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CONFERENCE PROCEEDINGS

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TABLE OF CONTENTS

TABLE OF CONTENTS

ARCHITECTURAL TECHNOLOGIES I – ENERGY ISSUES

ARCHITECTURAL TECHNOLOGIES II - INNOVATIVE METHODS, SOFTWARE AND TOOLS

BUILDING STRUCTURES AND MATERIALS

CLIMATE CHANGE I – ENERGY ISSUES

BUILDING CLIMATE CHANGE II –
STRATEGIES, PROTECTION AND FLOODS

SUSTAINABLE COMMUNITIES AND PARTICIPATION I –
PLANNIG ISSUES

SUSTAINABLE COMMUNITIES AND PARTICIPATION II – CONCEPTS, METHODS AND COMMUNITY

IMAGE, IDENTITY AND QUALITY OF PLACE I – PLANNING ISSUES

IMAGE, IDENTITY AND QUALITY OF PLACE II – PUBLIC SPACES

IMAGE, IDENTITY AND QUALITY OF PLACE III – CONCEPT, METHODS, EDUCATION

RESILIENCE OF PLACES

ADAPTIVE REUSE

INNOVATIVE METHODS AND APPLICATIONS FOR SMART(ER) CITIES

URBAN MOBILITY, TRANSPORT AND TRAFFIC SOLUTIONS

CITY INTELLIGENCE INFORMATION MODELLING

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ABSTRACT

The widespread availability of data enables the knowledge of urban phenomena: this knowledge relies on the development of a built environment information system. District Information Modelling at urban and building scale is a starting point that allows the creation of relationships between existing data, aimed to describe the performances of structures and infrastructure in a given territory: this information base will progressively connect with additional streams of data related to the use of urban facilities, linking environments and users in order to increase adaptability of services to human needs. This progression of knowledge on urban environments requires, on the one hand, an effort to relate existing data (created for sectorial scopes, with no concerns about possible interaction with other information) and, on the other hand, the need for a technological support in the management of new data fluxes coming from sensors and mobile devices, dynamic data concerning behaviours. Politecnico di Milano and University of Brescia are working on projects related to the use of information for the built environment management at urban (GIS) and building (BIM) scale for energy efficiency purposes. In the former case, the interconnection of existing databases on buildings allows to define renovation strategies on cities and districts, becoming an opportunity for the creation of an Information Model that enables the monitoring of the efficacy of policies undertaken, as well as the connection with new static and dynamic data sources. In the latter case, a Building Information Model, based on project documentation integrated with a laser scanner survey and enriched with specific Building Energy Modelling attributes, supports the decision-making process in operational and maintenance phases. The Model, connected with sensors monitoring the real building, allows the real-time connection with data concerning internal conditions and the storage of continuous data streams on the operational phase.

Keywords: district modelling, cognitive city, servitized assets

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INTRODUCTION

The transition from traditional forms of urban government toward new smart city management systems is now more relevant than ever considering the current demographic trends and settlements patterns. On the one hand, the growth of global population requires the implementation of urban management systems, aimed to reduce the anthropic pressure through an efficient use of available resources. On the other hand, cities compete with each other in attracting people and capitals, paying closer attention to the quality of life and urban environments. Population concentration in urbanized areas requires policy maker to address holistic sustainability (social, financial and environmental) concerns, considering, at the same time, the provision of high quality urban environments. Thus, a profitable management of the increased complexity of urban systems rely on the availability and on the smart use of data.

The concept of smart city is strictly connected to the extensive use of data and technologies aimed to support efficient governance models from many points of view, from mobility issues up to city planning activities (Fistola et al. 2013). For what concerns the management of built environment, and buildings in particular, the availability of an integrated system of knowledge is the basis for a smart assets management. The modelling of urban information at different level, from city-wide models to single building models, is the central idea of many smart city projects developed in different domains and it refers to internationally recognized data structures (BuildingSMART International, 2015) (Gröger et al. 2012). From this point of view, City Modeling and Building Information Modeling (BIM) are converging research areas that take advantages from a reciprocal interchange: the georeferencing of Building Information Models enables their location within a City Model, where each asset might be analyzed considering the surrounding built and natural environment; in turn, city and district models might be enriched and refined with data coming from BIMs, providing a finer grain base for territorial analysis and enabling the extension of facility management applications at urban scale (Kang & Hong 2015; Rafiee et al. 2014; Donkers et al. 2015; Tobiáš 2015; Hijazi et al. 2010).

