ITALIAN SOCIETY OF SCIENCE, TECHNOLOGY
ENGINEERING OF ARCHITECTURE

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RETHINKING
THE DIGITAL CONSTRUCTION INDUSTRY

A cura di

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MAGGIOLI EDITORE

ISBN 978-88-916-1807-8

Maggioli Editore è un marchio di Maggioli S.p.A.
Azienda con sistema qualità certificato ISO 9001:2008
47822 Santarcangelo di Romagna (RN) • Via del Carpino, 8
Tel. 0541/628111 • Fax 0541/622595

www.maggiolieditore.it
e-mail: clienti.editore@maggioli.it

Il catalogo completo è disponibile su www.maggioli.it area università

Finito di stampare nel mese di giugno 2016 nello stabilimento Maggioli S.p.A
Santarcangelo di Romagna (RN)

INDICE

"Integration of BIM-GIS systems for energy-efficient hospital buildings. The Streamer research and the case study of the Careggi Polyclinic (Florence)."

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Building Information Management, Energy, Sustainability, Life Cycle Management

Abstract

STREAMER is a research funded under the 7th Framework Programme, aimed at achieving "Energy-efficient Buildings (EeB)" integrated in healthcare districts. The scope of the research project at issue is to define and develop integrated technologies applicable to Computer Aided Facility systems through the combination of BIM and GIS systems to achieve semantic models for optimising the design and management of hospital buildings, in order to reduce the energy needs of the same throughout their entire lifecycle.
The research involves 20 partners coming from different sectors (university, industry, design engineering and construction). The Careggi University Hospital (AOUC), given its particular territorial and building characteristics, the energy systems involved and the computer-aided methodology implied in the management of structural/systems/organizational assets, was chosen as a case study for assessing the final feedback for the expected outcomes during the demonstration and validation phases. In the first place, a modeling methodology for the territorial ambits of the case studies was defined, with the assessment of the levels of detail and methods of representation of the transport network systems and types of energetic distribution connections. The BIM models for the pavilions were created based on such territory models by classifying the destination of use of each facility according to function, activity, type of equipment and end-users, and assessing possible inconsistencies that could arise during the modeling phases of the BIM and GIS supports, as well as the interoperability of the energy simulation tools required for the successive phase relative to environmental data analysis. The analysis of the physical characteristics of the facilities and spatial layout led to the creation of a set of Key Performance Indicators, necessary for assessing possible specific design choices and identifying several types of semantics-driven design methods to aid design choices defined, in large part, for the preliminary phase of the project.

1. Introduction

In 2015, Community Healthcare Expenditure compared to GDP amounted to around 10%, thus showing a growing trend which, as pointed out in the budget report for the year 2015, is likely to lead to financial instability that may be difficult for both individual communities and the entire EU welfare system to endure. If, on the one side, over 15,000 hospital buildings present in 27 member states represent a resource that is able to meet the growing demand for welfare services, on the other side, their conditions in terms of structure, systems and technology need to be reconsidered as regards design and management in order to rationalise the relative cost. As for Italy, the annual expenditure on building and systems maintenance within the ambit of healthcare property assets amounts to around 2 billion euros, besides 1.3 billion euros for electricity and thermal consumption (Agenas 2015). Within such framework, the European Union promoted and funded a set of research activities with the aim of significantly reducing, by up to 30-50%, energy consumption and carbon emissions produced by "building systems". In this respect, hospital buildings play a key role as they use 2.5 times more energy than an office in average. It is clear that such an ambitious project can only be realised by reconsidering all the lifecycle phases of the building, that is, the entire process from inception (design phase) to completion and/or retrofitting, utilization and management up to its demolition/alienation. Within such context, approaching the whole process by means of Building Information Modeling (BIM) becomes strategic in that it represents an aiding tool for managing information, as well as the design, simulation and analysis of solutions that can contribute to achieve high energy efficiency levels. The 2016 report of the European Portal for Energy Efficiency in Buildings reveals that 10 out of 160 projects funded by the European Community (within the 7th Framework Programme and Horizon 2020) are specifically focused on the implementation of BIM systems.

