The approach to BIM - Building Information Modelling as excellent instrument for the definition of design strategies and for knowledge, simulation and management of the buildings and architectural heritage.

Gerardo Maria Cennamo, Stefano Savoia

***Abstract*—**As regards architectural heritages, especially in historic cities, the level of knowledge becomes directly proportional to the possibility of management.

The qualitatively larger and better capacity for acquisition of an in-depth cognitive structure, the easier and more efficient the possibility of better management of the architectural and historical asset. The affirmation, even in the recent past, of new methodologies and cognitive and elaborative technologies, involving the natural and artificial environment has also involved areas typical of architecture by evolving traditional systems and methods of representation. When applied to the conservation, valorisation and management of the architectural heritage, especially in historic cities, the simultaneous evolution of these knowledge and technologies simulation helped evolve the discipline of representation towards a broader interdisciplinary direction, establishing a relational system of methods and leading and information that precede and complete the knowledge-analysis-design process.

***Keywords*—**Retrofitting, architectural heritage, historical cities, knowledge, managment.

I. Introduction

WHEREAS until fairly recently in the context of representation processes, the relational system between perception, elaboration and representation was perfected and completed through natural "intuitus" (physical environment) and human intelligence (perception and calculation), the dominant role taken, in terms of methodology and practice, by a third "virtual intelligence" derived from the contemporary evolution of post-industrial technologies such as electronics, informatics and telematics, has transformed the previous method of approach to the natural or built environment, as well as to design. If there is a problem that regards exchange and transmission of the information in the building production process, there is equally a problem for the definition of technical project and its information content, problems as regards the identification of any subject, object or action in the construction chain.

"There are a great many production and service companies in the building/construction process and relationships between the various players are complex.
In the "Construction set", the large number of production and service companies involved gives rise to increasingly complex relationships between operators. The risk of misunderstanding and confusion of languages and messages between the various operational spheres is so serious that it may well be represented by the biblical image of the Tower of Babel - a strange coincidence - that represents the technological challenge of building" [1]

II. Problem Formulation

The difficulties in which we most encounter today regarding how to use technical information in the building/construction process probably also arise from increasingly rapid invasive innovation in the industrial age that in just a few decades has revolutionized a repertoire of techniques and materials that had remained virtually unchanged for centuries. There is no doubt that these technologies supporting representation disciplines have brought about significant evolution in traditional surveying and drawing analysis methods to the point of creating an opportunity, if not actually a necessity for extensive analysis in this regard by professionals and academic

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experts. As noted by Della Vecchia and Mura in the treatise titled Treaty "Graphic Representation Technologies and Techniques", the history of visual representation has never seen such a radical transformation as that seen in the technical representation field.

In any case, the centrality of project design in the building process seems self-evident and remains fundamental in the knowledge process involving an architectural body through surveying and representation.

"The project, the integration of various project specifications, involves ever-growing complexity requiring input by various disciplines/knowledge systems, which in some cases are highly innovative, that are grafted on to consolidated traditions in architecture, engineering and technical plant. The organised and finalised interdisciplinary approach, the orderly integration of various project specifications, the management of the flow of information between the client and the various operators involved in the project and/or its execution, become synonymous with the quality of the design event" [2].

As a result of this centrality, it therefore becomes clear that the project embodies the possibility of managing and organising the information flow for the entire process, from the identification of requirements through to the end-of-life management of the construct.

Project management, given its fundamental importance for the administrator of the entire building process, can only take place using Quality Management tools.

More recently, various survey, acquisition and knowledge management methods have sequentially evolved in relation to the architectural heritage; mention may be made, for example, of the important INNOVANCE research project.

"*The InnovANCE programme, co-financed by the Ministry of Economic Development through the Industry Energy 2015 Tender, aims to develop an innovative system project through the creation of the first interoperable database in the construction sector in order to network its entire enlarged value chain.*

Under the scientific guidance of Milan Polytechnic University, partners such as ENEA, CNR, ANCE, SAP, Autodesk and construction component producer trade associations sought to develop the prototype of a new access, management and exchange structure for standardised building technical and economic information to achieve better organisation of flows and transfer times for technical-scientific knowledge, as the starting point condition for ensuring the full effectiveness and efficiency of the building product and the sustainability of the built environment.

