CONSTRUCTION SITE BIM REQUIREMENTS

Marco L. Trani[1], Manuele Cassano, Massimo Minotti and Davide Todaro

Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano Via Ponzio 31, 20133, Milan, Italy

Construction are characterized by some overall requirements (e.g. quality, expected time and cost compliance, productivity, profitability, workers' health and safety) to be satisfied. The necessary process to fulfil these requirements should start from the construction site design phase. The aim of the research is the implementation of construction site information in BIM models in order to support the execution phase design since the early stages of the project. These information concern, among the others, the choice optimization of site plants and equipment (i.e. construction site facilities), during the design phase. For this purpose, the creation of a BIM database of construction site facilities is needed. Each record of the database has thus to discharge a panel of BIM construction site requirements, each of them characterized by a set of physical and operational parameters whose relationships with project information lead the choices of the site designer. The methodology for the identification of these kind of BIM requirements has followed these steps: (i) definition of a set of information characterizing building elements/materials from a construction site point of view; (ii) construction site facilities identification and classification; (iii) first investigation in order to assess which is the adequate detail level of site plants and equipment graphic representation in order to create the above mentioned database. A case history is presented in order to show how BIM is useful for construction site designers to optimize their work, sharing information with the other figures involved in the construction process.

Keywords: BIM, information management, design optimization.

INTRODUCTION

Construction site design can play a strategic role if it starts from the early stages of the project since its requirements need to be satisfied both from the client point of view and the contractor (Chan 1999) In addition, many studies and experiences related to the use of Building Information Modelling (BIM) support the thesis that BIM method for construction site design and management can help the players of construction process to satisfy those requirements . Particularly, the wide options provided by the so-called Field-BIM allow, if properly developed, a significant increase of the quality of the whole manufacturing process, reducing time and costs (Ciribini 2012). This thinking is shared by other researchers whom describe BIM as a method to link in a better way designers and contractors (Harty 2010) in order to improve quality. Some other studies on times and costs evaluation have been carried out using 5D model able to drive cost control measures with work programme (Haque 2007). Other site aspects already taken into account are the production of safety plan using BIM (Zhang 2013) or *"falling prevention plan"* consisting in the insertion in the model of prevention and protection devices for workers safety, assuring a better hazard visualization through

[1] marco.trani@polimi.it

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the use of 4D models. (Sulankivi 2010). Some safety information have been furthermore added into BIM (Sulankivi 2013) in order to check automatically some safety rules (e.g. automatic control of falling risk and need of falling protection guardrail). Significant trends are also carried out by international administrations, that propose guidelines concerning construction site standard using BIM. An example is the Finland CoBIM standards in which is present a specific file about safety plans.

This brief literary review shows an undeniable attention of researchers to the issue of construction site management using BIM, but at the same time is possible to perceive a lack of attention to construction site design issues. Literature, in fact, focuses a lot on 4D scheduling and planning of construction sequences and on the visualization of site layout planning, safety planning and fall prevention planning without a definite design method.

Therefore, our research objective is to investigate the use of BIM in construction site design, focusing on construction site production elements (e.g. excavator, concrete mixer, et.) BIM requirements. Our goal is to cast light on the relation between the building model and its construction site, mainly in terms of construction players collaboration and information sharing between models, therefore postulating the need of a proper Construction Site Information Model (Co.S.I.M.) for each project.

OPERATIONAL INFORMATION MANAGEMENT

Usually, designers collect information on building elements and components oriented to their technical requirement performance. Nevertheless, those information contain operational information as well. On the same time, site production elements are characterized by a number of operational parameters (e.g. fork-lift max load) addressed to match building elements operational requirements (e.g. brick pallet weight). The two set of information are affected by project context criticalities that drive the final design choices (e.g. slab load bearing capacity). Each set of information can be incorporated in a nD model, creating the well-known BIM model and the postulated Co.S.I.M. . Figure 1 shows the relation between the above mentioned information typology set.

