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Expanding Boundaries:
Systems Thinking for the Built Environment

INTEGRATED PROCESSES FOR THE EVALUATION AND OPTIMIZATION OF BUILDING PERFORMANCES

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Abstract

An efficient way to reduce the consumption of materials and energy in buildings is represented by an improvement of building processes. A regulated information management is essential to avoid delays, cost overrun, errors and lack of performances during the whole building life-cycle.

Thus, the adoption of an integrated design process is becoming of great importance; BIM, considered as building information modelling and management, could be a way to perform such integrated processes.

A central repository for project data and information could be advantageous if knowledge is exchanged between different stakeholders (e.g. through IFC or gbXML). Moreover, BIM supports building performance analyses and evaluations, allowing, for instance, simulation of energy performance, computation of environmental impacts and estimation of costs. In this way, it is possible to compare several options and choose the optimal ones.

The importance of the link between BIM and sustainable buildings is underlined by the state of the art, such as the Green Overlay to the RIBA Outline Plan of Work, the series 10 of COBIM related to energy analysis, and the BIM Guide for energy performance developed by GSA.

An Italian case study for the improvement of the building process is Innovance, a research project with the aim of developing a national database for the construction sector. In order to improve the collection, storing, management and sharing of data, an unambiguous classification system and standardized technical sheets have been developed and a web portal has been designed to ensure the interaction among stakeholders.

Keywords:
BIM; Information Management; Behavioural Modelling; Interoperability.

1 INTRODUCTION

As the construction sector has a great influence on energy consumption and greenhouse gas emissions, AECO (Architecture, Engineering, Construction and Operation) industry is putting effort into the reduction of these impacts during the whole building life-cycle.

Several improvements have been made as related to technological aspects, but changes have been introduced even in the building process.

Indeed, several benefits can be achieved through an integrated building process.

Particularly, this paper focuses on the support of BIM (Building Information Modelling) to the evaluation and optimization of building performance and sustainability.

The research goals are twofold: 1) highlighting how an integrated process could improve the achievement of an energy efficient and sustainable behaviour of buildings; 2) considering how digitalization could support sustainability

evaluation through information management at building level.

The analysis aims to show how benefits can be achieved not only in the design stages, when designers can predict buildings' impacts, but also during the operational stages, when users' behaviour and activities affect buildings' emissions and consumptions.

In fact, sustainability should be actively considered in design, construction and operation of buildings, as clarified in the Green Overlay to the RIBA (Royal Institute of British Architects) Outline Plan of Work [0]. Each stage (from the strategic definition to the in-use stage) is characterized by sustainability checkpoints, in order to illustrate behaviours and activities that should support a more sustainable approach.

Also in the Italian context, sustainable aspects are recently considered, as it is emerged in a proposal for integrating the new Building Code [0]. The fulfilment of sustainable criteria is required, giving additional points to solutions with low environmental impact and low cost, evaluated during the whole life-cycle.

2 STATE OF THE ART

Many stakeholders are involved and a great amount of information is required during a building process [0], especially regarding well-performing and energy efficient buildings. However, the lack of communication, coordination and transparency among stakeholders often affects the fulfilment of requirements and performances. The fragmented nature of the construction industry hinders integration, both among the actors and the stages of a building process. For this reason, the effective exchange of information may be very difficult [0].

New methods and technologies have been developed to manage a great variety of information, improving its traceability and possibility of use. The whole building process is becoming more integrated and organic, with a close collaboration of several stakeholders, especially in the case of intelligent buildings.

Within this context, BIM is emerging as it allows the integration and cooperation, for example by making it possible to share information and documents between all the actors, through a central data repository. It is possible to use, exchange and update information along the building life-cycle, collecting data in a database and using them repeatedly. In this way, data are not re-inserted and so they are not redundant [0].

2.1 Evaluation of sustainability in design stages

Different methods and tools can be used to estimate and compare building performance since the design phases [0, 0].

In this context, topics of BIM and sustainability are interrelated. Several guidelines and standards have been developed by different corporations, as the series 10 of Finnish COBIM (Common BIM Requirement) related to energy analysis [0] or the BIM Guide for energy performance developed by US GSA (General Services Administration) [0].

Generally, the assessment of building sustainability is performed during the design stages, mostly for the certification rather than for the evaluation and comparison of different alternatives. This is mostly due to the lack of data and to the great amount of time required to perform an analysis. In order to bring forward this analysis, it should be useful to define and keep track of the necessary information and the appropriate modelling procedures for each specific analysis that should be carried out.

