needs to be

developed in order to make available a panel of models and information always ready for construction site modelling process and make design process more efficient.

The main task of the modelling work has been, then, the creation of detailed enough elements, simple to use and useful for the site design in order to guarantee a correct construction planning in the different phases of the design process. To reach this goal a precise sequence has been followed in order to gain a wide range of BIM site facilities, and in particular:

1. Study of the BIM design process in order to include construction planning [3]
2. Identification of information need during a construction planning BIM process [7]
3. Information research and standardization among manufacturers' data
4. Information selection for the different phases of the construction process
5. Definition of Levels of Development (LODs) for construction elements according to information need
6. Modelling of the elements provided of the correct level of information
7. Case studies tests

The wide information research carried out among data provided by construction elements manufacturers (equipment, machines, temporary facilities, etc.) brought to the finding of a wide number of information related to each of the studied elements. These panel of information, conveniently selected and standardized represents the highest level of information found for each construction element. It means that a data sheet has been created for each studied construction element, which covers the amount of information found in the data of different manufactures. As said this work implies a certain effort in standardization since the data are often expressed in a different way by the different manufacturers'. As showed in the figure below the produced sheet is considered as the "highest level of information detail" here achieved and completely represent the construction element which it refers.

The next step is to understand which are the correct information to be used step-by-step in the different phases of the construction project in order to correctly use the libraries in each phase. Four main phases were considered in this case which are taken from national [8] and international [9] standards. The research tasks consisted in the association of a correct level of development to each design phase in order to create elements that meet design exigencies of each phase. For what concerns formal name given to each LOD, the scale created by the American Institute of Architects (LOD 100/200 etc.) has been primarily followed. Then the created scale has been adapted to Italian convention, in order to be inserted to the Italian standard about BIM and levels of definition [10]

Figure below shows the process of information selection form the highest to the lower level of detail and the association of this level to a specific phase of the design process.

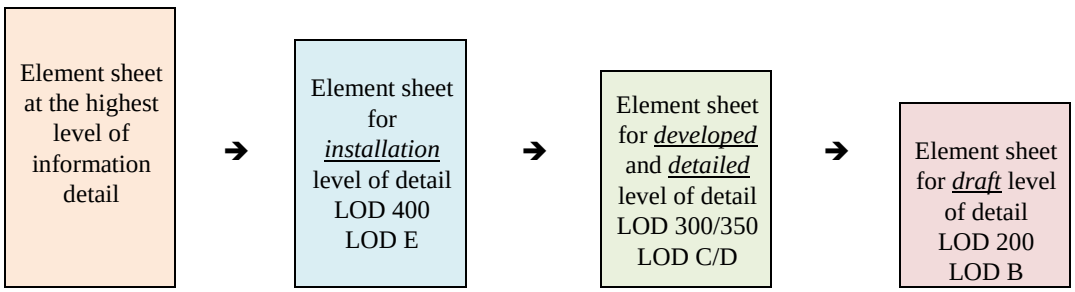


Fig. 1. - Levels of information discretization for construction elements

The main phases of the project considered are the following

Pre-design: carried out before tender by a client site-designer (made of *draft*, *developed and detailed* phases*)*
Execution-design: carried on after tender by a contractor site-designer (made of *installation* phase)

For what concerns the subdivision of the phases of the pre-design, it is possible to say that, for what concerns construction design, the developed and detailed design have almost the same level of detail (LOD 300/350). In fact the developed phase describes the site layout in general while the detailed phase describe the layout of the single work-zones. What changes between the two phases is then the focus on the area but the elements used have similar level of definition. A different level of development is instead applied to the draft phase (LOD 200) and to installation phase (LOD 400).

In particular, the first one (draft) is necessary to show the main needs in terms of construction site. The second (developed/detailed) is necessary to drive building design choices in function of constructability issues. Finally the third one (installation) is necessary to drive contractors' productivity choices according to the performance specifications defined during pre-design phase.

It is important to underline that both Italian and International standards consider more levels of development compared to those described. In fact Italian standard considers 7 levels of development (from A to G) while AIA considers a scale from 100 to 500. For what concern this research LOD F and G (related to as built) are not considered significant for construction equipment because of the temporality of their placement in a construction site. In addition this study will not show neither LOD A, even if developed. Considering the remaining LODs, the following are the notes added to general definitions of the Standard in order to characterize the construction elements and permits to associate them to a specific design phase.