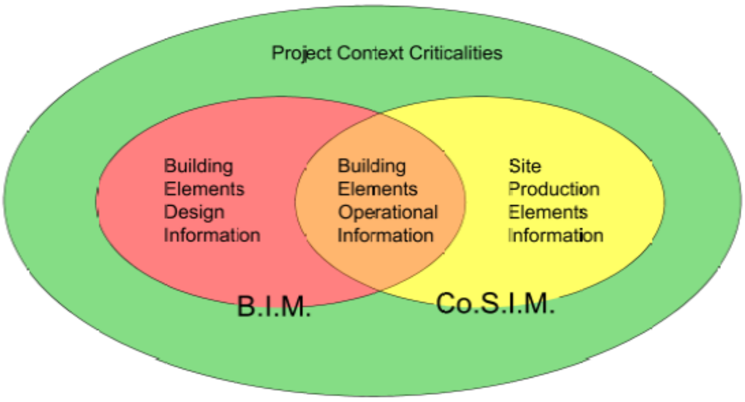

Figure 1: Information set relationship in construction

Since the starting point of construction site design is the operational analysis, it is necessary to follow a systematic approach in order to find out and extract, within design documents, any information necessary to make choices about the site. The operational information of building elements/materials have thus to be examined along their five life stages on a construction site as follow (Di Melchiorre 2005):

- Procurement: set of information about the provision of each element on construction site (e.g. dimension and type of packaging of products, etc.)
- Stockpiling: set of information about the temporary placement of a specific product on construction site (e.g. restraint mode, max overlay, etc.)
- Handling: set of information about moving a product on construction site (e.g. product weight, product fastening, etc.)
- Provision: set of information about modifications or adjustment of the product (e.g. preliminary cutting, folding, etc.)
- Laying: set of information about the final installation of a product (e.g. scaffolding, electric plant, etc.)

These information allow site designer to define construction site needs in term of the construction site facilities to be used in order to guarantee the correct performance of the product life stages on construction site.

The critical information related to the context have to be searched, instead, within the principal characteristics of construction site area (Turchini, G. et. Al. 2007) such as:

- Available spaces: characteristics strictly related to dimensions of the spaces usable for construction activities.
- Surface features: characteristic of technological-architectural, urban and naturalistic pre-existences
- Aerial restriction: characteristic related to aerial handling constraints such as plant networks
- Soil and underground features: characteristic related to the soil and floor and to the presence of underground plants
- Interference with other activities

The environmental condition analysis of the site area above described, can address designer choices in term of site elements properties, beyond the needs of the building elements/materials, and properly ensure a careful site layout and a detailed study of each phase of the work. (Trani 2012)

Starting from a first selected panel of site production elements, our study went on setting, for each one, an open list of *"work oriented"* requirements aimed to identify their operational potentiality, useful to be compared with building elements operational information as well as site context information. The following list provides an example of some requirements.

- Accessibility: requirement of the site element to enter/to be carried and move across construction site areas (e.g. dimension of truck)
- Stay: requirement of the site element to stay/be stored in specific construction site areas (e.g. weight of the element)
- Installation: requirement of the site element to be prepared for work in term of placement in operational area and connection to site plants (e.g. dimension of the element in working phase)
- Usability: requirement of the site element to need specific spaces surrounding for its use
- Productivity: requirement of the site element to conduct his function in a specific way

Next table provides an example of one record of the database of site production elements (i.e. mobile crane) in order to show how to manage its requirements performance on a construction site, applying its characteristics operational data. Particularly, in the last column, the table shows the relationship between the mobile crane characteristics, the site situation and the building elements, giving therefore information to address the choice of crane performance needed.

Table 1: Mobile crane requirements, characteristics and possible operational relationships

Requirement	Characteristics	Relationships
Accessibility	Dimension	**Compatibility with the dimension of construction site gates and roads**
	Turning radius	
Stay	Rest dimension	Compatibility with the dimension of storage area
	Weight	Compatibility with the load capacity of storage area
Installation	Operational dimension (open outriggers and counterweigh)	Compatibility with the dimension of working area
	Operational lifting capacity on outriggers	Compatibility with the load capacity of storage area
Usability	Additional space needs over physical dimension	Compatibility with the dimension of working area
Productivity	Boom radius	Compatibility with position of building element
	Height under hook block	Compatibility with height of building element
	Load diagram	Compatibility with weight of the element

BIM SITE PRODUCTION ELEMENTS

As it is known, BIM is principally based on an *"object oriented"* methodology of design characterized by the digital representation of the physical and functional characteristics of the building. The research of information within building and context elements is, obviously, simplified by the use of this methodology that allows to have in a unique box both graphically, numerical and/or textual data. Thus, construction site designer can query the model to reach all information needed instead of research *"by hand"* in different type of design documents. The real time interoperability offered by BIM technology allows also a more simplified way to obtain design update. The information contained in the design *"object oriented"* model (e.g. dimensional parameters, weights, supply unit quantity, etc.) can be transformed into operational information, setting a *"work oriented"* model that help construction site designer in the choice of site equipment.

