International Council for Research and Innovation in Building and Construction

The Hong Kong Polytechnic University
香港理工大學

Faculty of Construction and Environment
建設及環境學院

Department of Building & Real Estate
建築及房地產學系
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CIB World Building Congress 2019

Constructing Smart Cities

17 – 21 June 2019 (Monday – Friday)

The Hong Kong Polytechnic University,
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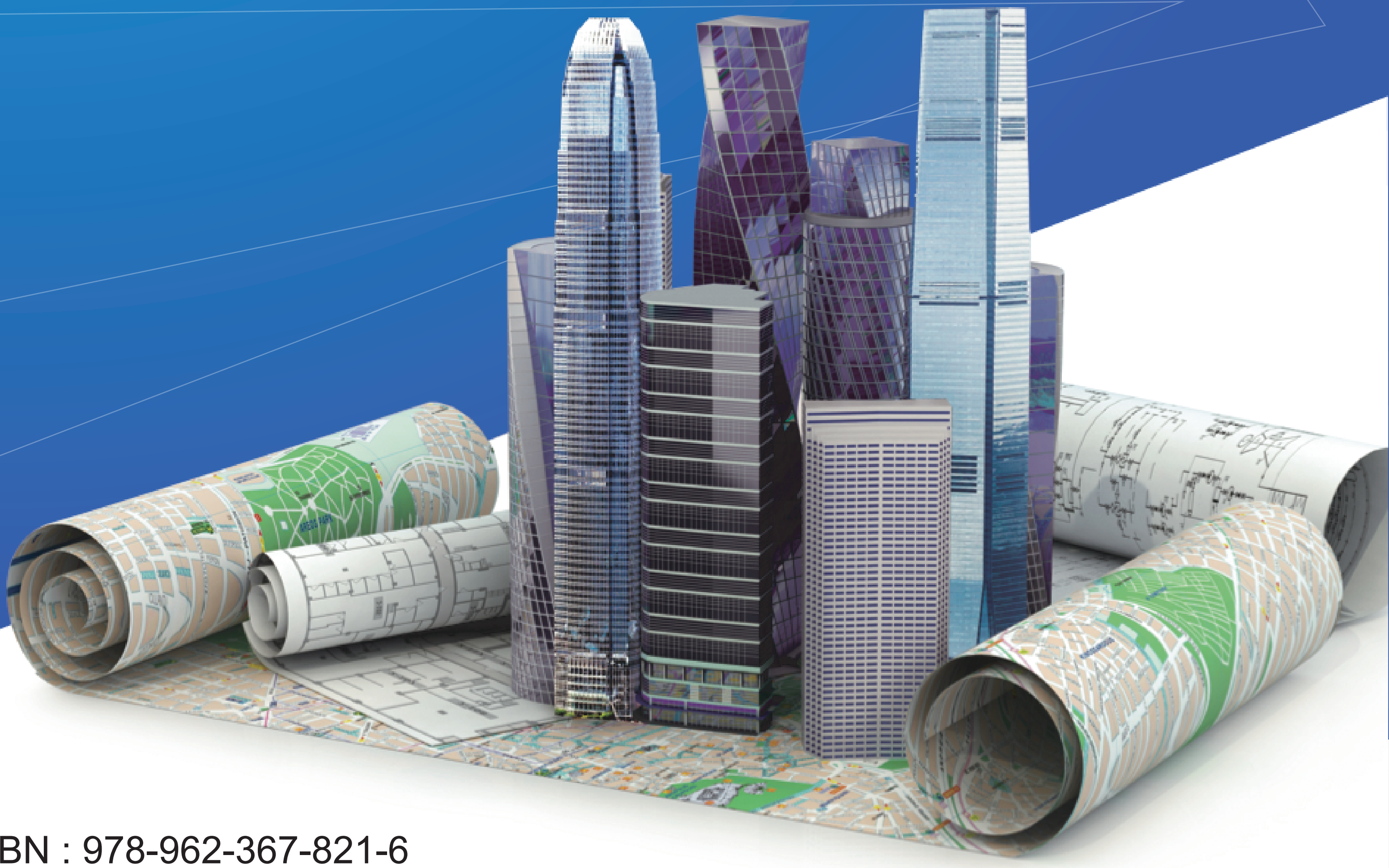

