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Representing and managing Real Estate: BIM for Facility Management

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Abstract This paper is intended to explore the potential of the *Building Information Modelling* (BIM) methodologies to be applied to the various stages of the construction process, particularly as far as international guidelines and *best practices* supporting virtuous operating flows are concerned: the IT component, mostly graphic during the design phase, is mainly integrated and renewed in an alphanumeric format, and becomes an integrating part of the management and maintenance of the artefacts. The case studies developed in collaboration with the Building and Logistics Service of the Polytechnic of Turin substantiate such procedures, which, even if they are not widely spread as of yet, reach interoperability targets: integrated approaches to information sharing processes aimed at defining adequate intervention schedules on both large and small scales, through the definition of strategies aimed at restricting the enforcement of incorrect solutions.

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INTRODUCTION

As far as the construction process is concerned, the standards of graphic and documental representation can be described through a cyclical assessment, verification and review method involving several professionals. In order to ensure an effective coordination of the information within the designing *team,* the data modification and implementation should be constantly performed, thus the data exchange among all project participants is correct and controlled. As is widely known, the three-dimensional models developed through the BIM (*Building Information Modelling*) technology[1] are based on unique and sharing IT standards, which can be managed through a complex and structured database archiving those data defining the architectural structure in its components: all information is parametric and intertwined through constraints and rules in order to guarantee its formal, constructive and relational consistency within the virtual model. The system also allows a thorough formal verification of the quality and coordination of the documents via tools and data performing sectorial analysis. The main goal of such a new work methodology is to obtain an overall representation of the artefact throughout the entire lifecycle: this is achieved by specifying size, quality, performance related information within the model as well as all its components. If the first traditional “assisted” design systems included the implementation of graphic works with information on the building performance through mere notes on static dimensional drawings, BIM systems include a higher amount of information, from performance sheets of building elements and materials to information on energy, technical aspects of the lighting system, sound system, physical and technical information, economics, etc.

If we leave aside the clear advantages in the creative and formal conception phases, this abstract defines a more recent and interesting field of application, that is, design interventions on the existing Real Estate, aimed at optimizing the procedures within the *Facility Management* sector,[2] where the relational database gathers information of different nature, deriving from significant operations where “uncertain” and “certain” data may coexist. As a consequence, we may have to redefine proper performance standards, in order to be necessarily differentiated according to the nature of the information itself: in this field of application there are currently no specific reference rules or bibliography defining the guidelines for the resolution of critical aspects introduced in the innovative process *workflow,* despite the fact that some international guidelines and directions deal with the correct scale/graphic and data content relationship associated to the all the designing phases.[3]

BIM systems currently allow to greatly benefit from wide range evaluations on the interventions that may be scheduled in public and private building assets, through the analysis of the relapses that such interventions may entail, not just from the construction point of view, but also as far as urban planning is concerned, that is, by monitoring resources and prefiguring design solutions including reliable preliminary evaluations. The potential of the system is expressed through its capacity to respond to

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[1] BIM is defined as the development, growth and analysis process of multidimensional and virtual models digitally generated through software applications. The most common information gathered in a BIM is the geographical location, geometry, material/component/system and technical element properties, execution phases, maintenance operations, end-of-cycle disposal.

[2] The international Facility Management Association defines Facility Management as “a business related discipline coordinating the physical working space with human resources and company’s activities. It integrates the principles of economic and financial management of a company, architecture, behavioural and engineering related disciplines”.

[3] For instance, the American *Veteran Affair Guide* published in 2010; the Finnish COBIM (*Common BIM Requirements*, 2012); the *CIC/Penn State* Guidelines (established by the *Computer Integrated Construction Research Program* of the Penn State University, 2011); the Guidelines defined by *USACE (U.S. Army Corps of Engineers*, 2010-2013).

complex queries, by providing with specific information related to all the suggested solutions. This way it turns into an irreplaceable operating tool for correct intervention planning, through the selection of suitable operating rules and the avoidance of incorrect solutions, whose negative impact is often shown just after huge financial investments have been made. In particular, it is widely agreed by the experts in the field that "[…] *the measurement of the business value of IT investment has been the subject of considerable debate within the normative literature. The difficulties in measuring benefits and costs are often the cause of uncertainty about expected benefits, particularly in the case of BIM. Thus, how then can an asset owner obtain business 'value' from investing in BIM? In addressing this issue a framework for obtaining value from an investment in BIM is proposed* […]"[4]. The combination and the coexistence of project, financial, technology and building, infrastructural, ecological and safeguard related issues forces the owners of large Real Estate to strictly check all activities, as well as carefully assess their compatibility with the constant urban transformations.