This is the starting point for the development of a database of site production elements made up by a series of BIM objects characterized by their proper standard requirements, as the example showed in table 1.

The same object (i.e. mobile crane), is studied in function of the graphical and informative detail level chosen for a specific project phase .

In the tender phase, when construction site designers make the first choices about site equipment to be used in the execution phase, the object must be characterized by flexible information in order to fit possible changes of the project until its conclusion.

For this reason, in this stage is better to create a simplified but more flexible model in order to fit simply continuous design update. The characteristic inserted represent in this stage a guide number (i.e. a range, a maximum or minimum) that assures the satisfaction of requirements. The exact characteristic will be given in the execution phase in which parameters have to satisfy guidelines of those given in the tender phase. Figure 2 shows the flexible characteristic of the mobile crane to be used in the tender phase and an example of a BIM representation of a real mobile crane that fits all the requirements given by the first one.

Figure2: Parameters of a BIM mobile crane for the tender and the execution phase

The following case history shows the use of this object in a real construction site during the tender phase, highlighting in particular the relation of the parameters of construction site object in function of the information obtained by design model that guide, then, the choice of the real machine used.

CASE HISTORY

The case history consists in a metal carpentry assembly for a restoration site of a building tower located in the centre of Milan. The metal carpentry is designed to support the scaffold that will be used for the façade restoration. The most difficult work phase of the carpentry assembly is characterized by the biggest steel beam of the project and the worst condition in term of spaces and constraints.

Table 2 shows the information of the steel beam used for the choice of the mobile crane requirements and how to achieve these information in the model.

Table 2: Steel beam information useful for mobile crane choice

Information	Value	Achievement of the information
Type	HEB 600	Structural design
Length	12 m	Structural design
Height	0.6 m	Structural design
Weight	2,5 t	Calculation from linear weight and length from structural design
Position	Graphical	Structural design
Lifting height[5]	9 m	Calculation from lashing angle and length

As explained, the characteristic of the equipment must be related with some area information in particular for ensure the absence of interferences for the workplace.

Table 3, similarly to table 2, shows area data obtained from the design model. Information obtained graphically led to a visual comparison at the moment of insertion of the crane and determined its dimensions in function of the minimum distance needed to avoid interferences.

Table 3: Area information useful for mobile crane choice

Information	Value	Achievement of the information
Dimension of available area for installation	14 m x 6 m	Graphically
Aerial restrictions present in working area	Part of the building	Graphically
	Street light	
Surface restriction	Bike parking	Graphically
	Underground station	
	Altitude gap	

Tables 2 and 3 summarize a set of information to be related to the flexible parameters inserted in the site object. Thus, when the object is inserted in construction site model these information represent some constraints that the crane have to satisfy by its requirements

Hence, according to the dimension of the available area of installation, mobile crane must be maximum 12 m length (considering at least 1 m on each side to allow pedestrian way around the crane for workers). The angle and extension of the boom has been decided in function of the position of the beam and the lifting height and has permitted to verify (by checking the load diagram with the weight of the beam) if the dimension obtained was correct or if it was necessary to find another solution. Figure 3 shows the final solution with all the parameters requirements to satisfy the need to assembly metal carpentry elements in that conditions. The mobile crane selected by construction firm during execution phase matches all the parameters requested.