In order to make a first step toward a real digital transition, cities are required to accomplish a crucial effort aimed to combine existing information on buildings stored in different datasets. If the modeling of new constructions can be considered as a relatively easy operation, the extensive collection and structuring of data on existing buildings might be a quite challenging task to be carried out on a whole city or district: this is due to the lack of connections between databases, created independently for specific purposes, without the early premise of an information-based integrated assets management. Nevertheless, in developed countries existing buildings interest the majority of urban assets and the availability of integrated information able to describe the quality of the existing building stock requires city managers to face current problems associated with poor data quality, out-of-date databases and lack of interoperability between different sources (UN-GMM 2015). Furthermore, the widespread use of sensors for the monitoring of the use of urban facilities requires static data to relate with new data fluxes: from this point of view the support of technology in the management of huge databases is fundamental in order to jointly consider the quality of urban facilities and users behaviors and to have the necessary informative layers to make the built environment adaptive to the human needs.

Politecnico di Milano and University of Brescia are working on projects related to the use of information for the built environment management at urban (GIS) and building (BIM) scale for energy efficiency purposes. The two researches outline the potential related to an information-based management approach that, starting from the state of the art, enables the definition of energy efficiency strategies at district level, whose efficacy is improved by the arrangement of adaptation mechanisms based on users' behaviors.

METHODOLOGY

The following sections provide a brief description of the two research projects: even if there are differences, from the point of view of the scale of analysis, of the data type used and data processing method, both address energy efficiency issues starting from a common "observation point": the building.

Energy need prediction at district scale

The use of geographic information for energy estimates at city scale is a common practice nowadays, especially thanks to the diffusion of 3D City Models gathering geometric and semantic data on buildings (Krüger & Kolbe 2012; Strzalka et al. 2011; Alam et al. 2013): such models requires building data having different origin to be associated to georeferenced 3D geometries, providing a digital "identity card" of each building. Nevertheless, building data do not always satisfy interoperability requirements and the interchange between existing databases cannot be considered automatic.

In Italy the introduction, at national level, of the Topographic Databases (TDB), the new usage-oriented 3D earth surface model, represented a first significant step toward the extensive modelling of the built environment, providing highly accurate 2.5D georeferenced data representing city items (roads, rails, buildings,…), connected to specific attributes describing the main features of each item. Nevertheless semantic and geometric contents, as required by current technical data specifications for the production of TDBs, are limited to airborne-acquired data and quick on-site survey: if, on the one hand, highly accurate geometric data will be soon available for all urban settlements, on the other hand semantic attributes will refer only to buildings features recognisable through stereo-pair images. This shortcoming neglects the exploitation of a substantial citywide buildings modelling as data on buildings interiors and other non-visible features are not considered. Nevertheless all these information having non-cartographic origin are currently stored in different public sectorial databases (e.g. cadastral data): the connection of existing public archives on the Topographic Database would enable a real modelling of built environment combining in a 3D georeferenced base all information useful to describe the buildings under all possible points of view. Moreover, the informative requirement of the TDB would be aligned to current international standards, first of all CityGML which is also adopted at European level.

A research group of Politecnico di Milano tried to address abovementioned issues and realized an energy need prediction analysing the features of each single building within a district of the city of Melzo (Milano Province) starting from the creation of a Building Information System: the latter is based on the TDB whose contents are progressively integrated with other external data. The idea is to test the use of TDB in sectorial analysis, like energy estimates, and try to go beyond the traditional cartographic scope these tools were created for, measuring the variation in the accuracy of analysis after a progressive integration of data coming from other archives.