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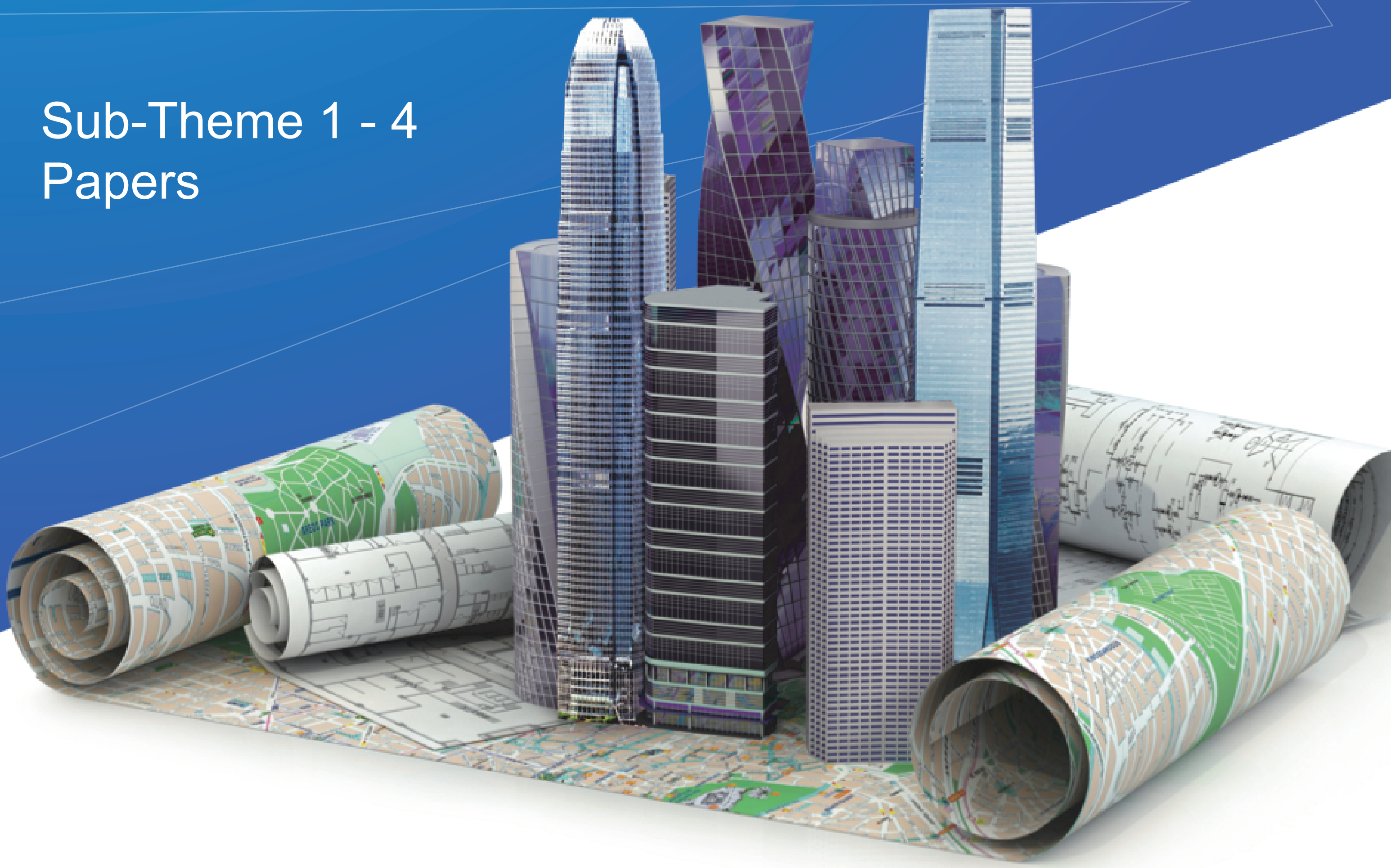

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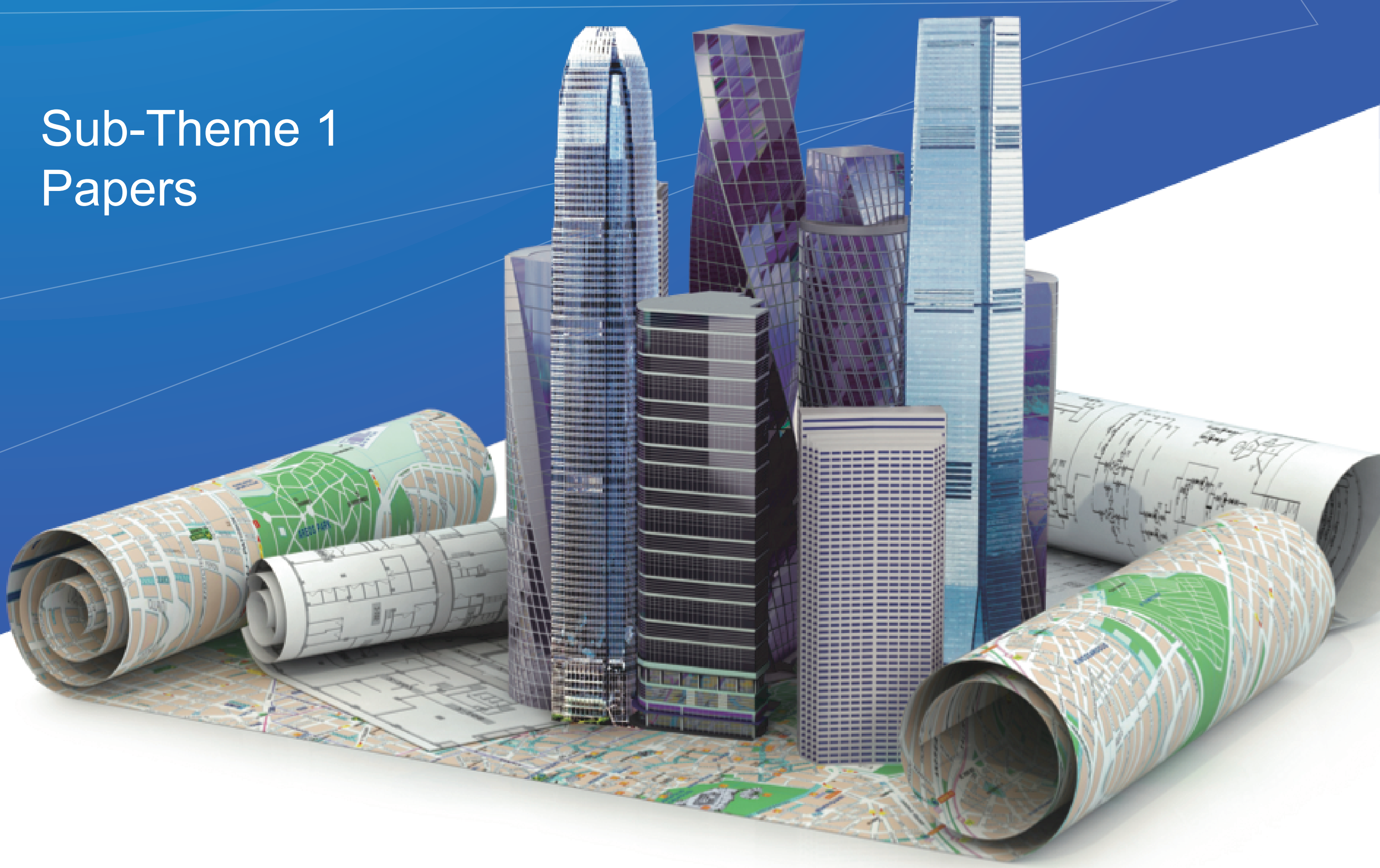