2. The Streamer research

STREAMER is a research project co-funded by the European Union under the theme of "Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems" of the 7th Framework Programme. The project, which commenced in September 2013 and has a four year duration, sees the involvement of 19 partners (5 large companies, 6 small / medium enterprises, 4 research institutes, 3 public hospitals and 1 private hospital) from 9 countries across the EU. The ultimate scope of the research is to reduce the energy use and carbon emissions of large healthcare districts, for which new build or retrofitting of existing buildings integrated into the same is envisaged. The research project is focused on two main innovation areas: technology and design. Technological innovation tackles energy efficiency through the typological optimization of the building-district, by analysing the spatial layout integrated in the technological equipment. The semantics-design innovation deals with energy efficiency issues and applies to methods and tools that are useful in encouraging collaboration among all the players involved in the process. The achievement of such dual objective is made possible through the creation of state-of-the-art design tools pertaining to Computer Aided Facility Management, with the combination of BIM and GIS (Geographic Information System) systems that are able to orientate and aid decision - making by players involved in both the project and the management of large healthcare districts. Such tools, through interoperable data, integrate information related to functional aspects (mainly referred to the spatial layout and the building envelope), systems (mainly referred to water, thermal, electrical and air treatment systems), besides aspects related to the context, that is, the optimisation of the correlation between the energy system of the individual building and that of the district. From an operational standpoint, the research unfolds in 4 progressive steps, namely: A) Conceptualisation B) Configuration; C) Optimisation; D) Generalisation. The collaborative work proceeded in 10 Work-Packages (WP), including 6 Research and Technological Development (RTD) work packages. The 4 healthcare organizations (France, The Netherlands, Great Britain and Italy with the AOUC were chosen as case studies for assessing the expected outcomes.

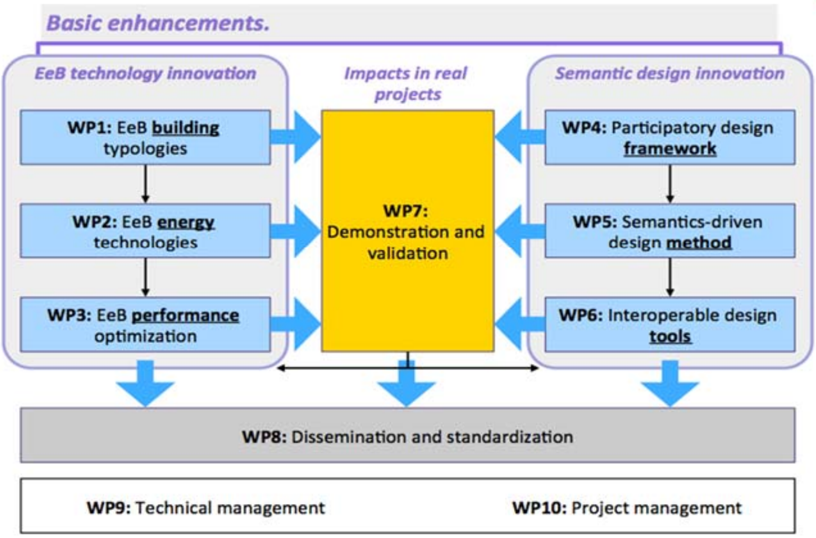

Fig1: Organization of Streamer research (Work-Packages). Source: http://www.streamer-project.eu