In addition, InnovANCE also seeks to be a strategic step towards optimisation in the building process and in the construction sector in general,

through rationalisation of information flows to merge the various stages (design, construction, operation and maintenance) and the various operators involved in the process (clients, users, designers, construction companies, component manufacturers, etc.) for purposes pertinent to energy saving and environmental sustainability through the shared application of the UNI 11337 standard: "Building and civil engineering works. Codification criteria for works, activities and resources. Identification, description and interoperability" [3].

Other interesting integrated data acquisition and management technologies through simulations of the architectural heritage have also been developed in recent years; for example, a major construction software interoperability format is the IFC standard - Industry Foundation Classes - developed by BuildingSMART Alliance (also known as IAI - International Alliance for Interoperability).

This publicly available format is recognised worldwide. IFCs are full-scale system for electronically classifying and describing the elements that may be included in a construction project, in a software usable format: doors, walls, windows, plant systems, spatial elements, etc.

IFC compliant applications make it possible to share and exchange data without needing to convert from one format to another.

III. Problem Solution

The resources made available thanks to progress in such technologies, all founded on a structured preliminary stage of data acquisition and representation of the architectural heritage, can be specified at various research levels, among which "modelling" is fundamental. Conceptually, it outcome ensure total sharing of data and information, thereby making it possible to share important survey documentation in order to develop any kind of graphic and simulation project; in this case, the graphical rendering of information is defined as "modelling" since it derives from the mathematical model (algorithmic) of the objects themselves, culminating in the definition of a photographically realistic image representing the three-dimensional model of the three-dimensional object.

One of the systems leading up to "modelling" is based on the knowledge and construction of complex systems, in qualitative and quantitative terms, capable of analysing the structure in question and the behaviours of models in a way that supports human intervention in areas such as prevention, diagnostics, information and other intervention especially in the field of risk assessment for masonry buildings.

By modifying the cognitive system of mathematics, it is possible to develop a functional renovation project model of the heritage in accordance with a fractal pattern whereby each element or sub-system (suburb, building, cell, component or part thereof) has a structure similar to that of the overall system.

"Modelling" (understood as an approach to modelling) and its systems can be transferred to the building renovation project thanks to their capacity for highly reliable assessment of every phenomenon interacting with the individual artefact or the entire built complex in order to prevent possible structural deterioration caused by intrinsic factors or aggression from the surrounding environment.

With modern CAD-BIM IFC-based systems, it is possible to build virtual representations of buildings which can be used by other IFC-compatible applications to perform calculations or simulations. The model is also useful for simulating the building's life cycle: from construction stages through to management, maintenance and decommissioning.

To understand BIM fully, one has to refer to the history of evolution in digital design, beginning in 1961 when Ivan Sutherland created, for his doctoral thesis at MIT in Boston, the first prototype of the instruments that would later be transformed into CAD (Computer Aided Design), with an additional step. Since the late 1980's, the 3D digital model in mechanical applications has been enhanced by a further development: the innovation introduced by object-based parametric modelling.

"...while in traditional 3D CAD, every aspect of an item's geometry must be edited manually by the users, with a parametric modeller the shape and set of geometric components is automatically corrected in accordance with changes in the context ... This means that any changes made directly in the model are matched by an identical change in the data set and vice versa" [4].

The ability to manage this matching was made possible for the first time by Graphicsoft and its ArchiCAD program that introduced the first Virtual Building Solution.

Designers were allowed to store a huge amount of data in the model of the building itself, i.e. geometry and dimensional-spatial data could be joined by the characteristic properties and quantities of the elements used in the project.

Consequently, the BIM model can incorporate any information associated with the building and its entire lifecycle and not only to the information necessary for its implementation: "*BIM is the process of creating and managing the information model throughout the lifetime of a building, from the planning stage to operation and maintenance by way of construction*" [5].