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A BIM approach for small construction sites

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Abstract

Keywords: Building and design techniques, BIM, Sustainable design, Construction management, Information transparency

The latest evolution of the building process leads professionals to face issues of sustainability and data management according to Building Information Modelling (BIM) procedures. The scarce availability of resources for the design, management and update of a BIM model for small construction site in the Italian context lead to clear resistance in the application of complex design and execution of BIM-based procedures. This is due also to the contractors' and suppliers' scarce competences and awareness concerning great advantage which could be achieved through the employment of BIM-based methodologies. Therefore, the possibilities offered by the BIM methodologies in the various phases of the building process, should be streamlined and tailored according to the client's requirements, the type of work (new construction, retrofitting, refurbishment, etc.) and to the reference market (public or private). This article presents a methodology for the application of BIM procedures to the construction phase of small building sites. The construction manager can employ procedures and tools that allow the streamlined integrated management of daily work progress in the constructions site. This allows to optimize time and resources in the construction management phase and in the subsequent delivery of the work to the client. The proposed methodology has been validated through a case study concerning the design and construction of a mountain hut in Trentino region, Italy. This experience involved the local stakeholders and entrepreneurs and has been appreciated since it allows a more effective and timely achievements of contract terms. Moreover, the case study demonstrated the applicability of the proposed approach and its replicability, despite some refinements and further applications should be carried out.

1. Introduction

Since 1960s, the automotive and aerospace industry perceived the benefits of using CAD technologies, in terms of faster processing and design reworking, reduced errors and evident progress in automation (Reffat, 2006). The construction industry, in line with his nature, which is very often aimed at continuing the tradition of design and technical solutions, did not immediately take advantage of the opportunities offered by the new tools and began to progressively adopt CAD systems in their 2D version (in the second half of the 1970s). The '80s can be considered as the beginning of the Building Information Modelling (BIM) approach in the world of design (Reffat, 2006). In the last 20 years a lot of investment has been made in the 3D interface, to create a model containing a wide array of information. Even today, the full potential of BIM remains not enough exploited by most of the designers, remaining limited to huge projects and constructions. For those reasons, advantages reached through the use of BIM in small/medium construction sites have been investigated and a case study concerning the design and construction of a mountain hut in Trentino region, Italy is presented. The implementation of the case study has been possible thanks to the definition for the employment of BIM in small construction sites

1.1 State of the art of the BIM approach

The lack of information between the parties involved in various ways in a project flow, have always been source of contradictions, replicated processes and asynchronous and redundant production of documents required by the standards and norms (Pärn, Edwards and Sing, 2017). Today's architectural challenges and the constant need of optimizing the connection among the phases of a construction process, coordinating the various actions and actors involved, finding, therefore, an easier and more correct management promote the "BIM approach". it is well known that the BIM is not only configured as a mere three-dimensional representation of the building, but collects a lot of information and data essential for the project such as: timing, quantity, quality and characteristics of materials, costs and operations. This specific model facilitates their dissemination within the project team or stakeholders and, potentially, also future users/maintainers of those architectural spaces (NBS, 2017). The main strengths enabled by BIM are a better management of information in relation to the traditional design process. In fact, if well-structured and managed during the whole building process, a BIM model allows an easy sharing of information to the entire working group (e.g. geometric measurements, positioning, data sheets, etc.). According to Rokooei (2015) BIM is not a single software, but is a new form of information processing and collaboration, with data embedded within a 3D model. In addition, BIM systems are increasingly used in construction projects to provide transparency and open access to project information, reducing information asymmetry. During the design and construction phases, interrogating the BIM model as a single information repository fewer requests for changes will be made, productivity will be improved (each stakeholder knows own tasks), accurate cost estimates will be developed and better visualization will be possible for site safety analysis purposes. The correct and coordinated sharing of those information ensures, in the end, a substantial improvement of the collaborative aspects for all actors (main and secondary) involved in the construction process; a situation that tends to reduce conflicts and possible delays (Eastman *et al.*, 2011), resulting in greater customer satisfaction and almost eliminate the risk of sanctions. The integration of BIM models with real-time data acquisition systems facilitates process monitoring, making knowledge not only of documental aspects but also visual/spatial clarifications thanks to 3D model navigation. BIM models also have great potential to support early detection of non-conformities: if properly structured and well managed, they can detect problems and differences between design and real construction on site, thanks to targeted tools such as real-time visualization and graphic overwriting. On the other hand, in the literature several problems have been identified in the use of BIM for the management of the construction execution process, especially in the context of small and medium-sized companies and/or design studios. In fact, the correct creation and management of a BIM process requires a high use of resources with a high level of qualifications and skills to control the huge amount of data and the high level of detail that can be contained by the model. Problems of misalignment between different parts of the model may arise, e.g. if they are managed by professionals working with different levels of detail (different LOD, described in the document BIM Execution Plan in the UK PAS 1192-2:2013). The training of skills (and/or their updating) represents a high cost for companies not to mention that for very complex models, a fundamental requirement is also to equip the work team with high-performance hardware. A further problem can be related to the different level of experience of the working group, the flow of design and implementation decisions can be reversed, starting from the BIM rather than the architectural composition: a "technocratic control of the project". All project decisions are subject to the control of the BIM and consequent to the design choices of the appointed designer. Further gaps arise from the non-automatic recording of changes in real time that cause missed notifications to the working group. Often, the project team is not immediately able to detect any changes in the project, if the model is not well structured and updated.