3. Careggi as a case study

The Careggi University Hospital (A.O.U.C.) covers a total surface area of 74 hectares, and is comprised of 52 buildings for a total surface area of 256.000 m2. Since 2000, the organization has been carrying out requalification works on most part of its property assets. The programme, which is currently under completion, relates to both renovation works and the realisation of infrastructure systems, such as the network for technological - systems connections and the construction of the new tri-generation plant, which supplies steam heat and electric power to the polyclinic. Of all 52 buildings, 32 have specific healthcare and/or didactic functions and include 44 operator units, with a capacity of 1,800 beds serving around 80,000 patients. The annual admissions to the Emergency Department amount to over 130,000, with 11,000,000 outpatient visits. From an organizational standpoint, the district is divided into integrated activities departments (DAI), sub-divided in organizational systems (SOD), grouped together, in turn, in homogenous activities areas (AA). Within such scenario, the research group chose to use the oncology campus of the Careggi hospital for validating the research outcomes. The choice was based on the future interventions that are to be carried out on the structural assets of the healthcare district, while taking into account the typological/construction characteristics of the buildings and their technological and organizational complexity. The campus includes a complex composed of three buildings located at the heart of the district and adjacent to the new tri-generation plant. The three buildings (Vecchio and Nuovo San Luca and Volano Sanitario), built in different periods, with models of spatial articulation that differ from one another, are divided into 1349 facilities that cover a total surface area of 23,280 m2, with a capacity of 228 beds and 7 surgery rooms. 8 DAI divided in 23 different SOD are active within the campus.

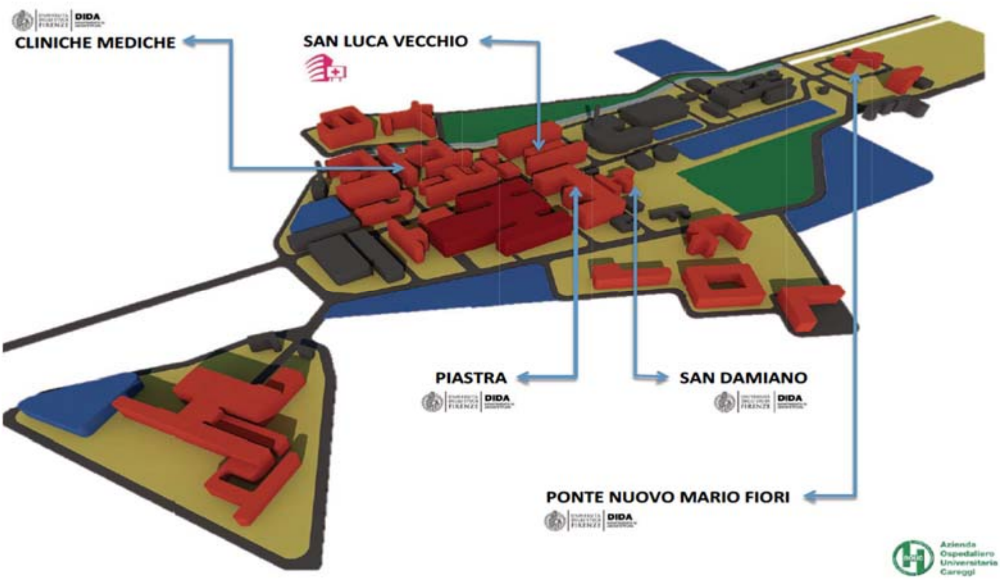

Fig2: AOUC area - identification of the 3 buildings of the San Luca oncological campus and the pavilions where experiments for realizing the BIM models are currently in development. Source:LabMon - DiDA

The Healthcare District Management, in light of the obsolescence and inefficiency both in terms of functionality and performance, of the old San Luca structure, had to decide whether to demolish and rebuild it or renovate it altogether. Thus, Streamer can be used for testing tools destined for aiding design choices declined according to energy efficiency criteria. In this respect, such criteria need to take into account three main data clusters described below:

- LAY-OUT: data related to the destination of use of the various rooms: number of beds, frequency of occupation of the same rooms (e.g.: day hospital, long stay, hospital stay only on weekdays, etc.
- ENVELOPE: data related to the stratigraphy of the walls that constitute the outer envelope, as well as the stratigraphy of transparent elements and that of floors and coverings.
- MEP: data regarding the type of heating and cooling systems, assessment of the type and characteristics of the terminals and the area where the systems are installed, and also, the type of central heating and cooling plants, cogeneration groups and any other device that could affect the building's energy model.