Such an intrinsic complexity forces to gather extremely detailed data and information, which, in the majority of the cases, are not or are just partially available. If we consider the management aspect as the key element for the correct preservation of an artefact, knowledge planning represents one of the key aspects from the methodological and conceptual point of view. The analysis of existing procedures leads to understand that the problem is normally dealt with by treating the graphic component of the descriptive/performance/maintenance work as a separate element. It is currently no longer possible to manage information in a sectorial way. A series of internationally spread approaches are detailed below, as well as analyses and trials conducted by a team of researchers of the Polytechnic of Turin in collaboration with the Building and Logistics Service of the Polytechnic of Turin,[5] in order to understand the processes to enforce such new Real Estate Management Systems.

RECENT TRENDS ON PUBLIC ASSET MANAGEMENT: THE FINNISH CASE

One of the most excellent examples of application of BIM systems to public asset management is the Finnish method set up by *Senate Properties,* a governmental institution managed by individuals with the support of the Finnish Ministry of Finance and Manager of the government tangible assets and venue rental. It was established on 3rd September of 1811 to supervise governmentally owned buildings, and it supplied services related to venue administration.

Since 2001, *Senate Properties* developed a decent number of pilot projects in order to adopt BIM in tangible asset management[6]. Based on this analysis, a model has been established to adopt and enforce BIM models on the construction of buildings managed by them: the company decided to

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[4] See. Love, P. E., Matthews J., Simpson I., Hill A., Olatunji O. A. (2014), *A benefits realization management building information modeling framework for asset owners.* Automation in Construction, 37, 1-10.

[5] The collaboration between the DISEG Department and the Building and Logistics Service of the Polytechnic of Turin dates back a few years ago: the management structure did not have the required expertise to undergo procedures consistent with the methodologies detailed in the memory. Thanks to the coordination between a group of Design researchers and the Service Manager, Architect G. Biscant, a close collaboration commenced. On one side it referred to theoretical and research knowledge, on the other, to the required research in order to assess advantages and disadvantaged of the BIM methodologies. On this matter, the writer, Engineer M. Vozzola and Engineer G. Cangialosi have been working on this double task since 2007, when the first project featuring BIM software began. In the first years Professor A. Osello was the Scientific Manager, and she still actively works on relating the Building side and the Information side by exploring several application scenarios, namely monitoring operations as well as the management of the existing Real Estate.

[6] Senate Properties currently manages over 10 thousand buildings, for a total of about 7 million square metres. Among the most important projects are the headquarters of the Ministry of Transport and Communication, the Mikael School, the Helsinki Music Hall and the Sami culture centre.

request the models in IFC format[7] from the 1st October 2007. The implementation of projects though parametric systems ensures that the overall price, as well as the feasibility of the project, meet the set requirements with greater security. In the first phase of the *Senate Properties* project, BIM models were requested for any type of intervention, including new construction work and recovery or renovation operations.

It is worth mentioning that the adoption of BIM methodologies in many foreign countries (Northern Europe and US among others), together with the tendering reform approved by the European Parliament (*European Union Public Procurement Directive*, EUPPD) indicates a growing demand for the use of BIM methodologies in designing operations in the public construction sector.

The adoption of such Directive implies that the twenty-eight EU members may encourage, request or enforce the use of BIM starting from 2016, as it will be shortly the case in England, the Netherlands, Denmark, Finland and Norway, where it is strongly required for publicly funded construction projects. This means that in the early future, not only will we have to hand in the paper format drawings, but also geo-referenced three-dimensional digital models, drawn in compliance with rules and conventions coming from professional practice. From such models several pieces of information may be deducted and used to set up the project validation process, with clear legal implications associated to the level of reliability of the model itself.[8] As far as the Italian Law on Public Works is concerned, the tendering Reform will be progressively enforced: the Environmental Commission of the Chamber of Deputies approved the delegated Draft and set the grounds to rewrite the public contract regulation.[9] The Decree will repeal those parts of the former Tendering Code (Law Decree n. 163/2006) not complying with European Directives and will introduce coordination dispositions. In particular, the actual new Tendering Code, to be approved by 31st July 2016, states that engineering and architecture services as well as all technical services must not be allocated based solely on price and cost criteria, but on the most beneficial offer from the economic point of view, in order to ensure more focus on project quality. In addition, projects shall be published online in order to evaluate all the offers and the use of BIM will be encouraged for the electronic simulation of construction related data. This means that even our country, which has been significantly idle compared to other EU members and overseas countries, is gradually adjusting to a new way of restructuring the entire supply chain of the construction industry. The distance between project and process is decreasing more and more over a short period of time.

During the phase of project planning, the added value will show in the decision-making process: the comparison of several architectural proposals will be based on the analysis of the costs and the benefit for the entire lifecycle of the artefact. In order to facilitate the cost review of the project and of the entire building, the quality of the data and metadata will be directly managed by the internal relational database of the BIM environment, through structured sheets including the data requested by *Senate Properties.* In addition, since the very first designing phases, great attention will be paid to the energy factor: the simulation of the building consumption will help the Institution make key decisions regarding sustainability. Then a further check of the building energy consumption will be performed when operational.

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[7] The "*Industry Foundation Classes*" (IFC) file format is standard, free and used to exchange data in the construction industry, in order to reduce data loss when moving files from one application to another.