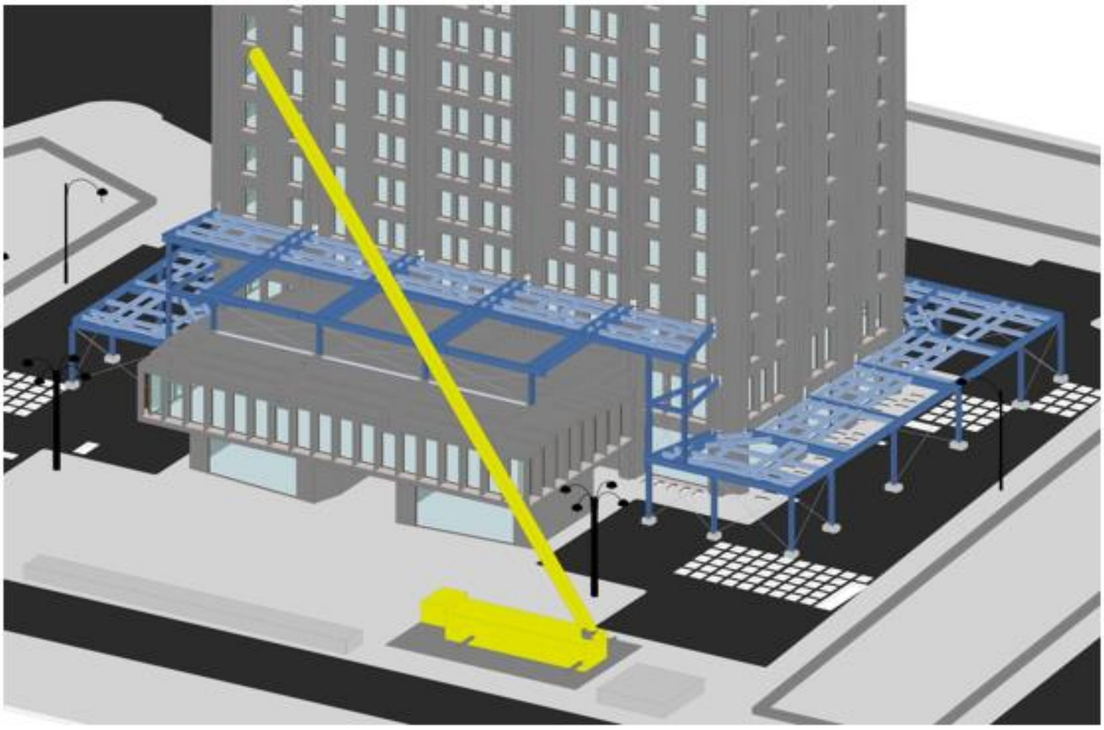

Figure 3: Insertion of the mobile crane into the model

EVALUATION OF THE METHOD

In order to evaluate the possible improvement of Co.S.I.M, a questionnaire concerning the use of BIM for construction site design were proposed to a number of about 100 Italian professionals expert in construction site but, in general, not in BIM use. The questionnaire proposed, in a clarity and practicality perspective, consists of 15 quick questions and 1 final open question with the ability to write any comments or suggestions regarding the topics. The questionnaire is very simple and easy to be compiled in about ten minutes in order to avoid waste of time of the survey sample. The questionnaire, divided into two sections begins with the fateful question, *"Do you know what is BIM?"*. The first section has the objective, through a simplified explanation of the BIM concept for those who answer *"NO"* , to get a first opinion about its applicability and usefulness on construction site.

The second section, made after a brief explanation of the method proposed, consists of 5 multiple choice questions whose purpose is to understand BIM key benefits combined with the applicability on the construction site. The questionnaire ends with a registry part is made deliberately in conclusion in order to understand what is the opinion of the respondents according to their occupation, their age and their construction experiences . In particular, this part has allowed us to be able to divide the different opinions from those who works for the company (i.e. employers, H&S managers and assistants, site managers, construction site supervisors and who work for client side (i.e. designers, Safety coordinators and Construction supervisors). Finally the last question allows the compiler to freely express his own opinion on the proposed themes also giving any suggestions on the proposed topic and to create possible ideas for future improvements. It happened that some professionals who did not know before the BIM, once they understood at a glance what it is, they seemed very interested to know in detail and, maybe to apply it into their work in the future.

