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BIM ORIENTED EQUIPMENT CHOICE ON CONSTRUCTION SITE

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Construction site needs a previous production design of each equipment working area in order to avoid possible criticalities that can affect productivity or safety during construction. The ongoing research is developing a method aimed to the integration of construction site design in a BIM design process. Construction site planning is a multiple step process one of which is the choice of the equipment to be used for construction works. In order to facilitate this choice, a design method, supported by a BIM equipment library and an advanced database, has been developed. In particular each equipment of the library has been characterized by a number of selected operational information. Their classification took into account different aspects of construction requirements such as productivity, sustainability, health and safety. Thanks to a BIM design approach the parameters that express operational information (*e.g.*, weight and dimensions, capacity, etc.) are immediately available for site-designer's tasks. He has in fact to match the information with site context and production requirements in order to assure the satisfaction of the above mentioned requirements. The database has been populated by a series of existing equipment supplied with their specific operational information. Moreover the database has been provided with a data-browser able to match itself equipment and site information, revealing a number of equipment suitable to site situation. The application of this method in real case studies confirmed a great decrease in site-design time and good matching of different type of information.

Keywords: Building information modelling, Construction equipment, Site design, Information management, Equipment database.

1 INTRODUCTION

Construction site is always affected by many variables that soon affect the development of construction works in terms of time, cost or safety. In order to face with more awareness these criticalities is necessary a detailed design of construction phases (Turchini *et al*. 2007). It is thus necessary to start to think on constructability issues since the early design phase in order to drive the project to feasible solutions and avoid problems during construction. Construction equipment choice is only one of the steps of site design, but has a great influence on functional-spatial and technological-productive layout of the site itself. Starting from a detailed classification of construction site facilities and equipment the presented study aims to assist site-designers, in each phase, in equipment choices in order to gain better solutions to site criticalities. This classification aims to identify equipment typologies and their main characteristics.

The actual design situation leads to develop each design discipline by BIM tools, as the clear advantages. For site design discipline, the Construction Site Information Modeling (CoSIM) has been postulated (Trani *et al*. 2014) as a model completely dedicated to construction phase of the building process. One of the characteristic of the CoSIM is the need of a series of modeled site equipment complete of operational information that reflect the characteristics stated in the classification. These equipments become the main part of the database, below described, which use implies a great support in construction site design.

2 STATE OF THE ART

Since many years, Building Information Modeling has been considered the current design method to be used also for construction site issues, especially for what concerns safety plan and working schedule. In particular, in this sense, is underlined the utility of these issue for site layout planning (Vimonsatit *et al***.** 2014) and management. The possibility of construction phases visualization permit a detailed design of construction works taking into particular consideration, first of all, safety aspects (e.g. spatial criticalities during time, site temporary facilities, safety devices, etc). The main goal is to facilitate safety planning production (Azhar *et al*. 2012) ensuring a detail level suitable for hazard identification before starting construction. Site BIM implementation need the development of objects libraries of temporary structures and equipment (Sulankivi *et al.* 2009). This kind of researches have been followed by guidelines for producing safety planning such as CoBIM Finland standard Series 13 and NYC Building Information modeling Site Safety Standards. The last one, in particular, takes into account equipment modeling and visualization in a BIM site layout. In particular, as part of the equipment, modeling and information developments of tower cranes (Wang *et al. 2014)* are studied with the aim of a BIM site planning optimization.

3 COSIM EQUIPMENT DATABASE

Assuming the need to prevent losses during construction phase, construction site design has to be carried out not only in the execution phase, but also during the design phase. In particular two main steps of site design can be identified (Trani *et al.* 2013):

- Pre-design phase: carried out before tender by a client site-designer
- Execution-design phase: carried on after tender by a contractor site-designer

Regarding in particular equipment choices, the two steps result very different as the first aims to give likely solutions, while the second concerns the real solution to be used during construction. CoSIM development follows thus two different levels of detail; the first one is necessary to drive building design choices in function of constructability issues, the second one is necessary to drive contractors' productivity choices in function of performance specification defined during pre-design phase. Both levels of development, instead, have to be focused on safety of workers. Two kinds of site elements have been developed in order to fulfill the exigencies of both design stages. This difference will be explained taking as an example the Aerial Work Platforms (AWP), equipment used, among the others, in the case study presented below.

3.1 CoSIM Pre-Design Equipment

The first level 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 contractor are not yet known, equipment choice has to take in consideration the type of equipment in function of the work to be carried out, but not the real equipment which will be chosen by contractor or subcontractor in function of its advantage. For these reason the CoSIM pre-design version of the equipment 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. Each CoSIM pre-design equipment, as showed in the case study, needs also to simulate its real use. That in order to gain from pre-design model those data is useful to verify the feasibility of each work. For this reason, each parametric equipment is created with the possibility to picture its operational mobility, to visualize in detail, as well as its working-places for safety control. Figure 1 shows a CoSIM simplified pre-design AWP and its parameter sheet.