[8] See *La rappresentazione tecnica convenzionale of* Lo Turco, M. (2015) *BIM and infographic representation in the construction process. A decade of research and applications,* Ariccia (RM), Aracne, pages 37-53.

[9] The Law Decree for the reception of Directives 2014/23/EU on concession agreements, 2014/24/Ue on tendering (repealing Directive 2004/18/EU) and 2014/25/EU on the proceedings for tendering of water, energy, transport and postal service suppliers (repealing Directive 2004/17/EU) shall be approved by the 18th April 2016.

The level of detail and development[10] of the BIM model required from 1st October 2007 is just the first step for a wider definition of such models.

Senate Properties, along with asset owners in the Northern countries, the US and the Netherlands are preparing more and more detailed systems for building modelling, mainly to support standardized management and maintenance procedures. The main peculiarity of this system lies in the fact that the models are developed in line with *BIM requirements*, and do not influence the project variables whatsoever, thus leaving total freedom of choice to professionals. This allows an overall control over the process, as well as the validation of the documentation and the direct responsibility of the Project Managers in case of mismatches between the requirements and the final project. The design process is developed and articulates in four hierarchically structured phases:

a. *Spatial group*, defining volumes and intervention areas;

b. *Spatial BIM,* establishing venues and their intended use;

Preliminary Building Element BIM, introducing the building envelope, the divisions and the features of the materials;

Building Element BIM, defining architectural elements.

Picture 1 Spatial representation of the intervention performed on the new University Language Centre (CLA in Italian) as per *Senate Properties BIM's requirement*. The infographics asset is growing clockwise. Developed by Engineer M. Vozzola

[10] BIM Information Exchanges protocols have been designed in association to the level of reliability and the purpose of the models in the BIM environment. They include the concept of LoD (*Level of Development*), that is, the informative content of a BIM model aimed at defining the amount and type of information that is actually required. The concept of LoD actually comes from the concept of *Level of Detail*, which was defined about 10 years ago by VICO Software to detail the accuracy of a certain project element. This mainly refers to cost calculation, whose concept is often misunderstood as it is often intended as the mere graphic Level of Detail that may be associated to different components.

The minimum informative content has been defined in each phase (*Minimum Modelling Requirement*)[11], and in the model of the artefact, it is represented by the data associated to the elements and particularly by the metadata of the architectural organism. These will be subject to checks and validation by the Commission. Once a phase has been validated, this becomes the starting point for the definition of the following phase and for the model implementation. *Senate Properties* can be considered a forerunner in the development of AEC/FM processes, hence stimulating shareholders to use effective methods aimed at improving construction quality. The current BIM requirements represent the first step to design, construction and maintenance coordinated approaches.

OPERATIONAL PROPOSALS: APPLICATION OF *SENATE PROPERTIES' BIM REQUIREMENTS* TO THE NEW UNIVERSITY LANGUAGE CENTRE OF THE POLYTECHNIC OF TURIN

This case study is one of the first experiments conducted by the previously nominated working group related to the Polytechnic of Turin. It is important to stress out that the first applications of the previously defined research contents date back 10 years ago and are an important piece of evidence to support the idea that the first interventions, although partial and perfectible, represented a useful point of reference for the adoption of skilled procedures, and contributed to the subsequent development of executive projects arranged exclusively through the BIM environment[12] and providing with a precious information "capital" to be used in further operations related to *Facility Management.*

Being a fundamental IT infrastructure and key tool for the arrangement of an apparatus of evaluation systems based on data capturing methodologies, simulation and analysis, the BIM system is equipped to gather and manage, in a dynamic and constantly updatable way, the data associated to the assets, to their functions and to maintenance requirements.

The historical headquarters of Corso Duca degli Abruzzi of the Polytechnic of Turin is a heterogeneous building complex which kept its original '50 structure: the invasion of spaces firstly devoted to courtyards, the upward extension of low buildings and the rationalization of the internal courtyard "empty spaces" are just some of the actions that were taken to satisfy an increasing number of students. In the last few years, the University took several actions in order to re-qualify some areas of the historical headquarters, some of which have been studied to test processes in the BIM environment, and to achieve the ambitious goal of defining a unique University model, constantly updated and searchable for information regarding areas, venues and interventions.

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[11] The definition of the *Minimum Modelling Requirement* detailed in the international *best practice* is the procedure defining the level of detail the models and its components should show at the different process stages.

[12] Some projects developed from the internal design structure of the BIM environment:
2009 Architectural and structural design of the multi-story underground car park at the polytechnic Cittadella: preliminary car park (operational cost about €20 million);
2010 Collaboration to the architectural design for the drawing of the Energy Center Preliminary Project, innovation hub devoted to energy and environmental related subjects (operational cost: about €15 million).
2011 Architectural design of the Executive Project of the Mollino Accommodation: participation in the Ministry call for tenders to allocate the funds (operational cost: about €7 million).
Architectural design of the Executive Project of the Codegone Accommodation. Ministry call for tenders arranged to allocate the funds (operational cost: about €11 million).
2012 Handing over of the Executive Project for the reconversion of the Former Thermal Power Station into Classrooms (operational cost: about €2 million).
2014 Construction plan and system plan coordination for the restructuring of the 5th floor of the Lingotto building (operational cost: about €1 million).