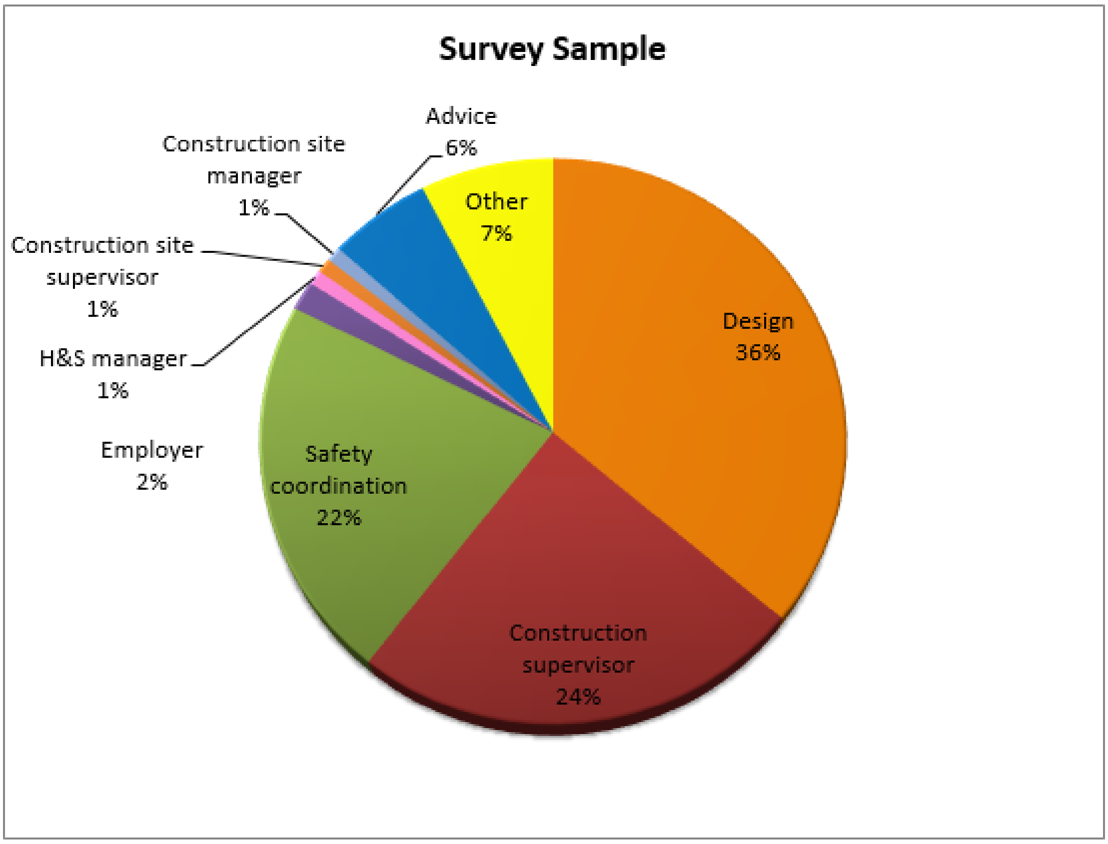

Figure 4: Survey sample

The results of the first part of questionnaire show good results about general use of BIM and also for the management of construction site, but only about the 50% thought that it can improve workers' safety. The results of the second part of questionnaire shows, instead, that a lot of interviewed thinks that this approach can really improve some site aspect like site plan production, scheduling, risk assessment and preparation of safety procedures for workers.