LOD B (compared to LOD 200)
Verifies the compatibility of the construction element in the spatial system of the construction site and if the context

LOD C/D (compared to LOD 300/350)
Verifies the compatibility of the construction element with production exigencies of the designed building elements

LOD E (compared to LOD 400)
Provides productivity data of the commercial model of the single construction element

Together with information development, obtained by the step-by-step selection of the information useful for a particular phase, it is important to emphasize which are the main thought about graphical detail. Construction planning, for its main use as scope as described until now, should not require an high level of graphical detail, as also NYC BIM safety submission manual describes [11]. According to this way of thinking, the different levels of information should be associated to a model, which has always the same level of graphical detail. Considering the usefulness of graphic visualization for construction site and safety issues, it is possible to say that such detail level needs to be sufficient to recognize the element itself, and to describe its main geometric characteristics. The parametrization of the geometric and functional characteristics permits moreover to cover different real situations, existing machines, and temporary structures. This research assign this kind of graphical levels of detail to LOD 300/350 or, in Italian scale, LOD C/D. However, other two different graphical details have been assigned to the other postulated LODs for construction elements due to some main reasons here described. First of all such differences in detail levels permit to immediately recognize which kind of LOD is used in a particular model. However, it only a simple task and it is not the main reason of graphic detail distinction.

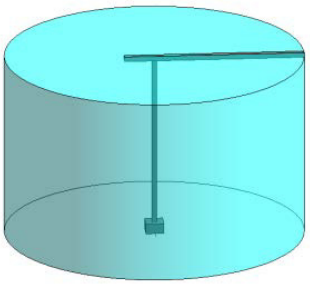
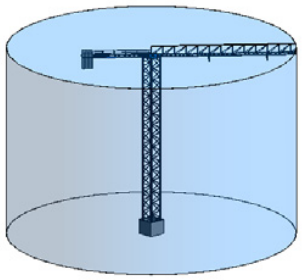
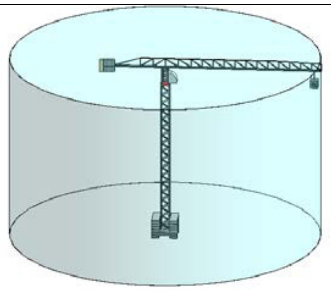
Considering LOD B it is possible to see that is characterized by simple volumes which represent objects. This choice was made because of site planners, in a draft phase, are not yet able to decide the type of element to be used but only to express the need. As an example, in front of a façade to be restored there's the need of a height working place that should be realized with a scaffolding system as well as with a mobile platform. A volume that cover the façade should be a good compromise to represent both elements as the need they have to satisfy. The element itself will be chosen in the next phase (developed phase) and then represented, as explained, with the graphical detail related to LOD C/D.

LOD E have instead a different meaning. In fact, as visible in the next paragraphs, LOD C/D clearly represents (graphically) the element and should be only improved by specific manufacturer information to become a LOD E. However, together with the possibility to recognize the LOD directly, there is another reason of the choice to make a

more detailed graphic improvement. It is indeed reasonable to imagine that, as well as happens with building elements (but also as until now happened with each kind of cad element), the manufacturer itself produces its models and makes them available to firms for installation design. Considering then also a commercial point of view it is reasonable then to imagine that the manufacturer try to represent as much as possible its real products, while taking into account the simplicity of using the models during design. According to this view it also reasonable to imagine that the parameters inserted by a manufacturer are able to cover only the models of the manufacturer itself without covering the others.

Following these principles, table 1 shows, as an example, a sheet developed for the element "tower crane" in order to understand the main differences in terms of criteria for information selection and graphical detail.

Table 1. Levels of development description for the element "Tower Crane".

LOD 200 – LOD B (Concept)	**LOD 300/350 – LOD C/D (Developed – Detailed)**	**LOD 400 – LOD E (Installation)**
		
Geometry Construction element represented by draft extrusions.	**Geometry** Construction element represented by extrusions with different configurations and calculated dimensions.	**Geometry** Construction element represented by solids with dimension equal to the real element | The model represents the main components (cabin, basement, counterweight, etc.) | Manufacturers' data are included as well as data for element management
Object 3D simple solids	**Object** 3D parametric solids	**Object** 3D complex solids
Main characteristics Influence volumes …	**Main characteristics** Operational configurations Loads definition Support Area …	**Main characteristics** Commercial model Operation dimensions Productivity parameters Installation Management Use management …

3. CoSIM Library Completion

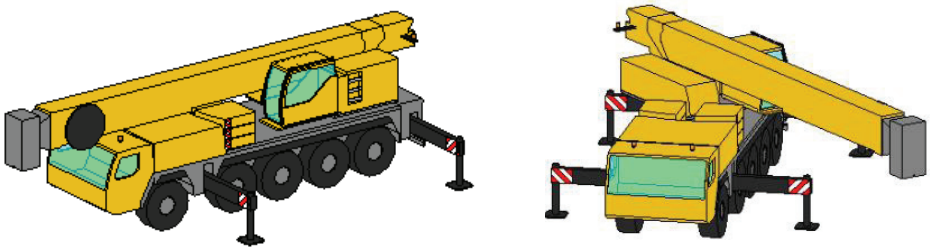
Having defined the type and the quantity of information related to each Level of Development and the criteria for the modelling of the elements, the research moves to the creation of the libraries according to what previously stated. Each studied element was then modelled in a different way for each stated level of development and the information were inserted as parameters of the model. This approach brought to the creation of a library useful for each phase of the design process according to the information needs of each step, here presented from the highest level of detail to the lowest.