Data integration allowed the definition of the model from a city planning scale. This is represented exclusively by building volumes as well as gross floor areas of the building internal levels. Each volume is associated to the alphanumeric metadata summarized below:
a) the name of the building, following the classification used by the Building Services throughout the year, to facilitate communications and uniquely identify building wings;
b) the intended use of the artefacts;
c) the construction timeframe, in order to identify the construction period, and identify several time phases.
The model can be questioned following a multi-criteria analysis, and through graphic or chart representations of the results: this is very useful, for instance, to purely fulfil management related purposes, extract areas in a table format and the intended use of the premises through theme-based tables. The following step is the creation of the architectural model of the areas undergoing requalification and restructuring interventions: the master plan on an urban planning scale also includes the information to enrich the urban model, whereas a general database is kept to archive the University data as a whole. The implementation took place and is taking place stage by stage, in different timeframes and starting from the volumes to which architectural data are associated. The University Language Centre (CLA in Italian) project has been set up in compliance with the Finnish guidelines, in order to prove that, at the state of the art, all models developed in a BIM environment meet all the previously detailed requirements, hence they satisfy all four validation levels.
The parameters associated to the element features sheets have been arranged as follows:
a) size parameters;
b) time parameters, in order to define all the phases of the project intervention;
c) technology and materials selected for compound systems, construction elements and associated techniques for future ordinary and extraordinary maintenance operations;
d) identification code, *i.e.* the acronym found in the Price List of the Piedmont region;
e) price for the development of the maximum metric calculation in the BIM environment;
f) specific references to the Maintenance Plan.
From the analysis of the above and the results obtained in the last few years of research, it is possible to evaluate the huge benefits of data representation and communication in the construction process. The acquired importance of the design switches from the “mere” representation of the architectural project to the management of the entire lifecycle of the analysed architectural organism. This is no longer put in place through a sequential and fragmented approach, but rather through the dynamic use of the models generated within BIM environments, as they are capable to set up communication networks along with the parties involved in the construction process via new interoperable communication standards.
To this purpose, the use of the most efficient systems for the coordination of the complexity of the construction process has been catching the attention of the scientific community for several years. This leads to the definition of methodologies and techniques for project planning and control that are typical of the industrial, mechanical and manufacturing design.
Two operational strategies have been identified for the correct management of the product throughout its lifecycle, both complementary to each other: The first one involves sharing the relational database of the BIM tool through specific software aimed at rationalizing management related operations.[13] The second and even more flexible approach allows control and implementation of the alphanumeric

[13] CAFM, acronym of *Computer Aided Facility Management*.

information directly *on site*, hence reducing technical back office time and populating the parametric database with new and more specific information, following asynchronous and multi-directional writing processes.

THE MANAGEMENT OF PUBLIC PREMISES THROUGH CAFM APPLICATIONS

Nowadays the majority of public and private companies have a complex internal organization: this is due to the growing number of processes of market adjustments performed to offer the best competitive responses.

In the previous paragraphs there has always been an explicit reference to the term "process" holding a wider meaning than the term "project", as it includes several activities that continue after the construction. Many of these processes do not represent the core business of a company, they are rather part of those ancillary activities (*no core*) allowing the company to work in a proper way. This does not mean these are secondary or less useful activities; it is often quite the opposite, as from their operation depends good organization, the employees' performance as well as resource saving. The management of the activity relates precisely to *Facility Management*, which represents a multi-discipline integrated and coordinated design, programming, planning and management approach of all services in order to support strategic activities, the *core,* and necessary to the operation of the whole structure.[14] An ideal management of the macro and micro activities in the FM industry should not disregard the use of technologically advanced systems as well as the application of innovating concepts.[15]

Facility activities are mainly aimed at three company aspects associated to each other: people, spaces and the building; within each of them, several activities take place, and are managed by FM operations, such as space and staff management, maintenance, surveillance, the canteen service, etc.