The AIA (American Institute of Architects) defines BIM as "*a modelling technology linked to a project information database*" thereby emphasising the intense relationship between the model and the database of specifications on which the model itself is built.

In short, BIM is not simply a 3D model but a broad methodological approach that potentially allows management and improvement of the entire building process.

"*BIM therefore comprises the set of processes applied in order to create, manage, obtain and communicate information between stakeholders at various levels, using models created by all parties involved in the construction process, at different times and even for purposes that are not necessary same, thereby ensuring quality and efficiency through the entire life-cycle of an artefact*" [6]

To all intents and purposes, the single information container would seem to make a decisive contribution to the reunification of the disjointed and fragmented set of operators involved in the process, encouraging them to implement correct communication for inclusion in a single model.

This objective would be achieved if operators used throughout the entire process a single Integrated Project Database (IPDB) or by means of BIM (effectively a synonym).

The BIM model makes it possible to handle in a shared manner the information required by the owner, building operators, technicians and construction companies, and the facility manager.

This potential, which has only in recent times become available to building process designers and operators thanks to the low-spread of appropriate software and hardware and huge memory capacity, is still today not completely expressed.

The causes for such difficult dissemination of BIM criteria are largely to be found in problems such as:

- Absence of a common language and shared semantics between the different players in the supply chain.

- Lack of standardisation in operational stages. Performance assurance (especially as regards energy) can be attained not only for the overall building but also for individual components, yet only through a complete collection and cataloguing of existing or otherwise required information.

- Usability and availability of information. Having standardised the language and shared semantics, entire supply chain must be provided with information through an easily accessed database.

- Lack of interoperability, i.e. the difficulty or at times impossibility for the various software packages used in the same project to exchange data and information, generating high risks of inconsistencies or data loss.

These impediments and problems are not exclusively found in Italy's somewhat backward context but are issues of international significance.

The search for maximum benefit in the complex AEC (Architecture, Engineering and Construction) and FM (Facility Management) sector is a matter of interest all over the world.

IV. The BIM model for the safety planning

Among the possibilities offered by the BIM model to the building process, the ones of the program management and safety in the construction site seem among the most interesting and less investigated.

The informative integrated system of the BIM process becomes, as said, the unique container of innumerable documents and information which are necessary to the building process management.

It is for this reason that this unique archive, towards the construction site and safety management, is responding to two fundamental needs:

- planning and coordination: sequence definition of the activities in the construction site, displayed and communicated to all the concerned people, so to minimize risky situation and to properly implement the necessary actions and arrangements

- knowledge of the productive process: it is basically referred to an enough and constantly updated knowledge of the operative work conditions and the related danger situations. These activities, which are normally carried out by coordinators, managers, appointed people and workers, are often intuitive and based on previous experiences.

The usage of the BIM model may supply to these needs an informative potential, oriented to granting major efficiency levels.

"For the construction industry and in general in the construction sector, so to improve the information transmission it has always been used better solutions compared to the two-dimensional images, that is the three-dimensional in scale models so as the virtual ones during the planning or executing phases. For these purposes generally it may be used the BIM model so to correlate the building methods and procedures with the technical work elements and, in a latter stage, making these information more comprehensible by inserting the time in the virtual representation so to display the building process as an animation made by phases in sequence. This means to supply additional information, which are the construction phases relation, so to say the logical-chronological sequences of the building procedures and the cause-effect connections.

Therefore, as far as the safety is concerned, the 3D/4D visualization may provide a remarkable contribution to the communication and information on actual building situation especially related to:

- information on detailed work and related phases risks;

- visualization of construction phases and related coordination;

- specific instruction and rules of the building site

- visualization of technical and productive solutions during the assembly transition (provisional works) and the conclusion;

- particular announcements and messages.

Furthermore more generally the sectors where the parametric drawing technologies and support to BIM decisions may provide an important contribution to the safety in the building site are:

- 3D/4D layout model of the building site and plants;

- visualization of the building site most significative phase sequence (digging out, elevation, demolition) and related preparation;

- visualization and modeling of the provisional works, formwork and safety solutions (scaffoldings, bulwarks, supporting frameworks, safety lines,..);

- support to safety control during the work in progress"[1] .