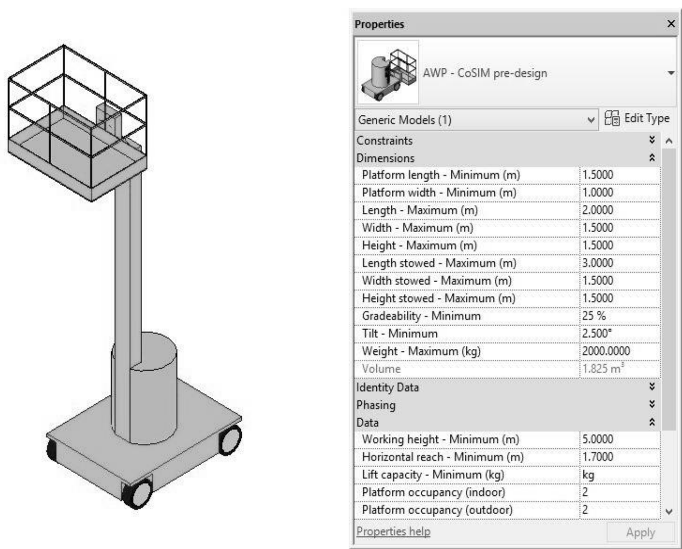

Figure 1. CoSIM pre-design library: Aerial Work Platform.

3.2 CoSIM Execution Equipment

CoSIM execution-design is realized to prefigure the real construction site that will be managed by contractors and so is made up with commercial elements. Figure 2 shows different kind of existing AWP which characteristics are taken from technical data sheets of each product. As for CoSIM pre-design equipment, all issues that characterize each machine are collected in a parameter sheet. Each equipment is provided, as well, with the possibility to simulate its operational mobility, in order to better visualize real safety conditions of construction site and verify possible interferences.

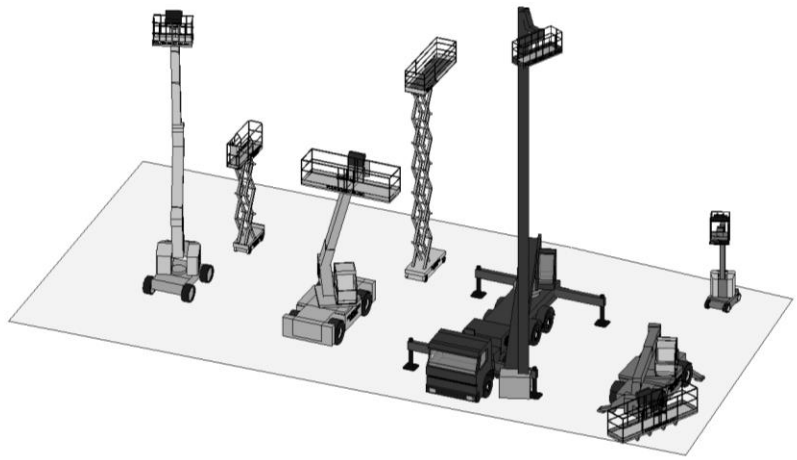

Figure 2. CoSIM execution-design library: aerial work platforms.

4 COSIM EQUIPMENT ASSISTED CHOICES

The assisted choice of the equipment to be used on site is made up by the use of the presented CoSIM elements and by a list, made in Excel© format, of real equipment, complete of its own characteristics grouped in a proper database. Database has been firstly populated by a wide research among manufacturers' datasheet. Then it has been further implemented with other new equipment chosen for the real case studies. The database is not only made-up of a list of equipment but is also characterized by an automatically search system. Site design begins with client site-designer who, using his experience and knowledge, chooses the equipment for a particular work depending on its operational characteristics and surrounding situation. Inserting the pre-design equipment into his CoSIM, he has then at his disposal a BIM-like data sheet to be modified in function of the expected use (and that modify the 3D model itself acting, for example, on dimensions). Having obtained the suitable parameters, those values have to be input in the database which automatically selects the equipment that satisfies the requested operational conditions.

In this way the client site-designer can immediately verify if the equipment identified in his CoSIM exists in commerce or if he has to change some operational conditions. On the other side, contractor site-designer has the possibility to have at his disposal (in the database) a series of equipment that comply performance specification given during the design phase. To be used in this step the database must be previously further implemented adding specific parameters related to construction management needs such as rental costs, energetic consumption, etc.

The contractor final equipment choice is then ready to be inserted in the execution-phase CoSIM. The final choice can be now approved by the contractor site-manager.