2. Methods

2.1 The Methodological approach

The methodology applied for the development of this article can be divided into three steps. In a first phase, an extensive research and critical reading of scientific articles on the topic of BIM and its possible future implementations has been carried out. This has allowed to understand how today the BIM approach in Architecture, Engineering, Constructions and operations is conceived according to different scales of intervention and its possible evolutions. Understanding strengths and weaknesses, modules within a BIM software, which could give competitive advantages especially for small construction sites and professional firms made up of small teams of professionals have been identified (Tauriainen *et al.*, 2016). Finally, operational procedures have been defined and put into practice in the context of small construction sites, as well as used in the simulation of a particular case study in an "extreme" high mountain environment.

2.2 The BIM approach for small construction sites in Italy

The introduction of the BIM approach for the design of engineering and architectural works is much more problematic with regard to the design of small buildings, standardized to local regulations, compared to huge construction sites, systems and structures much more complex (airports, skyscrapers, shopping malls, railways etc.). In the context of an Italian small design studio, it is very expensive, if not excessive, to implement methods and software capable of speeding up the phases of creation and management of a project, especially for a private customer whose only claim is to have a home, paid the right amount, without any excess of volume, shapes and finishes, whose approval is successful at the first presentation at the local offices in charge. One might even think that the time taken for the elaboration and layout of the project itself, with the subsequent modifications and variations, is the justifying basis for the designer's remuneration. Instead, every modification of the project is a wasting of time that has to be optimized. The designer's task should, in fact, be not only the design phase, but also the consequential control and management of the project (Deshpande, Azhar and Amireddy, 2014). Nevertheless, very often the need to remain into deadlines for the presentation of the project, compromise the following phases. According to Xu (2017), the use of a BIM process can overturn this working methodology and ensure more time for the designer who can use it for the creative phase and for the control/calculation of forms. Obviously, a BIM model for a "daily" design will not need the same level of complexity/completeness of a model made for worksites of great complexity and high cost, but respecting some parameters and strategies can perfectly meet all the needs and expectations aimed at saving time and energy. In this context, a properly defined BIM model, according to appropriate simplification criteria (Sacks, Radosavljevic and Barak, 2010), can provide support:

- for the creation of an infinite, and at no cost in terms of time, series of elevations and sections, essential for a presentation of the project before the various municipal/environmental commissions;
- to update in real time during the creative phase, the resulting changes in the various plans and

sections, in all the tables and views connected. This allows the immediate verification of any errors and non-conformities, keeping the project aligned on all its components;
- in checking the variations requested by customers and technicians in such a way that they do not represent a criticality, the tools placed within the main BIM software, allow in fact an immediate modification of thicknesses, shapes, heights, without using the classic tools of copy, modification, size, merge, etc.;
- the direct involvement of the customer because through the model and the apps (often connected to the software) which, by understanding more easily spaces, inclinations, colors, surfaces (compared to a normal 2D view), can receive and provide information even without being a technician in the field. All this saving paper/meetings and subsequent discussions due to misunderstandings and expectations not understood;
- in the realistic representation and setting of the project, in fact all the main BIM software have an internal rendering tool. In the presentation phase of the project, even a medium quality rendering (i.e. without further steps and modifications to improve its realism) allows both customers and control bodies to have an immediate indication of volumes, finishes and inclusion in the context of the project;
- for the visualization of parallel views of the same model, as needed, through the tools of overwriting graphics. In other words, it is possible to produce specific views for demolition and reconstruction operations (with colors in line with the standard), or information on the state of progress of construction site operations (for example, a check on individual windows and doors and any non-conformities due to assembly failures or errors by a specific team), receiving the updating information directly from the construction site reports produced by operators not trained in the use of BIM tools;
- allowing the easy visualization of the project and the model by the entire team of technicians sharing in the cloud architectural, structural, plant engineering and operational aspects, with the possibility of modification and updating in real time even on volumes, finishes, the plant engineer and possible the