V. The BIM as Real Managment Archive for Facility and Building Management

Another interesting aspect is the usage of the BIM model for the management of the building during its life cycle.

It is self evident that after the conclusion of construction work or building reconstruction, the BIM model becomes spontaneously the informative technical archive (to better say real estate management archive). First of all the developments prepared for the works are available "as built". These developments are subject to a cleaning operation and combined in the BIM model together with other documents especially related to the management such as:

- O&M Manuals;
- Submittals;
- photos;
- closeout documents;
- record models

Furthermore by defining the usable surface features through functional categories it is possible to obtain the spatial and quantitative building allocation, so to summarize for each floor, building and sector the needs for the management cost evaluation and its time planning.

A real estate management archive is indeed featured by:

- facilitating the overview of a building or a real estate complex so to balancing and coordinating the management interventions;

- organizing and defining the operating structures, supplying suitable infrastructures;

- graduing the archives setting up and real estate management activities;

- evaluating the interconnections arising from legislative decrees and/or by national, regional, provincial and municipal source regulations;

- aming to cost control by integrated analysis and coordinated intervention acts fitting in a uniform action context;

- managing safety aspects related to maintenance by evaluating the works interference risks.

The real estate management archive, via its complete informative system, is also aiming to overtake asystemic reasons in building management.

The real estate management activities are finalized to the preservation and/or improvement of a building system. These activities require the availability of substantial data generally supported by documents and technical information.

The real estate management archives represent the main infrastructure used by the subjects in charge of the real estate management. Thanks to this infrastructure, useful or necessary information may be acquired for a certain purpose and therefore appropriate decisions may be taken. The undertaking of appropriated decisions is the fundamental requirement so to obtain efficient outcomes in the real estate management activities. The real estate management is completely put into effect after the fulfilments of a building system, but it arises from the previous working phases where many of the future management conditions are decided.

This is the reason why it is important that the documentation processing follows efficiently the whole life cycle of a building system since its early stage and this is what occurs managing the whole process with a BIM model.

[1] M. Bragadin, “Building Information Modeling e sicurezza” in: *Atti del Convegno Sicurezza sul Lavoro in Edilizia*, Bologna, Italy, 2012

On the contrary, when it doesn't happen, the documentation looses partially or even totally its value and under certain circumstances it may be the result of relevant diseconomies and heavy inefficiencies.

Briefly the main objectives of the BIM approach to the building management are:[2]

• Improve performance and longevity of building systems through consistent, effective and proper facility maintenance and operations;

• Manage space efficiently to optimize space utilization;

• Streamline move process to minimize disruptions;

• Monitor and control furniture and equipment;

• Track and manage maintenance and work order requests;

• Expedite recovery and communication in the event of a disaster;

• Manage deferred maintenance liabilities.

VI. Conclusion

Given the difficulties to be overcome for effective dissemination of BIM is would be appropriate here to summarise its direct and indirect advantages for the entire building value chain. In the first instance, it seems evident that the most obvious benefit is obtained in terms of managing information and documents. The same model can incorporate different kinds of information describing the building (functional, objects, abstract and logical objects) and documents related to describing the process (tables, costs, activities). Collection into a single set of information makes it possible to:

- improve data communication and understanding;
- documentation consistency;
- fewer errors;
- fewer unexpected changes in the course of work.