The approach adopted aims to evaluate the benefits deriving from a geo-referenced integrated information on buildings, computing the analysis using three level of integration and enrichment, each one determining a specific "Data Package" (DP) available for the computation of the energy estimate. The DP.1 comprise only coarse TDB data and a list of assumptions is adopted in order to complete the energy estimate. In the DP.2 TDB data are semantically enriched with other data coming from existing archives. The alignment between TDB and cadastral map, in particular, led to the definition of a univocal relationship between buildings in the TDB and buildings in the cadaster, enabling the automatic transfer of building data from the cadaster on the Topographic Database: in this way detailed information describing the feature of each single building are available and the energy estimate can be computed with fewer assumptions. In the end, in the DP.3 also geometric contents of the TDB were enriched through the acquisition of BIM data for all buildings under analysis: the information base for the energy analysis become more and more refined, enabling consideration on all the structural and architectural components that characterize each building.

A Smart Campus demonstrator

A building in use is a system of complex interactions related to architecture, building physics and, especially, users' behaviours. A smart building supports holistic sustainability, including all these cross aspects and answering to new questions that have to be solved about the built environment ideation, design, construction and maintenance within the ongoing industrial revolution 4.0 (Fletcher, 2016). In this sense, such a building can be defined as intelligent, since it has to contain and manage years of accumulated knowledge about the built environment, supporting users' behaviours and needs and acting as a service rather than as an economic product. The construction paradigm is changing and a fundamental rethinking of the built environment is required; technology seems to be the key of this transition towards intelligent buildings and smart construction. Moreover, BIM Level 3 aims to consider and include the management of real-time data in use, collecting data with sensors and making decisions based on that information (HM Government, 2015). Sensors, in fact, represent an interface for users' interaction, collecting data just using the building and giving a feedback on how the building should adapt to changing requirements.

The University of Brescia has been involved in a research project named SCUOLA – *Smart Campus as Urban Open LAbs*, aiming at promoting users' awareness on energy consumptions. The research activity is focused on smart consumption monitoring systems and control of users' behavior by means of real-time data collection. The project is a collaboration between multidisciplinary research teams working on construction, mechanical, electrical and IT topics, including Building Information Modelling linked to monitoring of users' activities and indoors conditions and development of IT tools for data collection and users' interaction.

The case study is a two-floor classroom building, characterized by low energy efficiency. Realized in the nineties, it is located in the department of Civil and Architectural Engineering of the University of Brescia (Figure 1). The building has also an underground floor where two computer laboratories are located. A two-level glazed atrium closes the south-east side and it is used as a free study room during the day.

Figure 1: Smart Campus demonstrator

Figure 2: Architectural Building Information Model

An Asset Information Model of the building has been created - including architectural (Figure 2), structural and MEP elements - in order to digitalize the original documentation, to update it to the as-built condition and to support an energy analysis by means of a BIM-to-BEM (Building Energy Modelling) workflow (Ciribini et al, 2015). Moreover, other BIM uses have been implemented related to the operation and maintenance phases and the creation of an information base in order to support the decision-making process in case of any possible future intervention on the building.

In addition to the energy performance issue, the subject of users' behavior has been also investigated and behavioral patterns have been defined by analyzing variables influenced by users' behavior, such as the impact on indoor air quality and the distribution of occupants and activities during the week. This kind of analysis was originally performed at a simulation level (De Angelis et al., 2015) but at present the research project is going ahead with the monitoring phase in order to verify the occupancy rate and indoor conditions. The monitoring system includes 94 sensors installed in classrooms, laboratories, circulation and common spaces, collecting data on building consumption, weather conditions, thermal consumption, electrical consumption and building environmental conditions (Table 1). Smart plug plants have been installed in the computer laboratories to measure and control electrical devices plugged in standard electrical outlets. Informative totem have been also installed in order to share real-time information about the building in use directly with the users. The attendance monitoring is now ongoing.