3. Results

3.1 Case study: high altitude prototyping

The case study concerns the construction of a high-altitude mountain hut (Figure 1, 2, 3 and 4), with prefabricated structure, potentially installable in any high mountain context, considering its speed of assembly and compositional/technological characteristics. The case study allowed to test the robustness of the proposed methodology The spherical design and the frailty of the construction site are elements of fundamental importance to test the BIM approach. Every activities schedule hypothesis must first of all start from the consideration of the particular boundary conditions that characterize the work and the influence that these have on the technical and operational choices. Timing and weather conditions certainly play a fundamental role, due to safety problems and delays in execution that may occur, but also the "technical" time related to the individual works. In fact, in such a context time comes into play on the hours of possible use of the helicopter as a means of transport and lifting at height of construction materials and workers. First of all, in order to optimize the working time at height, it is necessary to provide for the setting up of a construction site at the base, near which the starting and landing area for the helicopter will be set up. Since this is a metal supporting structure, it is possible to make the most of the prefabrication. Apart from the preparation of the foundation laying plan (which will be carried out with a mini crawler excavator weighing no more than 1 ton, brought to height by helicopter, and left there until the end of the work, being able to use it both as a drilling rig and for inserting the metal anchor bolts of the foundation into the rock, and finally also as a means of support during the laying of the various components), the only structural construction phase on site is represented by the casting of the foundation slab in reinforced concrete. The necessary concrete, delivered to the starting pitch, will be brought to height by helicopter and discharged from the bucket directly into the housing dug into the rock. The metal structural elements can be pre-assembled in the workshop, in order to define in advance and optimize the assembly and assembly times. The organization of the site from the design phase provides that the individual pieces or "segments" of the sphere from the pitch are brought to height, partly pre-assembled, but taking care to create portions not too bulky and weighing less than 1 ton, maximum capacity of the helicopter. The helicopter is also necessary during the assembly phases of the structural components, as it serves to hold the various elements in place before they are connected to each other, to form a final stabilized and self-supporting structure. Finally, the finishing, completion and furnishing materials that will be brought to the pitch and from there brought to height must be considered. Considering the use of the helicopter also for transport of the workers and technicians at height, it is assumed that the number of rotations strictly necessary for the complete realization of the work can be around 40 divided as follows: 20 for the structural works, 10 for the finishing and plant engineering works, 10 for the transport of people.