The creation of a single information container provides the Project Manager in charge of design and construction activities (or the Process Manager for public works) with a formidable coordination and verification instrument. Creating a 3D model of an existing building could, or should, take place through a survey with laser-scan technology and its precise digital rendering. More generally, this should become standard practice especially for buildings of particular historical and cultural importance, thereby compiling an information archive for the building - "*digital storage, analysis and information management technologies have found in the three-dimensional model their natural support for synergic development of potential. The 3D model in itself is an entity initially consisting of geometric and topological information about the materials which can all be geo-referenced.*

Moreover, the model - intended as close to life-size simulation of the architectural phenomenon - collects related architectural, spatial and figurative qualities. If the 3D model is diachronic, it is suitable for representing the modifications and transformations taking place in the course of the building's existence. Last but not least, the model can be provided with information about construction equipment, by reproducing the technological characteristics of the construct, i.e. depicting the culture, knowledge and construction skill of the authors. If the 3D model then becomes an interface and substrate for an archive comprising a large and heterogeneous mass of information relating to a given architectural object, there is considerable additional potential - in terms of historical-critical study - for the restoration, maintenance and management project of the asset, as well as its protection, preservation and valorisation. All this by no means excludes economic, management and planning questions" [7]

At this stage of the project, detailed surveying has not yet been carried out and therefore the results of conventional surveying were used as provided by the Local Council in order to draft the Ex Arsenale di Verona Project Financing proposal.

In any case, the potential offered by digital laser-scan techniques in architectural surveying in order to produce 3D models obtained from surface analysis based on point clouds had already been tested positively by the project team for another project involving an historical building in the design stage: the Domus Mercatorum in Piazza delle Erbe, Verona. Modelling was thereby developed starting from the existing 2D survey using version 16 of ArchiCAD software developed by the Hungarian company Graphicsoft since 1986. This software is historically the first to have introduced (in 1986) the first Virtual Building Solution allowing designers to build a three-dimensional virtual representation of their projects. This was a significant step forwards since it became possible to store a huge amount of data in the model of the building: these data settings included both geometry and spatial data of the building as well as the properties and quantities of elements used in the design project. Current versions of the software have evidently expanded these initial characteristics to allow integrated object design.

[2] San Diego Community College District, BIM Standards for Architects, Engineer & Contractors, Version 2.0, 2012

References

[1] G. Garau, E. Dal Zio, “Technical information for the building project. The program tabs.” Padova, CLEUP, 1990

[2] O. Tronconi (edited by), “Smart building”. Milano, ETAS Libri, 1990

[3] Website of Milan Polytechnic University. Avaible: http://www.polimi.it/

[4] A. Osello “The future of design with BIM for the engineers and the architects,” Palermo, Dario Flaccovio Editore, 2012

[5] V. Zacchei “Building Information Modeling. New technologies for the evolution of the design - construction.” Roma, Aracne Editrice, 2010

[6] A. Osello (cited publication)

[7] S. Brussaporci, M. Centofanti, R. Continenza, I. Trizio, “Information systems for the management, protection and use of historical buildings.” 16th ASITA Conference, 2012

[8] Savoia S., “The approach to the BIM – building information modeling – for the restoration project. A methodological proposal for the intervention on the building of ex Austrian arsenal in Verona.” thesis, degree in Civil and Environmental Engineering, International Telematic University UNINETTUNO, Roma, 2013

[9] G. Cennamo, S. Savoia “The role of knowledge in the definition of analysis and design strategies. The approach to BIM - Building Information Modelling as a new frontier for the representation, simulation and management of the architectural heritage.” in *Recent Researches in Applied Economics and Management - Business Administration and Financial Management*, processing of the 5th

International Conference on Applied Economics, Business and Development (AEBD '13) Chania, 2013, vol. 1

[10] G. Cennamo “The centrality of energy retrofitting in the historical city as a challenge for the immediate future. The role of the representation as instrument for control and evaluation of the processes of transformation; case study for a sustainable regeneration”, in *Recent Researches in Applied Economics and Management - Economic Aspects of Environment, Development, Tourism and Cultural Heritage*, processing of 5th International Conference on Applied Economics, Business Development (AEBD '13) Chania, 2013, vol. II

[11] A. Koiv, A. Mikola “Ventilating of Old Apartment Buildings”, in *Recent Advances in Energy and Enviroment Integratedd System*, processing of the 2nd International Conference on Integrated Systems and Management for Energy, Development, Environment and Health (ISMAEDEH '13), Morioka City, Iwate, Japan, 2013