This should be possible by connecting, as an example, BIM and LCA (Life Cycle Assessment). Indeed, the research and implementation of BIM has become widespread as it can be considered as a process to support communication (sharing data), collaboration (acting on shared data), simulation (using data for prediction) and optimization (using feedback to improve design, documentation and delivery) [0]. Therefore, BIM should support the design and analysis of building systems since the early design stage, when specific sustainability trade-off analyses could be conducted, different design options could be compared, decision-making processes could be performed, "what-if" scenarios could be developed, and most effective decisions could be made [0, 0, 0, 0]. Since the conceptual design phase, all the stakeholders should be able to acquire, store and organize data related to different performance of components, and so to generate feedback during the design process [0]. Once these data are stored, they could be made routinely available and could be updated during the whole life-cycle.

These data could be used in BEM (Building Energy Models) to compare different design choices and predict future buildings' behaviour. However, as values and schedules are only assumed for most of the input parameters, results are not accurate enough to predict the real consumption during operation [0].

BIM and BEM could be used together to perform buildings' performance analyses along the whole life-cycle. Several researches have been carried out in relation to the theme of interoperable information modelling for energy performance analyses, focusing on open formats as IFC and gbXML [0, 0, 0]. However, interoperability still represents criticalities in relation to the complete integration and unambiguous interpretation of results between BIM and BEM [0, 0].

2.2 Evaluation of sustainability in operational stages

The achievement of optimized performances in buildings is challenged by the uncertainty that affects the surrounding environment, consequently buildings' impacts should be considered also in operational stage.

As related to buildings' use phase, the gathering of required information for the assessment of buildings' performances could be improved through real-time metering and monitoring technologies. The collected information could be useful for the definition of control strategies by which it would be possible to harmonize sustainability goals with comfort goals.

BACS (Building Automation and Control Systems) could measure real impacts and consumptions, monitoring and controlling different building systems. In this way, appropriate feedbacks could be provided to users, increasing their awareness and promoting sustainable behaviours. At the same time, these feedbacks could be used to train buildings in order to adapt their behaviours to particular conditions.

Recently, pervasive sensor networks allow an accurate and dynamic monitoring of the indoor environment, taking advantage of the knowledge of the overall building and executing actions for forcing the building towards expected states [0]. Indeed, control policies could be implemented in advance, through integrated models for the prediction of the near future behaviour of the controlled environment under specific conditions.

In this context, BIM could be coupled with real time monitoring systems gleaned from BACS for recording and storing parametric real-time data [0]. Some attempts have been done in using remote sensors to populate BIM models. Data acquisition technology has already been integrated with BIM tools (i.e. Onuma Planning Systems), linking models with real time energy sensors, lighting and webcam data [0].

3 CASE STUDY

Innovance is an Italian research project funded by the Ministry of Economic Development. The aim is the creation of an interoperable platform for exchanging information in the building industry, through a central database to smartly store and share information.

3.1 Goal

The scope of the research project is threefold: 1) developing an unambiguous classification system for every object of the construction sector; 2) collecting informative attributes through datasheets; and 3) designing a user friendly website.

The Italian construction sector is characterized by a great amount of rules, definitions and practices, causing difficulties in data transmission among stakeholders. For this reason, the aim of the project has been the creation of a coding system based on a standardized and unequivocal name. In order to manage and use information through the construction process, technical datasheets have been defined among homogeneous objects categories. Users can easily and quickly retrieve and compare information throughout a web-based portal that relies on a database.

A great part of the information stored in the database could be used for a sustainable design of buildings. In fact, several specific sections of the database are related to the assessment of environmental impacts (in conformity with UNI EN 15804:2014 [0]) or to the simulation of energy performance (according to the Italian normative context).

3.2 Methodology

The classification and definition of every object involved in the construction process have been the core of the research. The database is structured considering objects belonging to:

- Functional-Spatial System, for describing a whole building and its division into functional and spatial homogeneous areas
- Technological System, for collecting information on construction products, in site elements and technical elements
- Processual System, related to activities, machineries and manpower

As related to the development of an unambiguous classification system, the research has been carried out starting from the literature review, analysing existing coding standards, i.e. UNI 11337 [0], UNI 8290 [0], and OMNICLASS [0]. Each object is defined by an unequivocal name, made by the aggregation of seven characteristics. These seven fields are: category, typology, reference standard or function, principal performance, geometry, dimensions, physical-chemical characteristics (Fig. 1).

Fig. 1: Unequivocal name.

Moreover, every object is described by a set of standardized informative attributes, identified through a direct partnership with association and federation of product manufacturers and

construction. As related to the technological system, the main sections are: code, description, use, manufacturer's data, performances, sustainability impacts, geometry, visual aspects, physical-chemical properties, tolerances, composition, transportation, packaging, product declarations and attachments. A standardized template for each category of construction objects allows storing data always in the same position, enhancing comparisons and statistics between them and simplifying decision making processes (Fig. 2).