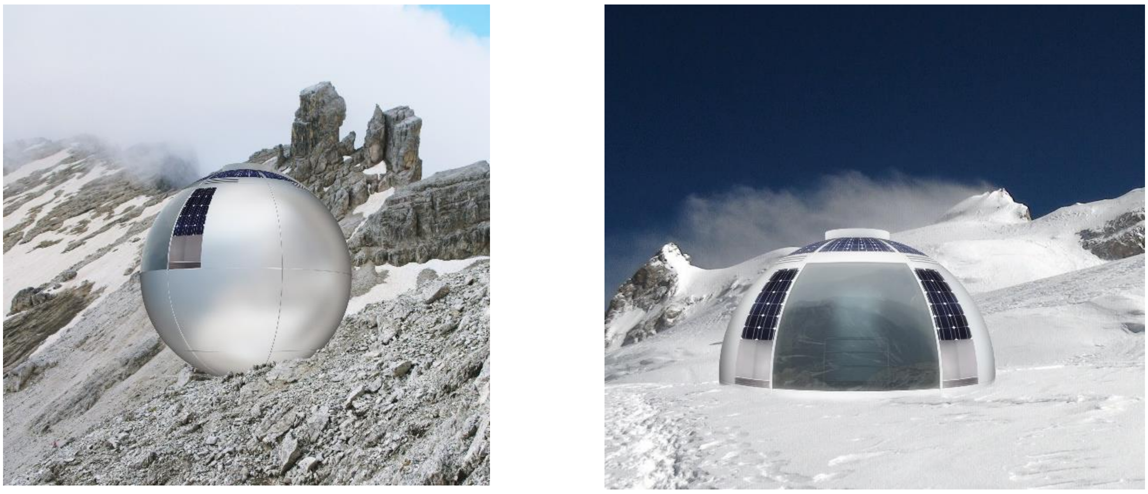

Figure 16: Summer and winter vision of the Mountain hut

Figure 2 – Mountain hut section

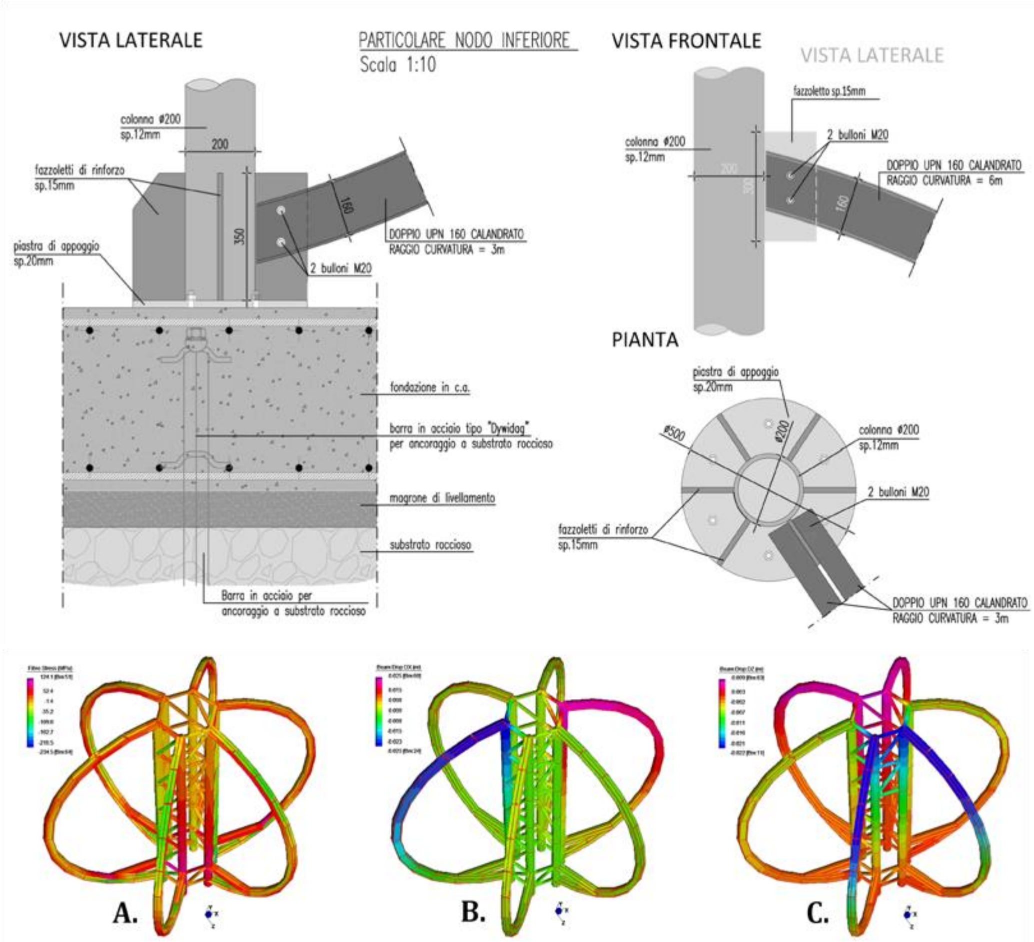

Figure 3: Construction details and calculation of wind tension and forces on X,Y,Z axes

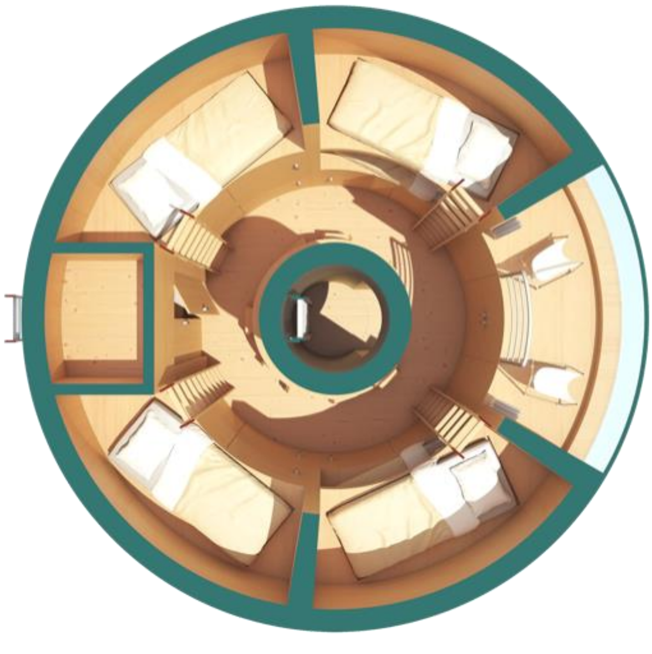

Figure 4 – Mountain hut plan

3.2 BIM: from Model to Management

The management of the entire construction process can be an excellent example of the use of BIM for small and very small construction sites. Associating each component with specifications on assembly and subsequent maintenance, from the moment of the design phase, a booklet of the project building is defined, which is useful both for the teams involved in the construction and for those who will manage the building during its life cycle. Thanks to the graphic overwriting tool, it is possible to manage the building site phases of the module, encoding actions and colors, which are updated automatically as the information entered daily in the dedicated schedules changes. This approach leads to overcome the use of the BIM model in its classic setting based on the asset/object by inserting information and variables related to the activities of site construction and management of the project site. To achieve this, it is necessary to change the setting of the model from the beginning, agreeing with the various stakeholders specific working methods, activities and classification of the elements. This, at first, may lead to a higher cost/use of resources for the creation of databases that can be linked to the various assets of the model, but this initial effort will be compensated by a facilitated and always updated management of the site. The applicable procedure is relatively simple and does not involve writing code or specific (and expensive) plug-ins. Once the assembly operations have been agreed (following the instructions of the companies involved), they will be associated with the individual assets of the project. In all the main BIM software, it is possible to create, edit and modify information/activities. All this information, stored in the model, can be displayed with colors and / or screens for easier sharing of delays, contingencies, non-conformities or simply the progress of work. All this information can be exported in simple Excel formats, to be delivered to the teams on site. Direct modification of the source BIM model by personnel not specifically trained, could increase the risk of errors and confusion/entropy in the project management of the site. (Figure 4)