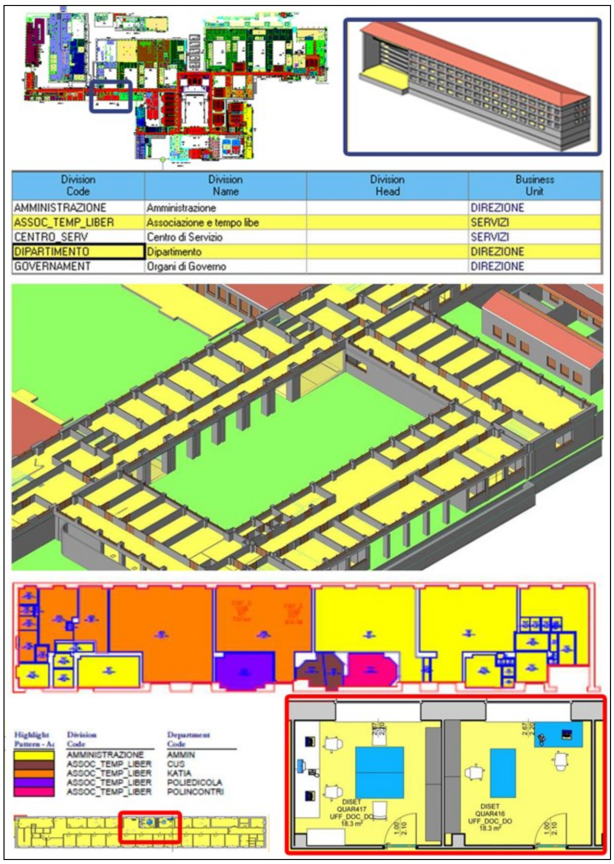
There are two strategies of activation: the first one involves the externalization of ancillary activities to other companies; the second one includes the arrangement of a functional division within the company itself. The Polytechnic of Turin opted for the second strategy, and arranged an area for the integration of processes and IT systems (IPSI) by following the directives of the Directorate Board. The IPSI area already set up the FM project of the Polytechnic in autumn 2009. The project is intended to optimize the management of the University internal processes, by making available an IT system containing the data of all the activities. This way a database is created as a point of reference to obtain information and set up further analysis. The existence of such an IT system not only allows internal data management but also helps to set up and manage actual work proceedings. As it happens in other cases, the University includes several areas dealing with multiple activities linked to the academic world, (and not only that!) such as didactics, constructions, logistics, accountancy, etc. A meticulous research for software to provide with valuable assistance in the management of the involved sectors has been conducted: the software chosen was included in the CAFM group, a series of IT products simplifying the access to complex information, linked to the company *assets* through an integrated system of alphanumeric and graphic database, in order to ensure virtuous processes. This type of products is precisely intended to help manage large data flows, otherwise very difficult to process.

[14] See Lo Turco M., Vozzola M., Dalmasso D., *Il BIM per la gestione del patrimonio immobiliare* in: Garzino G. (by) (2011), *Disegno (e) in_formazione. Disegno Politecnico*, Santarcangelo di Romagna (RN) Maggioli Editions, pages 225-249.

[15] Dalmasso D., *L'interoperabilità per il FM*, in: Osello A. (by) (2015), *Buiding Information Modelling, Geographic Information System, Augmented Reality per il Facility Management,* Palermo Dario Flaccovio Editions, pages 155-170.

Such a technology is also associated to the use of BIM software and allows to be connected to it as well as to exchange information in an interoperable way. For instance, the strong links many specificities of a company have with the space they are executed, e.g. in premises or staff management. In this case, it is easy to understand how management software must be able to interact with parametric software as well as to operate through charts and graphs.[16]

In this case, the software is made of modules, each of them aimed at storing and managing data associated to a specific company aspect, such as goods care and inventory, staff administration and S*pace Management.* Each module is an independent unit, and includes all charts that may be associated to the database, allowing the *Facility Manager* to perform his/her duty. It is worth mentioning that such tools do not prevent professionals from making decisions, but are exclusively aimed at extracting information and performing multi-criteria analysis.



Picture 2 Different views of a parametric model to be used for *Facility Management* operations
Developed by Engineer D. Dalmasso

[16] The definition of the group of IT attributes associated to technical and spatial element is backed up by the analysis of the existing information exchange protocols, such as the "*Operation and maintenance"* COBieDrop standard, specific for the management and maintenance phase. As far as the codification of technical elements is concerned the UNI 8290:1981 Regulation applies: *Residential Constructions – Technological system – Classification and terminology.*

Such a procedure solves the problem of updating numeric data of a database in a short time, as shown through a comparison deductions from the survey campaign and uploads in the relational tables. The example that best shows such an operation is certainly the update of the employees' workstations in the correspondent offices: given the frequent staff relocation, as well as the department redistribution, the update of the previous IT system had failed, and, in some cases, there were discrepancies between the system information and reality.
At the end of the implementation operations the first reports were drawn up on the functional merging of the uploaded data, including information on the premises and the employees, with the correspondent photographs. As soon as the survey campaign continued, the model has been integrated with other ancillary elements, such as plants and furnishings. The potential of the parametric software in use is very high and the amount of elements that may be included in the model is virtually infinite: to this purpose a devoted section is needed for a more in depth analysis.
As far as the FM project is concerned, the virtual basic model is currently replacing the traditional CAD drawings. The change is anything but trivial; it rather represents an actual quantum leap, forcing the entire Construction and Logistic section of the Polytechnic of Turin to adopt the BIM methodology in a more structured way. Such a change will encourage a higher integration between parametric software and FM applications; hence all analyses may be carried out on related databases. This will guarantee a higher control on processes and, in time, complete data interoperability.