Fig. 2: Technical datasheet.

3.3 Results

The result of the project has been an open web-portal for the use and exchange of data between several stakeholders.

The web portal should allow users to manage their projects, by these functions (Fig. 3):

- objects creation, allowing the definition of an unambiguous name and adding information to technical datasheets according to the standardized structure of the database
- object search, in order to download and manage information related to all the stored objects, also with pre-formatted views targeted to different users' categories (clients, designers, contractors, manufacturers, etc.)
- BIM server, to manage a project, from the early phases to construction, use, maintenance and disposal or handover. This section contains standardized folders in which users can upload documents and drawings. It can be used also as a repository, to store BIM models; database interoperability is guaranteed by the adoption of the IFC protocol
- BIM library, allowing users to exchange standardized BIM objects and use them in their own models.

Some actors who can benefit from the portal are:

- manufacturers interested in uploading information about their products;
- construction companies interested in consuming stored information about

products and machineries in their projects, loading data related to in site elements and assembled systems, and adding information related to their activities
- architects and engineers interested in using objects (in particular BIM objects) in their projects
- customers interested in collecting information related to involved stakeholders and following the development of the project.

Through the availability and transparency of all the collected data, stakeholders are able to choose the most sustainable alternatives that fulfil the required performances.
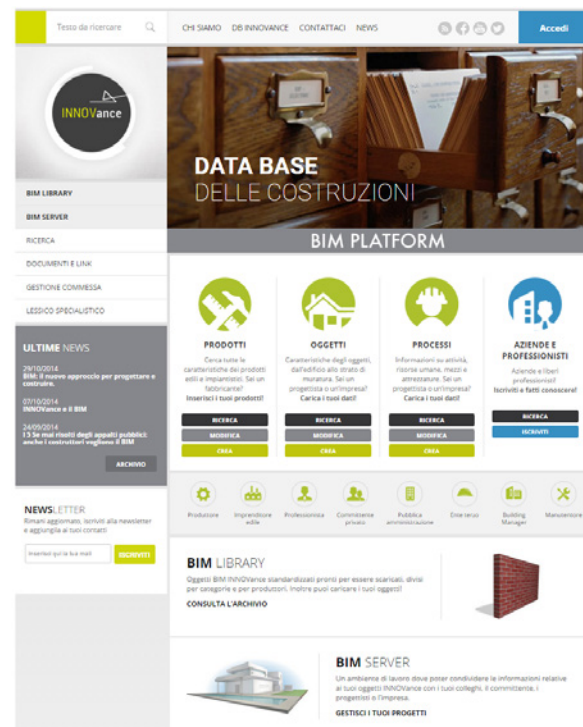

Fig. 3: Web-portal.

4 FUTURE WORKS

As related to sustainable buildings, Innovance can be a useful tool, especially in design stages. However, as emerged from the state of the art, it is important to consider sustainability also in operation.

In this way, it should be possible to correlate predicted performance in the design stage with real measurement in the operational one. This would allow defining how occupants can affect buildings' sustainability and how buildings can modify their behaviour according to different conditions. Starting from these considerations, future works should consider building behaviour in operational stage, defining a framework for the evaluation of buildings' sustainability using a whole life-cycle approach, in order to:

- understand whether and how the centrality of users can change the building process
- propose a proper structure for data management and a correct flow of information among different systems for the acquisition and use of knowledge
- extract useful information from available and multifaceted data and develop web interfaces to inform involved stakeholders using real time information.

Therefore, it should be possible to:
- compare how buildings in use differ from the expectations of their design, considering not only the way buildings are designed, but also the way they are used and managed
- define control strategies for the reduction of building impacts;
- provide feedback to users, making them aware of their behaviours.

5 CONCLUSION

BIM is an important process to support the evaluation and optimization of buildings' performance, especially considering aspects, such as:
- Integrated design and management of well-performing buildings need BIM as a process for allowing collaboration and cooperation among different actors and skills.
- Simulation of building performance since the design phase requires the integration of tools for parametric modelling and performance analysis.
- Monitoring of building behaviour in the use phase represents the connection between tools for parametric modelling and systems or devices for building automation and control.

In Italy, however, BIM is increasingly becoming widespread, although the implementation process is still at the origin – often only limited to case studies – and proceeds slowly, with a heavy lagging behind other countries.

In this context, Innovance is proposed as a tool to support the implementation of BIM in the Italian construction sector, as it enhances an ordered information management, with particular regard to the design of well-performing buildings.

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