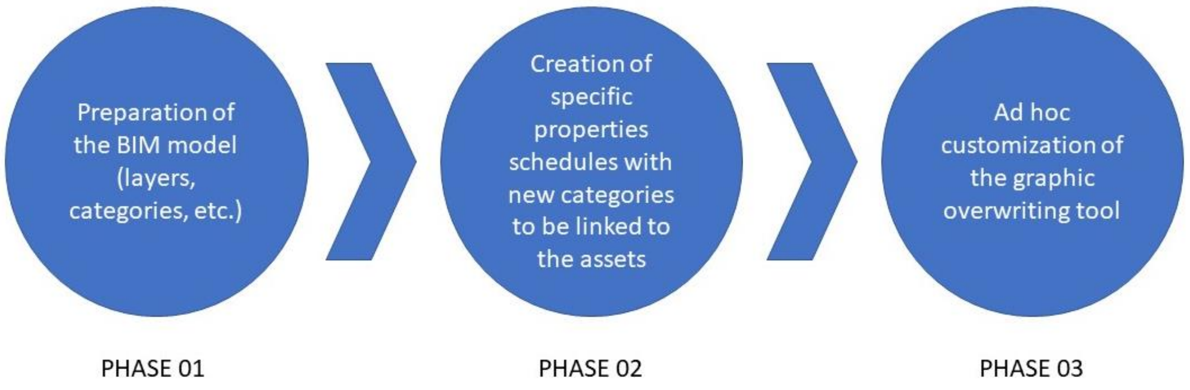

Figure 4: Working phases

Moreover, through the proposed approach a simplification of workloads and activities and certainly not an increase in them has been provided: a worker must be able to concentrate on his activities without having to worry about updating the BIM model directly, during the working day. Through these simple excel tables (which will replace the usual site documentation), each worker or team will be able during the day to indicate what has actually been assembled on site and report any problems not in general but related to the specific asset or component. The project manager will collect these updated tables and bring them back into the BIM model which, thanks to the graphic overwriting tool, will be automatically updated: it will be possible to view and verify the progress of the project practically in real time without a high commitment of resources (Figure 5 and 6). The practical and fast possibility of visual updating of the model and its databases, also allows easier sharing and explanation to third parties and non-technical stakeholders.