INNOVATING APPROACHES: FROM BUILDING SITE MANAGEMENT TO FACILITY MANAGEMENT

The transition from an academic based knowledge system to a construction based knowledge system may represent a discriminatory element when it comes to establishing effective data and information flows, which should be correct and transparent, supported and guided by graphic language as well as complying with standards and reference technical regulations.
Testing management methodologies for the control of work progress involve more and more construction companies, including small sized ones, as they have to beat a "good craft level" in order to compete in more demanding markets, due to constant changes in the industry. The common goal to define methods to rule such an objective complexity suggested that construction site design shapes, because of their double analytical and brief nature, may actively compete to create relationships, comparisons, verifications and choices that, if consolidated, must be imagined as a flexible and time reliable IT system, which is implementable and dynamic, as well as capable of supporting fast and adequate decisions.
As shown below, those methodological and operational systems tending to be updated by digital mediation lead to wider targets, and devote resources (in a more and more strict way) to the production, management and lifecycle of the artefacts, even when their functions have been fulfilled.
In order for the data gathered through Management performed control and orientation activities (*Project Manager*, Site Managers, Operation Managers, Safety Coordinators during engineering work, *Facility Management*, etc.) to become useful information in the decision making process (i.e. when provided with an appropriate level of detail and promptly) their organization shall be mostly dealt with by automatic processing systems. They shall integrate the geometric components of the project with the associated alphanumeric system.
The possibility of easily question the database gathered on site, and produce short and comprehensive work progress *reports* may be a discriminatory element to wisely re-use the information and relate it to

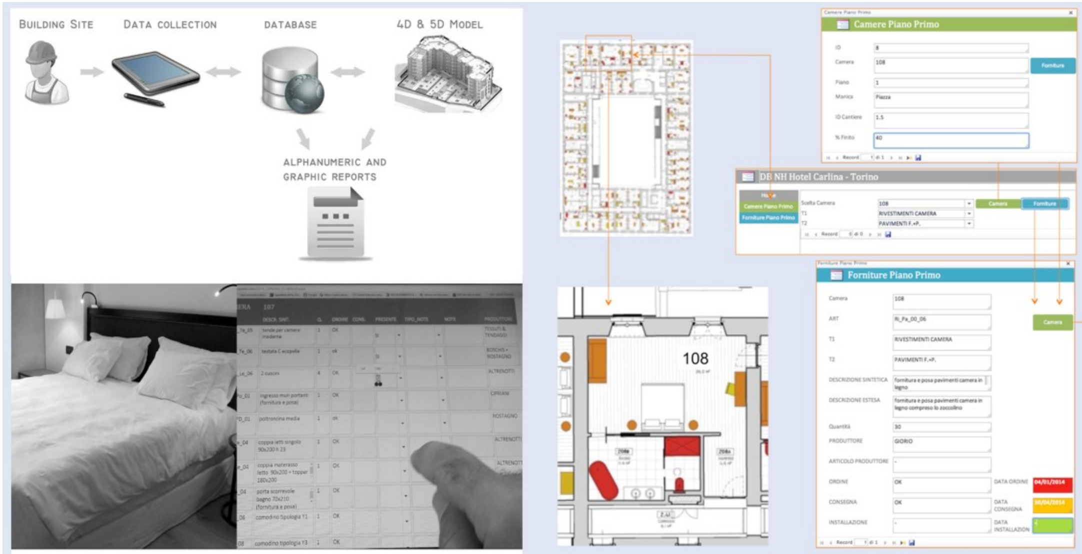
maintenance plans and files, as well as to ensure good communication and transparency to the clients and to all roles involved in the construction process.
A second type of approach is preferred in the most complex intervention cases on existing assets, in which a way to control and compare *As-Built* (when available) and *As-Is* is required. This differs from CAFM applications, and tends to maximize efficiency and effectiveness in the survey phase.
In bibliographies, either project, site or management data can be interpreted as the result of several components: an alphanumeric component, associated to quantity and quality information, a graphic component, associated to geometric features of the vector model, a topological component, associated to the relationships between data; the meta documentation system is equally important, especially in order to re-use data. This refers to a component of the data itself, which describes and qualifies it in terms of skill, precision, timely updating and reliability.
In order to ensure the effectiveness of the operational aspects of maintenance, nowadays we are trying to organically concentrate such components in a cluster of alphanumeric models, both three-dimensional and parametric, designed through methodologies connected to IT construction systems (BIM technologies) as well as management systems of relational databases (*Database Management System*, DBMS). This way, the geometric/dimensional information is stored and processed along with regulatory, performance, estimation, material and management related information. In order to turn into the hub of the IT Management System, the project database shall be enriched with further elements to keep track of their own activities, possible variants and the expected performance throughout time.
The act of moulding the artefact for the site use should be “simplified”, as it should be “strictly designed for control and orientation activities”, in order to show solely the main information subject to supervision. In order to manage all technological systems required as well as their correspondent associated parameters we no longer have to consider specific data of previous design phases, thus faithfully “stimulating” good building practices.
The integration of BIM/DBMS technologies with *mobile* applications may lead the construction process to *cloud based* management systems, in which the information of one project are made available anytime and anywhere, and directed to specific applications for *Field Management.*
The goal is to improve the efficiency of the process through adequate IT tools allowing the generation of a circular flow firstly supporting the control and management of the work, and later of activities and spaces. This feeds the database and decreases repetitions, redundant elements and manual transcriptions by the involved professionals.
If we think of the amount of project data represented by numbers and letters (alphanumeric component of the project) of a BIM environment, schedules are defined as project views listing all the elements of the geometric model as well as their descriptions: objects, materials, areas, volumes, etc. The schedules behave the same way as graphical views: every change made to the schedule mirrors in the model, hence to all the other views and vice versa.
The arrangement of an IT architecture that relates BIM to DBMS IT technologies is likely to require skills and resources for that particular purpose as well as investments in hardware and software products. The commitment (time and money) required for the arrangement of the “project model” may also be applied to all subsequent operations throughout the implementation and the useful lifecycle of the designed work. The geometric and alphanumeric database represents then a privileged information storage space to control and guide site operations, and subsequently, the artefact maintenance. Such a complex *repository* may also be used by users not specifically trained in information geometric modelling. In other words, the project model, when properly generalized, also includes parameters associated to site operations and maintenance, following a consistent date gathering and updating