3.1. LOD E

CoSIM execution-design is realized to prefigure the real construction site that will be managed by contractors and so is characterized by a layout made of commercial elements. Following the definition given to LOD E (inserted in the Standard UNI 11337) this level of development "Provides productivity data of the commercial model of the single

construction element" Then the element represented need to be similar to the real one and to contain all that information that characterize the single model represented. The panel of information represents the starting point of the modelling of an element. Some of them are related to the geometry of the element (e.g. dimensions) that must comply in order to read and view the same information. It is important however to underline that differently to the other levels of developments such information are not changeable since represents a specific model with its specific characteristic. The only changeable parameters are that particular parameters that implies a different configuration of the element or part of it. As an example the represented mobile crane has as changeable parameters that related to mobile parts of it that permits to represents different configurations of the boom and of outriggers. Figure 2 shows the modelled mobile crane for LOD E in different configurations. As visible in the images the graphic detail try to represent the model of the selected element in its different configuration. The model itself need to comply the right compromise between representation and usability of the model during design. This is the reason why some details of the element are anyway neglected in order avoid awful details that make the model heavy and so scarcely usable. The changeable parameters are instead needed in order to simulate the operational mobility of the element (in particular machines), in order to better visualize real conditions of construction site and verify possible interferences.

. Fig. 2. - LOD E mobile crane – Graphic Detail and different operational configurations



3.2. LOD C/D

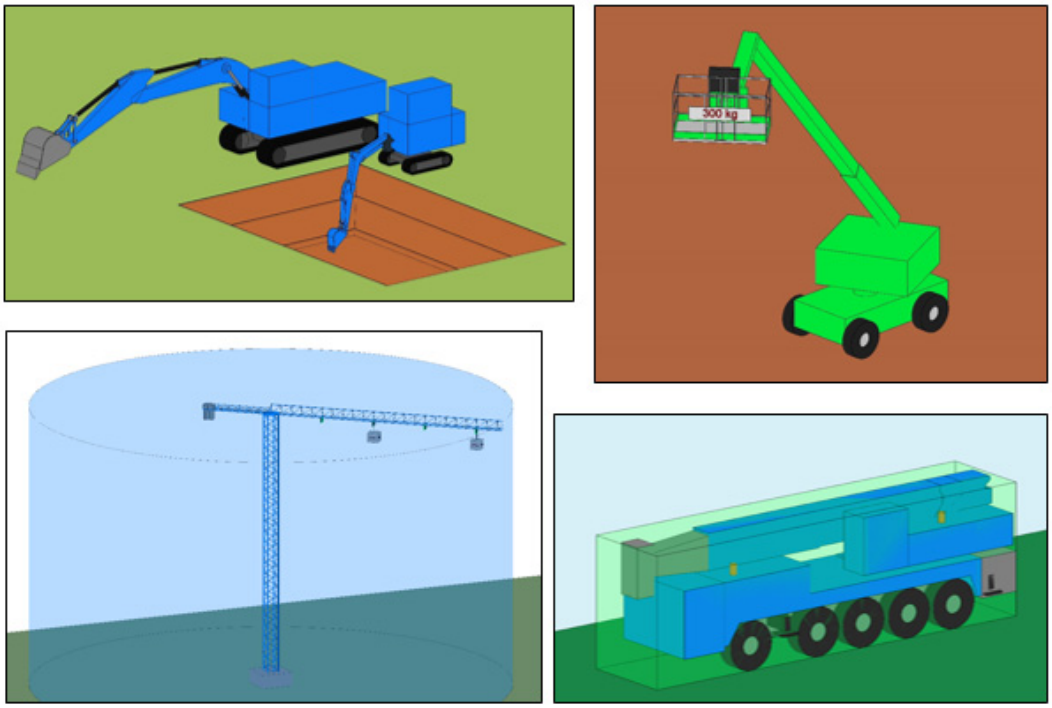
The LOD C/D levels of CoSIM development concerns the client phase in which site-designer produces a CoSIM able to satisfy client needs in term of time, cost and workers' safety. Since the contractors are not yet known, equipment choice has to take in consideration the type of equipment according to the work to be carried out, but not the real equipment which will be chosen by contractor or subcontractor in function of its advantage. In fact LOD C/D "Verifies the compatibility of the construction element with production exigencies of the designed building elements". The solution chosen are not the definitive one but should be a feasible solution among the once existing in the market.