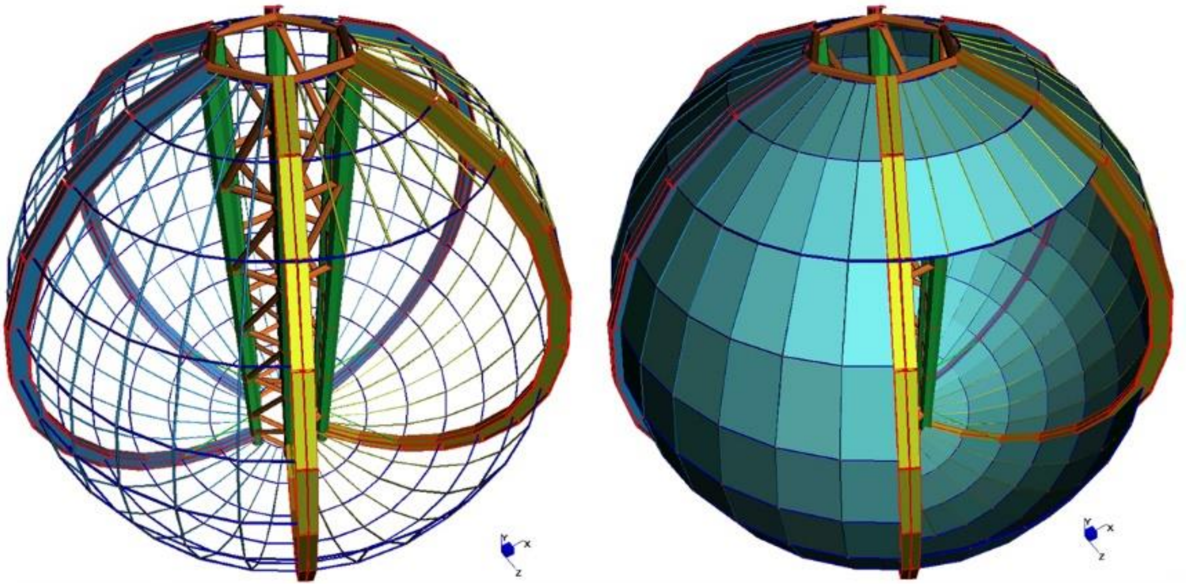

Figure 5: graphic overwriting model

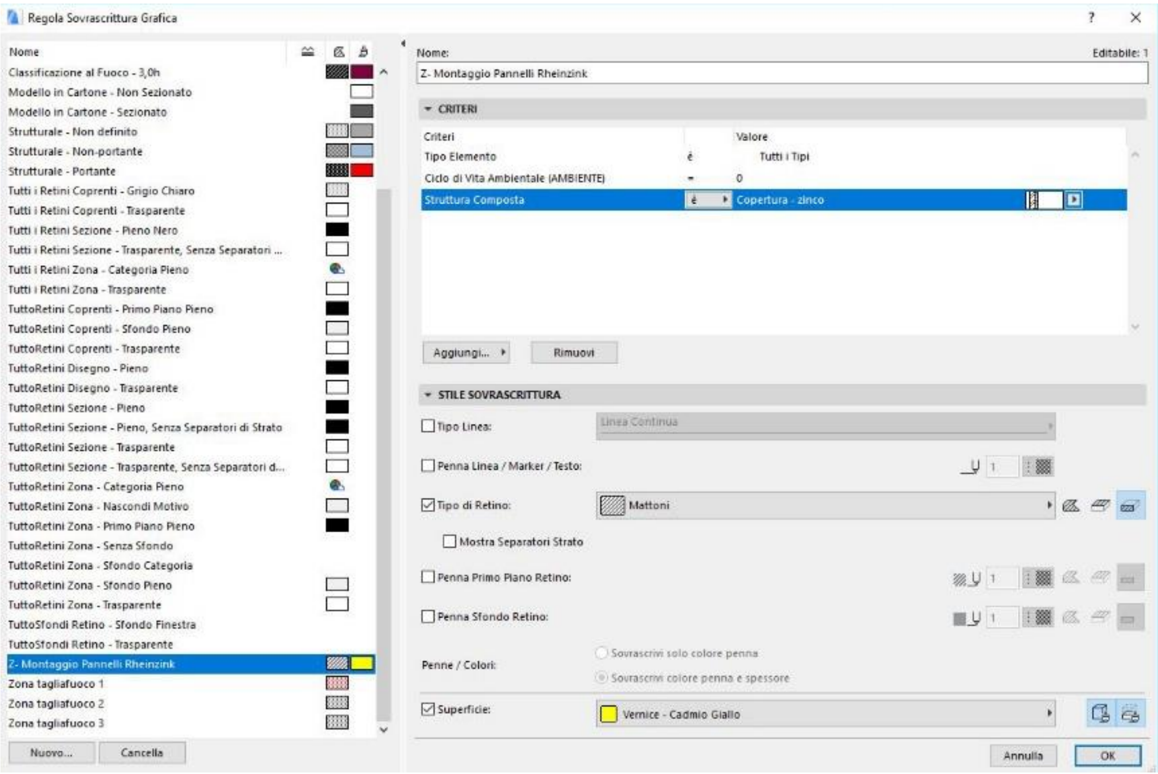

Figure 6 – Graphic overwriting interface (Archicad Graphisoft v.22)

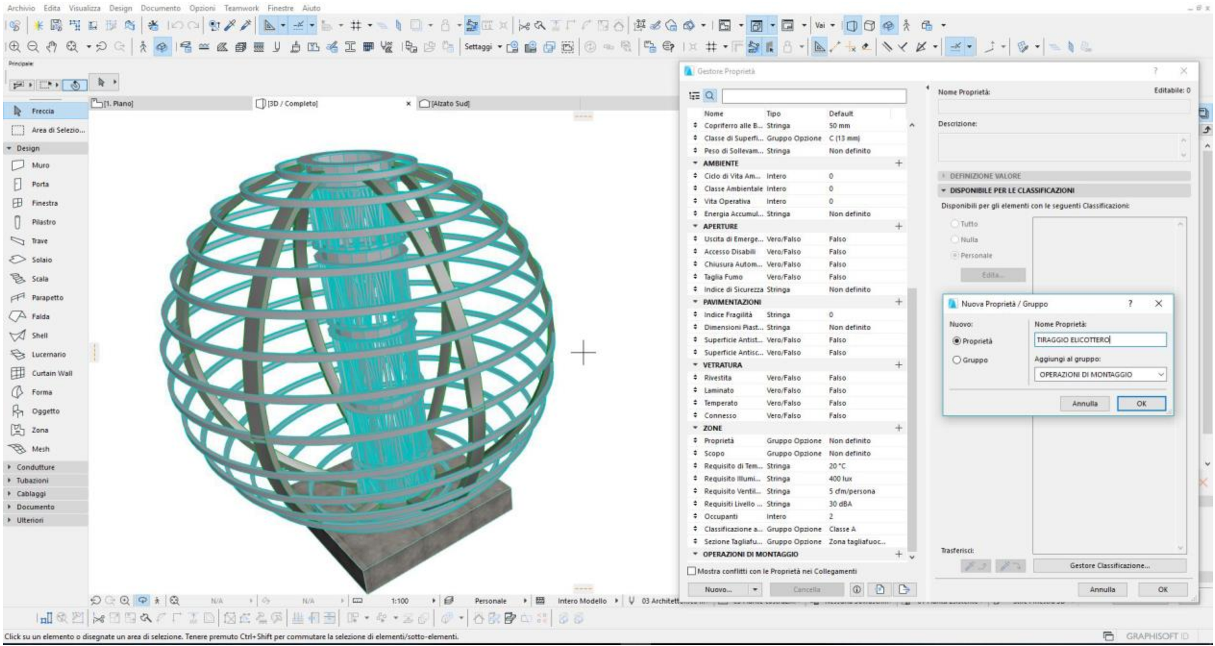

Figure 6 – New specific properties schedules creation (Archicad Graphisoft v.22)

4. Discussion and conclusions

The application of appropriate BIM procedures represents the future of design and good architecture/engineering even for small and medium projects and is being producing a deep chance in AECO sector: the transition from paper to digital design. Those who claim a depletion of the compositional/creative phases of the project, have nothing to worry about: the sketch and freehand drawing can co-exist at the beginning of the design process, with the new methodologies there will be a decrease in mechanical and sterile operations and an easier definition and control of errors both in the design and execution phases, allowing a saving of energy and time that can be better used to optimize the phases of definition and development of the project, with obvious positive consequences on the phases of control in execution, and in compliance with time and cost of execution. In the context of small or medium construction sites, it is not conceivable the presence of a real BIM manager, the appropriate definition of data exchange methods through the use of specific programs / procedures ensures the collaboration within the information management process even of non-specialized operators, simplifying the work of the project manager as well as the public control operators. The recognized need for specialized and continuous training for a correct use of BIM procedures should not be a negative factor but rather an opportunity for generations of "new" professionals who will find spaces and roles of responsibility in an increasingly hard and competitive construction market also calling for an upgrade on the public administration side of BIM technology (Cheng and Lu, 2015; D.Lgs n. 50, 2016; Gazzetta Ufficiale Della Repubblica Italiana, 2017)

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