process, aimed at better controlling the material supply, the progress and timeline of the work and the associated financial flow. This also involves those people in charge of site management and artefact management who do not have to necessarily “work on” the geometric model. If compared with software solutions, the new suggested procedure does not require users to be trained in the BIM environment, and, if compared to the majority of mobile applications, it may be used *online* and *offline* by writing numbers and letters directly from the site area, in a coexisting way, that is, directly on the BIM model.
The possibilities of feeding such archives from virtual stations set up online (web applications) opened new possibilities of on-site controlling, hence considerably reducing boring data re-editing times typical of *back office* tasks. The most efficient way in IT terms (although it is subject to the availability of performing network infrastructures), is to arrange a software system to support the interoperability between several computers on the same network, that is, within a distributed context. Such a feature is obtained by associating a software interface to the application, for the associated service to be externally displayed.
Generally speaking, the construction IT system for control activities must comply with the following:

- be reachable and updatable, including when offline;
- track logins and people operating on data gathering and their modifications, as well as diversify the options for each user;
- guarantee the database integrity and durability;
- reduce the possibility of doubling the operation of data load;
- Allow report processing in a more linear and consequential way than data flow, with no further modifications (*templates* for *reports* and *layouts*).[17]

From the user’s point of view, and as shown in the schedules, the structure of the DBMS is represented by a series of charts where each line represents a homogeneous element (instances) included in the class/whole (component) and the columns are the attributes describing such elements. The indexation of the elements via a code (generally called primary key) makes it possible to identify and relate each element to other elements of the same class or of different classes, following a relation that may either be one to one or one to many, according to the case, and vice versa.

[17] The carried out experience made use of specific tools, both widespread in a professional environment and owned by the clients themselves (see case study below):
- the Autodesk Revit software has been used in BIM environment;
- BMS Microsoft Access has been used as a relational database;
- dynamic writing languages for the interaction with web applications (asp, php and xml).



Picture 3 Workflow for data registration on site and control of several *Facility Management* operations: management of the furnishings of former Albergo di Virtù. INNOVance research project (http://innovance.dd.agoramed.it/, consulted on 02.11.2015). Courtesy of Architect F. De Giuli

In the database charts, the information is represented in a simple and homogeneous way. This considerably facilitates certain procedures, such as updating and removing redundant elements, controlling and identifying inconsistent elements, connecting to other data, producing greatly aggregated short reports.

Despite the mathematical economy and simplicity features of a relational data model, the majority of professional engineers and architects believe this is unrelated to the project. On the other hand, it represents a conceptual reference picture, which is very useful for the design process: relational databases, including the geometric ones, when associated to BIM systems, may become extremely efficient and productive tools.

In the construction process, nothing is more important than the definition and the discovery of the spatial and chronological relationships between the different parts of the work.

The arranged computerized architecture includes several users' profiles, which may be classified based on several levels of knowledge of the applications in use:

- basic users: exclusive access to the database for data consultation, update and integration;
- average user: on site update and control of the consistency between the project and its execution (photographic survey, comments, measurements carried out on 2D drawings taken from the model and in the building);
- advanced user: updating and checking consistency between *As-Built* and *As-Is* (photographic survey, comments, measurements carried out on 2D drawings or on portions of the navigable three-dimensional model).

CONCLUSIONS

A set IT system is able to convey knowledge and awareness of the project and process (material, construction components, processing, operational functional areas and spaces) and allow the production of their specialization, which is consistent and physically begins in the construction site itself, in a transparent and circular way, with no procedural repetitions and following a virtuous flow. It either starts from general surveys, or by allowing detailed analysis to be associated to the single components.