[12] P. Mastny, Z. Mastna “Energy Systems for Modern Buildings” in *Environment, Ecosystems and Sustainable Development* (EEESD '13) proceedings of the 9th International Conference on Energy, Lemesos, Cyprus, 2013

Fig. 1, Example of axonometric cutaway on the digital survey processed by BIM

Fig. 2, survey point cloud, Domus Mercatorum in the city of Verona

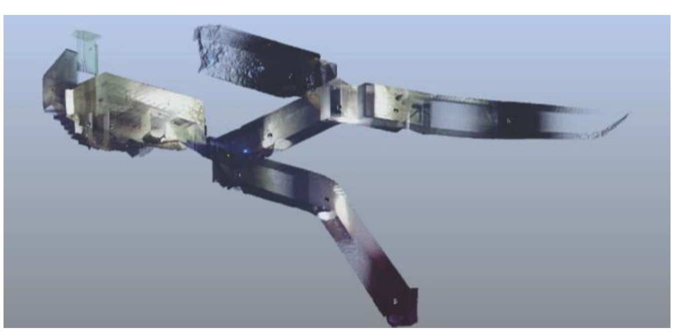

Fig. 3, survey point cloud of basement level, ex Arsenale Verona

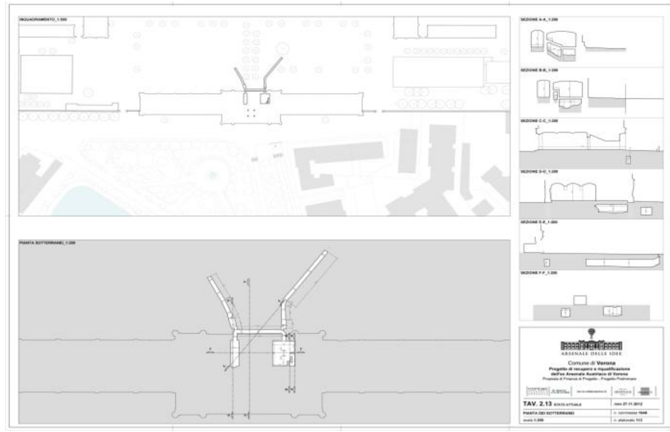

Fig. 4, survey of basement level, Ex Arsenale

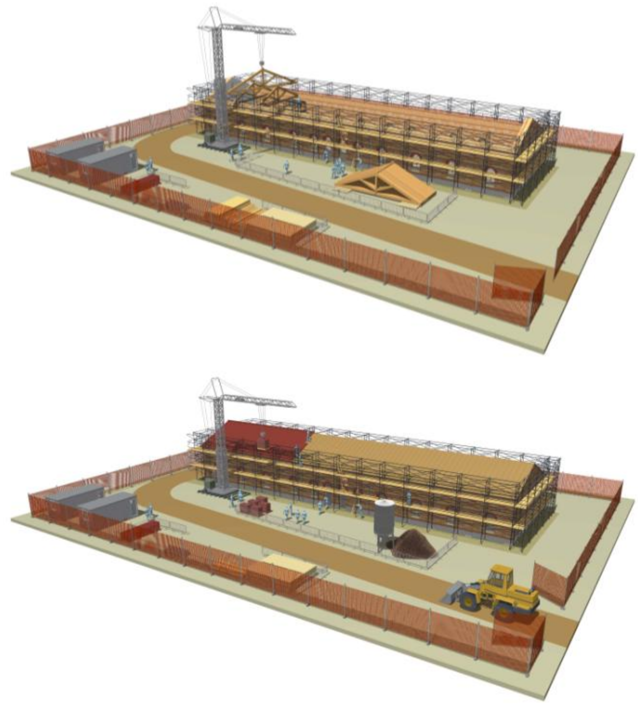

Fig. 5 (a, b), use the 3D model for worksite and planning. First phase: setting up of building site and surroundings, demolition, existing covering removal and new truss positioning. Second phase: conclusion of covering system installation, wall restoration, frameworks, inside works, plants and finishings, outside arrangements