5 CASE STUDY

In order to better understand the database operation, one of the real tests carried out for method validation is here presented. It concerns the structural rehabilitation of an indoor trucks load/unload area. In particular the work consists in the review of the steel structure by adding some elements in order to rebuilt the roof for making it accessible. It is a very small site but represents a very useful case study in this phase of database test and improvement. In particular the test concerns the choice of the handling machine for steel beams and of the AWP. As visible in Figure 3, the working area is very close and has to contain also temporary material stockpiling since it is not possible to occupy the outside area. The equipment choice has been driven by the worst condition of work that is represented by the mounting of new roof beams. In fact this work needs to be carried on without dismantling the roof as the load/unload area need to be used also during works. For this reason equipment such as cranes or elevators cannot be used so that the AWP has been considered also for beams handling. For this reason parameters that drive the choice of the AWP has taken into consideration not only the high of work and the number of workers, but also the capability to raise a beam of 60 kg weight and 3.5 m long as well as manual equipment. Since this design situation implied lot of constraints it resulted as a good case study for the test of the database operation. Figure 3 shows the CoSIM pre-design work configuration with the consequent datasheet containing parameters useful for real equipment choice. Figure 4 shows the excel sheet that allows the equipment research in the database.

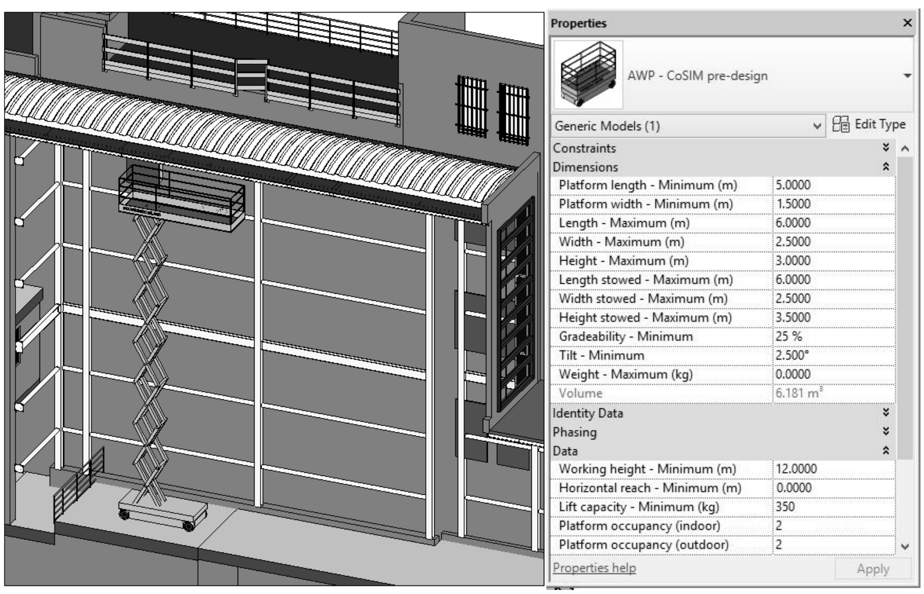

Figure 3. Pre-design working configuration for steel roof beam handling and mounting.

6 CONCLUSIONS

The presented AWP database is actually populated by almost 50 different models and its development is still in progress by searching new datasheet and inserting equipment encountered on field. Such a database has been developed for different type of equipment and the most developed are tower and mobile cranes. Since there is a need for precise modeling, the databases development process is still long. However the first results from case studies encourage continuing this work since construction site design gain advantage from this especially in terms of site-design time. Furthermore such an approach helps many designers to find and exchange precise information about working phases. However, this instrument has not the purpose to fully automate construction site design process but must be used as a design support for decision making that has to remain, anyway, a designer's task.

OPERATIONAL DATA INPUT		
Working height - Minimum	12	m
Horizontal reach - Minimum	0	m
Lift capacity - Minimum	350	kg
Platform occupancy (indoor)	2	
Platform occupancy (outdoor)	2	

SITE DATA INPUT		
Platform length - Minimum	5	m
Platform width - Minimum	1,5	m
Length - Maximum	6	m
Width - Maximum	2,5	m
Height - Maximum	3	m
Length stowed - Maximum	6	m
Height stowed - Maximum	3,5	m
Gradeability - Minimum	25	%
Tilt - Minimum	0	°
Weight - Maximum	-	kg

Search

Equipment model	H18SX	VD21X	GS-3384 RT
Working height (m)	16	23,00	12,00
Horizontal reach (m)	0	0	0,00
Lift capacity (kg)	500	1000	1134
Platform occupancy (indoor)	5	7	7
Platform occupancy (outdoor)	5	7	7
Platform length (m)	6	5,80	5,40
Platform width (m)	1,89	2,50	1,83
Length (m)	4,18	5,77	3,94
Width (m)	2,25	2,50	2,13
Height (m)	2,97	2,24	2,68
Length stowed (m)	4,18	5,77	3,94
Height stowed (m)	2,97	3,13	2,00
Gradeability (%)	25	N/D	25
Tilt (Maximum)	N/D	N/D	N/D
Weight (m)	7300	15500	5445,00

Figure 4. Example of database search and results: three models found.

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