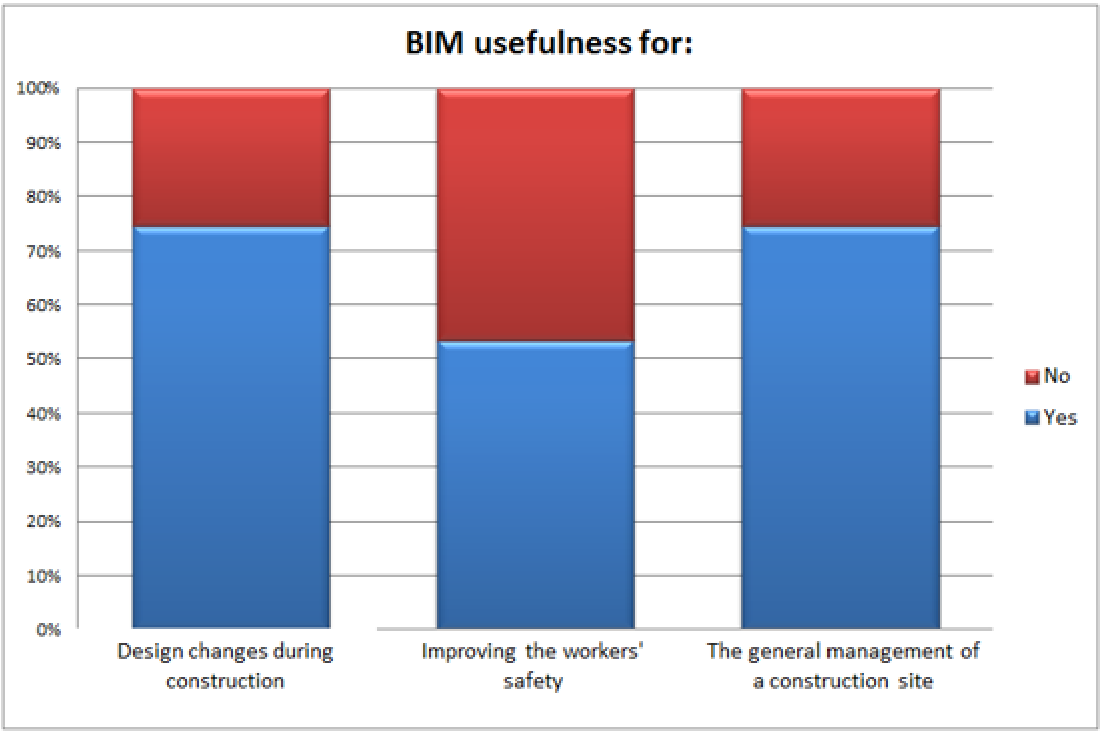

Figure 5: Results of first section of questionnaire

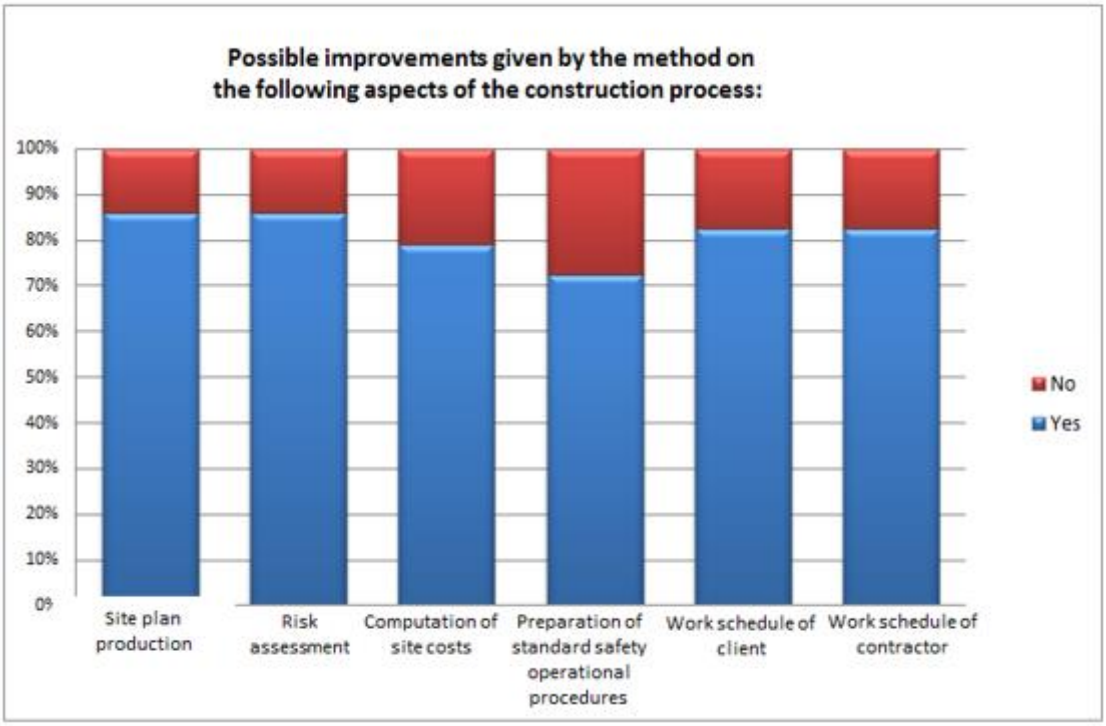

Figure 6: Results of second section of questionnaire

CONCLUSIONS

Optimization means, as well, the satisfaction as much as possible of the overall needs of a construction site such as productivity, time, cost and safety of workers. Since the strategic role of construction site design for a successful project it needs to be supported by a methodological approach. Since its quick diffusion, BIM can be the way to implement this approach. The implementation of the construction site design for its integration in a BIM design process is still long. It starts from the three dimensional design of the site phases thanks to 4D application. Other aspects were studied, like the visualization of single workplaces in order to study in detail safety aspects and, thus find a way to communicate these issues to workers in order to better ensure their proper safety. In order to achieve a better integration between construction site design and other disciplines a good information management must be ensured. As showed, construction site designer need a specific set of information related to each object of the model that he has to take into consideration and these information must be related to the elements that he has to put into construction site plan. Thus, the need to develop a standard database arose. On one way, there is the need to classify all the construction site information that construction site designer can squeeze from the project in order to guarantee a more complete and speedy availability of useful operational data. On the other side, there is the need of the availability of a wide range of elements typical of construction site whose characteristics can be related to the information achieved. The implementation process of these database is very long since the difficulty to find flexible parameters for each different type of element (handling machine, earthworks machines, scaffolding, protection system, small equipment). The final aim is to make the work of construction site designer faster and of high-quality. The development of a complete database can bring, then, the research to study the use of advanced method to check automatically the relationships between information and warn if there are some criticalities to be solved. These methods are searched among clash detection and model checking instruments which will be studied specifically for construction site needs.

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