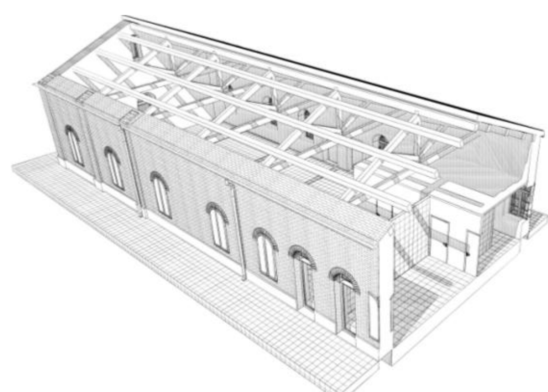

Fig. 6, modeling 3D of building test

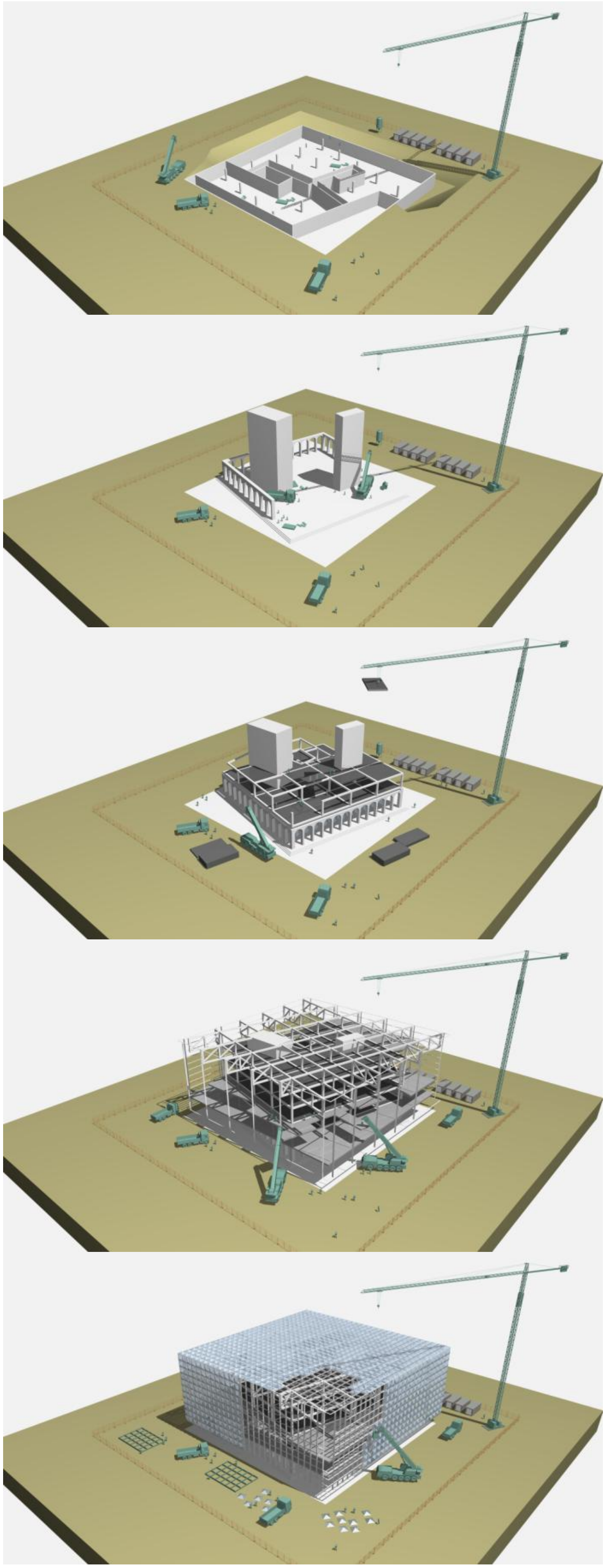

Fig. 7 (a, b, c, d, e) Building site, foundations and basements, structures of stiff units, prefabricate ground structures, covering steel structure, closeout structure