For these reason the CoSIM pre-design version of the construction element could be generic since it has to represent simply a type of equipment. Being generic, it needs to be modeled with changing dimensions and configuration in order to simulate different machines of the same type. Furthermore, each CoSIM pre-design equipment, as showed, needs also to simulate its real use. That in order to gain from pre-design model those data useful to verify the feasibility of each work. For this reason each parametric element is created with the possibility to picture its operational mobility, to visualize in detail, as well, its working-places for safety control.

The modelling process of these level of detail resulted simpler on one hand because of the volumes represented are not so complex as the ones of the LOD E. On the other hand, the parametrization of the visible information requires a particular modelling effort in order to comply the needs to represent a large number of possible solutions in a unique model. In fact, in this case the changeable parameters are not only that related to the different operational configuration of a machine, but also that related to its dimensions, and its operational parameters. In fact the type of machine, in order to be efficient during design, need to represent a large panel of possible solution to carry on. Its parameters need to be chosen according to the work to be undertaken (relationships with the building elements) and according to the placement of the element itself (relationships with the context).

Images in Figure 3 shows some examples of models that follows different configurations according to the machine type and to the operation (it is valid also for temporary structures). The excavator, for example, is represented in the image with two different dimensions that are functions of the parameters inserted in the model. In the same way the mobile crane is here represented in its different operating configurations of a mobile crane. It is obvious that such a modeling does not imply simply the 3D representation of the elements but a means to realize a strict relationship between the graphical visualization and the information contained in order to make possible the proper use of a machine. If, in fact, is changed graphically the dimension of an equipment and this changes do not reflect into information the whole method doesn't work since the need of making continuous adjustments during design. It is visible in the Figure 3 the LOD C/D model of the mobile crane. As a comparison with the LOD E is visible how graphic detail is less developed than the other. This is made by more simple geometries able to represents different models of the same type of element. Furthermore, simpler geometries are less difficult to be parametrized.

Figure 3 - CoSIM LOD C/D library: Dimensional and operational configurations of machines



3.3. LOD B

LOD B "Verifies the compatibility of the construction element in the spatial system of the construction site and if the context". It is immediately visible from this definition how this level of development is mainly characterized by dimensional information of the main shape of the elements that need to be related to the spaces inside or outside the construction site. For this reason the modelling of such elements results quite simple especially for what concerns temporary facilities. They are represented as simple volumes characterized by a specific color and identify the main function (the need to be satisfied) of the element itself. In particular Figure 4 shows the simplicity of such models which aim is to verify their possible use with the given area. For what concerns the level of information, parameters are reduced to that directly related to the main dimension of the element and are so all related to the geometry itself.

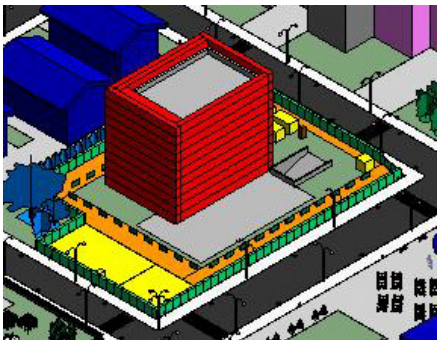


Figure 4 - CoSIM LOD C/D library: LOD B Temporary facilities – Graphic detail

4. Conclusions

The need to realize the framework effectively usable on field by the development of construction models required the creation of libraries (as happens for other design disciplines) aimed to construction planning. The objective was not to create an entire panel on construction elements able to complete the needs in terms of elements, and it should be an arduous task. The created libraries consisted instead in a reasonable number of elements provided of needed information and of operational configuration to be used during design. The library contains a number of 30 elements each one (except spaces) developed in three different levels of development that means more than 100 modelled elements in total. The library can be considered exhaustive (for the chosen elements) until the LOD 300/350 since it represents generic elements that can be used in any case during pre-design phase. For what concerns installation elements the modelling comprehends commercial models for each type of considered elements in order to underline the requirements for representing elements in such detail level. The modelling of other brands should be only an exercise with no research outcomes.

For what concerns usability of the elements of the libraries, and their functionalities, could be considered complete, since their functionalities have been successfully tested in different case studies carried out during the research. Several tests have in fact carried out during the design of different real projects for the production of construction and safety planning. As a result is visible an increase of design efficiency particularly in terms of construction design time for each phase of the project. The availability of models and related information permits in fact to manage each phase without time loss due to information search and pure modelling/drawing of the construction phases. Together with this, the main output of the research consisted also in the insertion of this study in the Levels of development stated by the new Italian standard about BIM (UNI 11337-4)

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