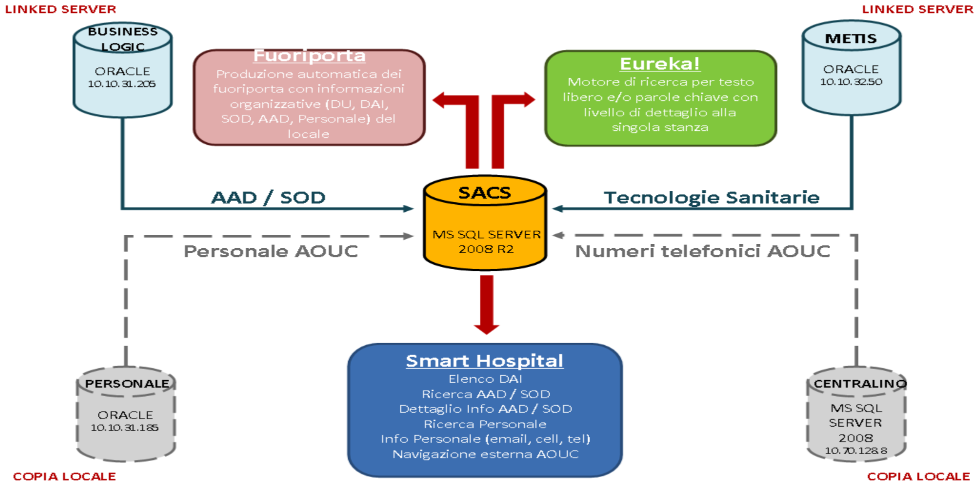

Fig3: Correlation between the SACS central and the organization's databases, including the list of applications currently managed by the system. (Source: LabMON: DiINFO)

4. Data collection method

The hospital is a paradigmatic condition where the project phases up to the final realization follow one another without solution of continuity. The recurring modifications following technological and systems integrations turn the hospital facility into a fluid space that inevitably becomes the object of complex design choices, that is, of evaluations that must take into account not only the impact of a single intervention but also the impact on the overall system of reference. (Del Nord 1998). Having affirmed that the correlation and interoperability of information is the core issue of the research project, the group pertaining to AOUC, flanked by the

University of Florence (in particular, the Careggi monitoring lab comprised of architects, biomedical and computer engineers), contributed to realize and test the modeling of the BIM and GIS systems, ..tools to enable stakeholders to manage and use big quantities of different kind of data in order to intuitively understand the characteristics of the energy performance (Ostello 2014). Such modeling was defined with the aim to assess (on the basis of the case study) the system's potentialities and identify which existing data could be recovered and used for expanding the model to the entire territorial scale of the polyclinic. In this sense, the design approach was taken according to procedures ascribable to the Facility Management aimed at defining proper standards for information representation and management (Lo Turco 2015), necessary for both the computer simulation models (MLS) related to the project and the interoperability of the data management system already in use within the organization.

As mentioned earlier, Careggi is equipped with a System for the Analysis of Structural Assets (S.A.C.S.©). Such system manages a set of information related to all the 52 buildings of the polyclinic through a dynamic publication that can be consulted online. S.A.C.S. © is a custom system that controls cartographies in DWG format, whereas the software feeds a Data Base (DB) which, by using polyline metadata as a system for the classification of information, provides, for each space, an information package regarding STRUCTURE, ORGANIZATION AND SYSTEMS. The records relative to each space are managed as homogenous families and can be grouped together based on correlation requirements. The system, by crossing the ambient codes of the organizational codes, realizes a "Link-Bridge" on other databases in use within the organization (Marzi 2014). The SACS experience was used as an operational model by the partners concerned to tackle the phase regarding environmental classification and the information management methodology. By starting over again from the classification of the SACS domains (broken down in 42 main DU destinations of use and sub-divided in 256 DC classes), the WP1 of the Streamer project (Energy efficient Building typologies - Bouwcollege) classified the spaces according to 4 main layers. Each of these layers has its own properties, investment costs, growth/downsizing requirements, and marketability of the property (NHBI 2007). Said layers contain the "STREAMER SPACE UNITS" (SSU), each of which relates to the SACS articulation of the DU-DC. Upon conclusion of this phase, according to WP1 and WP2 (Energy efficient Building technologies), the spaces according to the following Macro-Labels were broken down and classified:

• RoomName	• HygienicClass
• RoomType	• AccessSecurity
• Amount	• UserProfile
• Area	• Equipment
• FunctionalAreaType	• Construction
• BouwcollegeLayer	• ComfortClass

5. Modeling methodology

Each Label was prearranged for classifying the complexity of the tasks and potential consumptions, to be calculated as a % against a master of reference. The labels and the SSU refer to the set di Key Performance Indicators (KPI), with the aim of meeting the reliability and representational requirements of the phenomenon under consideration. The following indicators were identified: 14 indicators of an organisational nature, 22 of a structural nature regarding the physical structure of the spaces and 9 of a technological nature pertaining to instrumental-electromedical equipment and relevant use. According to such articulation within the ambit of the specific WP7 (Demonstration Validation), the modeling phase for the BIM–GIS supports was initiated.

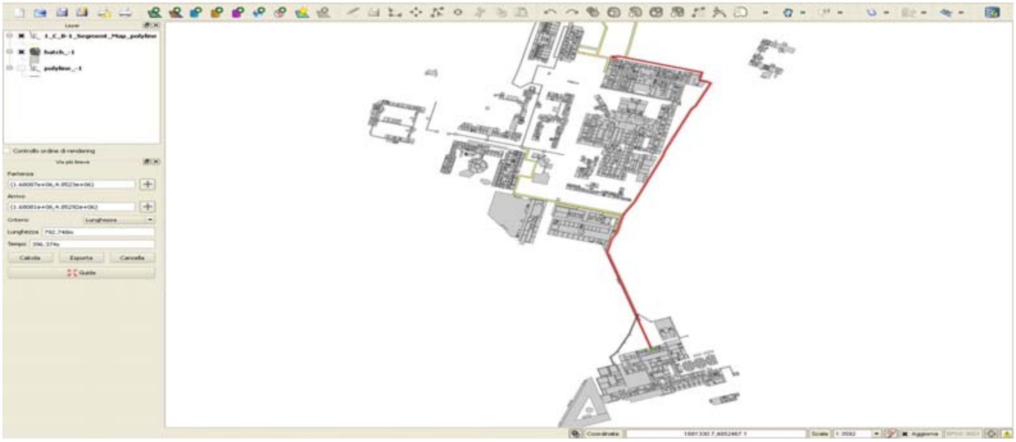

Fig4: GIS elaboration AOUC, SACS+QGIS area. (Modeling source: L.Marzi-S.Leone)

Based on the nature and homogeneity of the data stored in the SACS© database, a GIS model of the entire healthcare district was created. The *shp.file* was elaborated using the individual polylines as a modeling tool and importing both the physical (dimensional) parameters and the correlated DB. Through such operation, a data analysis system (hierarchized according to normalised levels for floors above ground level) was defined in order to group together - for the entire district- all the information of organisational and structural nature stored in the SACS. The adoption of the GIS platform was necessary for modeling some data deemed crucial in calculating the KPI, in relation to the dimensional parameters of the systems networks, to parameterize the activities of the operational units involved with respect to the entire district, and to process the information regarding orientation and exposure. The following phase entailed the preparation of a three-dimensional model with a level of detail (LoD3) of the three buildings of the oncology campus that were to be used as a basis for realizing the BIM at the same level. By referring to international experiences (Approach-Senate Properties), the BIM was modelled with the aim of creating the

"sample" (San Luca Vecchio) for assessing interoperability with the analysis and energy behaviour management systems, and using the tools defined within the WP3 domain (Design decision-support and lifecycle validation tool).
The detail scale of the model (BIM3) and the file layout were defined according to the energy analysis phases; information relative to the *envelope* was managed by means of a calculating frame related to wall types, managed by and parameterized in IFC libraries, while the packages related to window fixtures were catalogued and elaborated based on a specific survey, modelled according to libraries specifically defined and created for the model at issue.