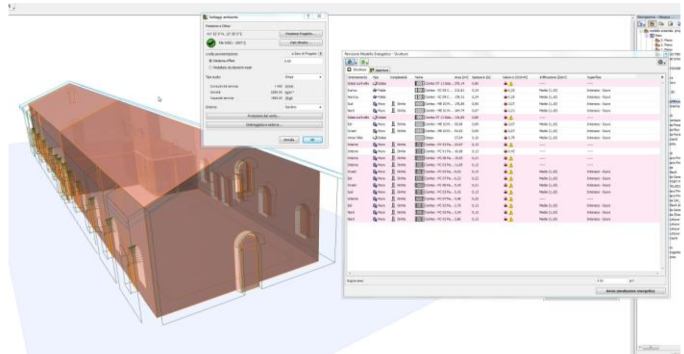

Fig. 8, use the 3D model for energy analysis

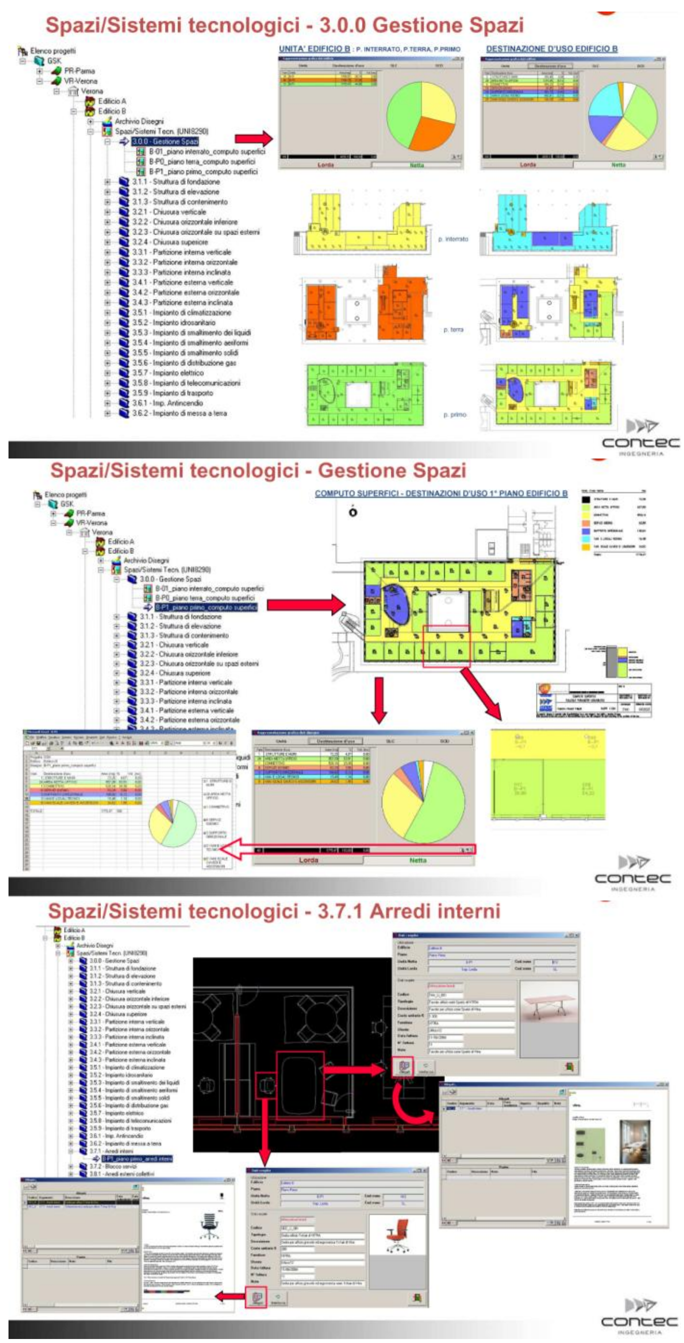

Fig. 9 (a, b, c) Spaces management, summary data extract of spaces usage/cost. Technical information plants management for mantainance purpose. Furniture and equipment management