A strong point of such a process is the application of technology and information that is already been used by the Project Management (BIM and web), and the reduction of the need for additional and expensive software packages. The current commercial applications on the market already manage the construction site data and documentation; however, nowadays this is the main reason behind the need for a data functional management system to implement the construction site model. They do not allow a bi-directional flow towards the BIM system; hence they may achieve homogeneous data management within it through interoperability and graphic representation tools typical of the construction industry IT technology. From the IT system to the BIM system, the carried out simulation highlights a consistent data flow in the construction site associated to the future *Facilities* for a more agile *back office* processing with no gaps or omissions.

The operational development may be represented by the possibility of including the three-dimensional geometric component in the web application (as in a sort of construction site videogame), hence specifically improving the graphic interface for data entering (greater convenience and speed in data entering), by linking this component to the georeference of the positioning of the field detector allowing the peripheral device to correctly locate the information.

The integration of several technologies, being interoperable by nature, is a strong point as it can involve multiple parties in the construction industry, as well as from the artefact management point of view.

The suggested flow structure includes the use of two “tested” and widely used technologies (perhaps not so much in case of BIM database management, but it certainly works in the case of the database dynamic writing starting from *web service*), however they are rarely integrated with each other. This is the innovating side of the methodological proposal for the detailed simulations: to rewrite part of the model, including with no proper BIM associated tools (*i.e.* to act on the alphanumeric component of the project) as well as from virtual sharing stations (on the site, in operating centres, etc.) certainly opens the construction process not only to those skills that are normally dealt with by control and orientation teams, who do not necessarily have to operate on the geometric model, except for extracting measurements or topological relations.

At the end of the project, and based on the actual survey, a BIM model may be set up, to be updated accordingly and to be used in the management of the artefact throughout its next useful lifecycle (manual and dynamics maintenance).

The same methodological approach may be applied on a larger scale to the definition of three-dimensional models of entire urban districts. This can be used to plan more effectively interventions and to manage maintenance, consumption and energy production monitoring and control in the district with variable granularity, that is, scalable from the district level to the level of a single space of a building.

References

Eastman C., Liston K., Sacks R., Techolz P. (2008), *BIM Handbook: A guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractor,* Hardcover.

AA.VV. (2014), *Il processo edilizio supportato dal BIMM: l'approccio INNOVance - BIMM enabled construction processes: the INNOVance approach.* In: ISTeA, Bari 10-11 luglio 2014, pp. 91-109.

Ciribini A. (2013), *L'information Modeling e il settore delle costruzioni: IIM e BIM*, Santarcangelo di Romagna (RN), Maggioli Editore.

Garzino G. (a cura di) (2011), *Disegno (e) in_formazione. Disegno Politecnico*, Santarcangelo di Romagna (RN), Maggioli Editore.

Hardin B. (2009), *BIM and Construction Management, proven tools, methods and workflows*, Indianapolis, Indiana. SYBEX and Wiley Publishing Inc.

Lo Turco M. (2015), *Il BIM e la rappresentazione infografica nel processo edilizio. Dieci anni di ricerche e applicazioni - BIM and infographic representation in the construction process. A decade of research and applications,* Ariccia (RM), Aracne.

Osello A. (a cura di) (2015), *Buiding Information Modelling, Gegraphic Information System, Augmented Reality per il Facility Management,* Palermo Dario Flaccovio Editore.

Love P. E., Matthews J., Simpson I., Hill A., Olatunji O. A. (2014), *A benefits realization management building information modeling framework for asset owners*. Automation in Construction.

Volk R., Stengel J., Schultmann F. (2014), *Building Information Modeling (BIM) for existing buildings—Literature review and future needs- Automation in Construction*, Elsevier.

Ghosh A., Chasey A. D. & Mergenschroer M. (2015), *Building Information Modeling for Facilities Management: Current practices and future prospects.* Building Information Modeling. Applications and practices, American Society of Civil Engineers.

Yalcinkaya M. & Singh V. (2014), *Building Information Modeling (BIM) for Facilities Management–Literature Review and Future Needs. In Product Lifecycle Management for a Global Market*, Springer Berlin Heidelberg.

International rules and protocols:

BS/PAS 1192-2/2013, *Specification for information management for the capital/delivery phase of construction projects using building information modelling*.

AEC (UK) BIM Protocol V2.0, 2012.

BIM Project Execution Planning Guide – V2.1, Pennsylvania State University, 2011.

COBie Data Drops, UK Cabinet Office, 2012.

Common BIM Requirements 2012 Volumes 1-12, COBIM V1.0 Finland, 2012.

CSI Uniformat 2010, CSI and Construction Specifications Canada, 2010.

Level of Development Specification 2013, BIM Forum, 2013.

Project Building Information Modeling Protocol Form, American Institute of Architects, AIA Document G202™– 2013, 2013.