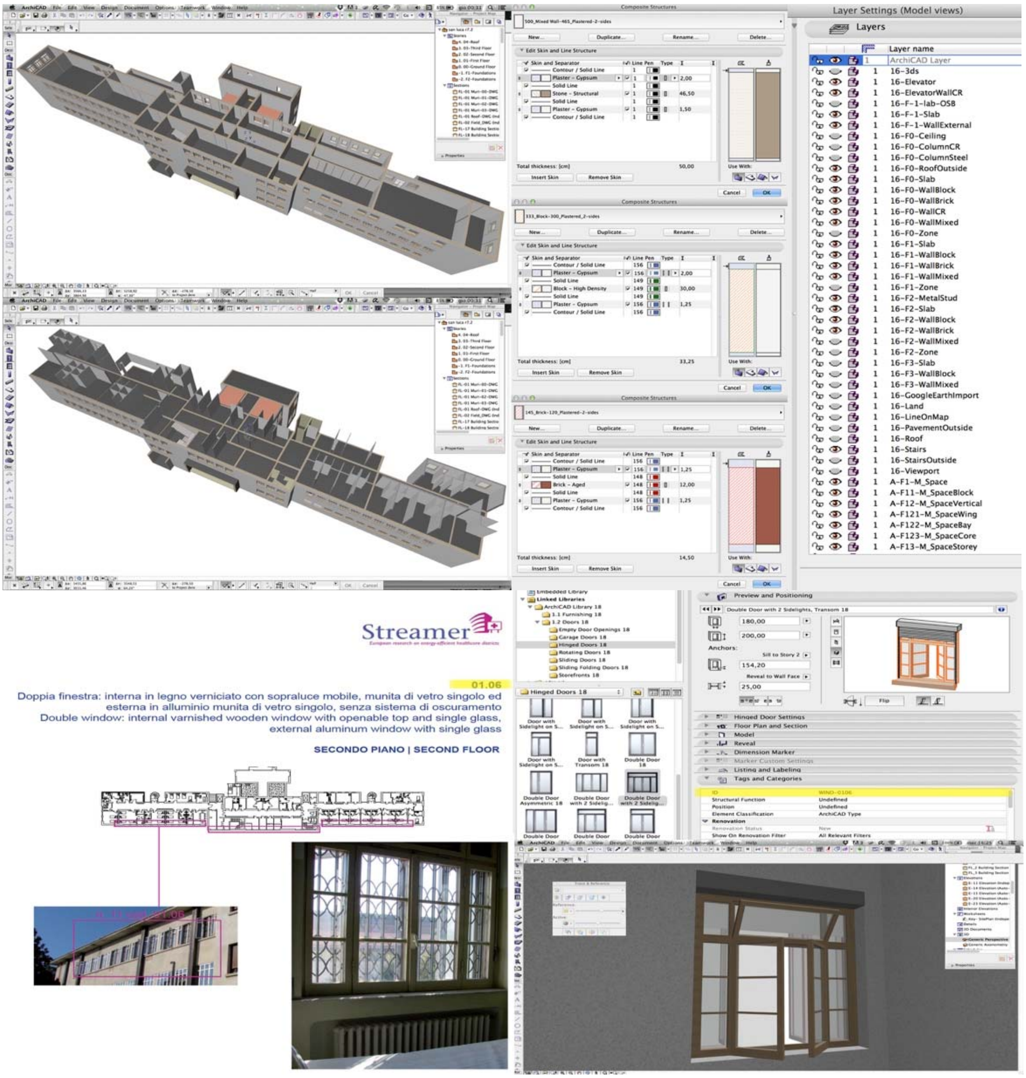

Fig5: Elaboration of the BIM relative to the pavilion of the Vecchio San Luca building.ArchiCad. (Modeling source:B.Turillazzi- S.Leone- L.Marzi)

Information regarding the spatial layout was inserted into the BIM model (in xrlm format) using the "zone tool" functionality, by importing, in particular, SACS data (in dynamic format), relative to SSU, staff and existing *assets* and the healthcare organization. Such operation was made possible by programming an apposite *tool-stamp* which enabled to correlate each DB anagraphic zone used by the SACS.

Fig6: Elaboration of the BIM relative to the pavilion of the San Luca. 3D zones and utilization of the model on a Simergy Pro interface platform for EnergyPlus. (Modeling source: L. Marzi - S. Leone- Becquerel Electric)

The evaluation process and the building energy simulation were performed (or better, are currently being performed) by using the IFC as a bridge for exporting them to platforms specifically dedicated to such purpose. As mentioned earlier, the modeling process was performed while seeking to determine which data was most critical to the energetic simulation process. Such operation is deemed crucial in properly optimising and sizing data in order to expand it to the healthcare organization’s property assets, consisting of over 15,000 facilities. The research was conducted starting from a large scale model of an architectural detail and reducing its contents as the results of the energetic simulations indicating the actual values necessary for formulating said simulations were yielded. The above simulations are becoming more and more relevant for both energetic and organizational parameters (in relation to the WP3 - design configurator tasks). As of today, we can affirm that the “simplification” of the model is operable both within the package of information regarding the systems characteristics and in relation to data relative to several types of finishing works. Also, we have verified that the best simplification is operable with regards to the management of window fixtures and transparent shields, where the level of detail for modeling can be reduced in favour of the definition of the IFC Labels, through which the libraries are managed. Similarly, we verified that it is more cost-effective to manage the information regarding finishing works and punctual elements for managing mechanical systems by operating directly on the DB, appositely inserted into the 3D zones managed by IFC parameters.

6. CONCLUSIONS

The adoption of BIM-GIS systems for managing complex assets surely represents a great opportunity today to improve the quality content of the various design - management phases related to built environments. Simplifying several functions, as well as the capability of the systems to manage multiple information assets (divided according to scale, type and utilization method) will surely contribute to promote this new process management concept. This paper illustrates an emblematic scenario under which, due to a high structural - functional and operational complexity, the research activity represents an opportunity for assessing both the analysis capability of the integrated BIM-GIS tools and their interoperability with respect to the information ambits already present within the framework referenced herein.

Acknowledgements
The research leading to these results has received funding from the European Community's. Seventh Framework Programme under Grant Agreement N. 608739.

7. References

- Agenas, a cura di (2015). Monitoraggio della spesa per la manutenzione degli immobili del SSN -Area di riferimento: LEA-Spesa Performance. http://www.agenas.it/lea-spesa-sanitaria/monitoraggio-della-spesa-per-la-manutenzione-degli-immobili-del-ssn. (ultimo accesso aprile 2016).
- Marzi L. (2014). Strumenti e metodi per la gestione dei patrimoni edilizi sanitari. L'esperienza del laboratorio multidisciplinare dell'A.O.U. di Careggi. TECHNE 08. 241-249 pag. ISSN online: 2239-0243.
- Del Nord R., a cura di (2008). L'Ospedale del Futuro. Modelli per una nuova Sanità, "EdA, Esempi di Architettura", n. 4, anno II, il prato, Padova.
- Osello A., Moglia G., Del Giudice M., Boido C. (2014) BIM and GIS for the Dimm(er) methodology. In atti del XI congresso UID, Convegno internazionale dei docenti della rappresentazione. 975-982 pag. ISBN:9788849229158
- Building Differentiation of Hospitals – Layers approach, Netherlands Board for Healthcare Institutions (NHBI), 2007, 10-12 pag.

- LoTurco M. (2015) Rappresentare e gestire patrimoni immobiliari: il BIM per il Facility Management. In TERRITORIO ITALIA. Volume 2. 33-38 pag. Editore Agenzia delle Entrate. ISSN:2240-7707
- Sebastian R., Böhms, H.M., Bonsma, P., Van den Helm, P.W. 2013. Semantic BIM and GIS Modeling for Energy-Efficient Buildings Integrated in a Healthcare District. IS-PRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, II-2/W1: 255 -260 pag.
- 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.
- Ciribini ALC. (2013), L'information Modeling e il settore delle costruzioni. Maggioli ISBN: 9788838761574