Table 1: Monitoring System – Building Environmental Conditions

Sensors collecting data about building environmental conditions			
Symbol	Description	Unit	Update
T_{amb}	Temperature	°C	15 minutes
U_r	Relative Humidity	%	15 minutes
L	Luminosity	l_x	15 minutes
S_w	Status-window (close/open)	Bool	Event
N_p	Number of people	Int	15 minutes
C_{CO2}	CO2 Concentration	ppm	15 minutes
C_{VOC}	VOC Concentration	ppm	15 minutes

RESULTS AND FURTHER WORKS

Both the researches described in this paper are still in progress: outputs validation, for the energy need prediction at district scale, will be produced and documented in the next moths. Energy strategies to improve the performance of the Smart Campus demonstrator (De Angelis et al., 2015) and the results of the BIM-to-BEM interoperability workflow (Ciribini et al, 2015) have already been published. Currently, data are collected from sensors monitoring users' behaviors.

For what concern the energy need estimates at district scale three different outputs were produced using three different level of data integration and enrichment: real consumption data are being acquired and integrated in the Building Information System created. This will allow to measure the accuracy of the energy analysis carried out and will enable considerations both on the improvement in estimates precision related to a progressive data refinement and on the costs and efforts required for the realization of such refinement.

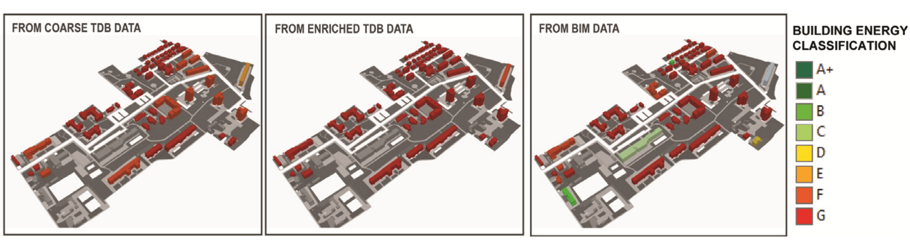

Figure 3: 3D visualisation of building energy classification obtained with three different Data Packages

The availability of such fine grain energy analysis provide crucial information for the definition of efficiency strategies, implementing and coordinating retrofit and renewal interventions systemically at district and urban scale in place of leaving the development of measures on single buildings by private owners. Moreover, the yearly collection of consumption data will enable the detection of consumption trends within the district and the monitoring of the efficacy of energy reduction strategies potentially implemented. This data-based approach in the definition of urban policies would ensure a higher efficacy and viability of urban regeneration strategies. In the end, the Building Information System might be tested on differ type of analysis, like vulnerability assessments in case of environmental risks. Its potential in the development of assets management applications might also be investigated.

For the digitalization of the Smart Campus demonstrator, an asset information model has been created based on original paper documents, integrating lack of knowledge with a terrestrial laser scanner (TLS) survey campaign. Original documents and pictures of the state of the art have been included in the BIM database in order to effectively create a virtual representation of the building on the base of which to support eventually decision-making processes and maintenance activities.

Sensors have been installed and the monitoring system is now ongoing. Real-time data is available through Web Service REST. The next step will consist in linking the dynamic data captured from the sensors to the Building Information Model in order to enrich the database with information coming from users during their activities. At present, the Department of Information Engineering of the University of Brescia has developed an API in order to link the database with the BIM by using an URL attribute. A future aim of the research project will be the direct involvement of users by means of mobile apps and smart devices in order to add their feedback to the building as-built condition and real-time data coming from the monitoring system. Users will be also informed about real-time data of building use with informative totem that have already been installed.

CONCLUSIONS

The proposed researches synthetically outlines what is the general trend of digital information in the construction industry: every asset has its own story and its own "baggage" of data related to its specific characteristics and to the surrounding environment.

However, buildings are also social places and their performance and operational conditions are influenced by the way people use spaces according to their activities and needs. Enhancements in new technologies and the development of digital ecosystems enables the interconnection and the gathering of many different types of data that refers to built assets and the definition of new city management systems: position is the key that brings together information in a digital geo-referenced environment, building and district data, static and dynamic data, providing an essential information basis for more informed decision making.

Adaptive systems will be developed, able to detect the real time situation of built spaces, perceiving changes due internal uses and external conditions, planning alternatives responses, choosing the best action to undertake and monitoring the effect of such action (Mostashari et al. 2011): a Cognitive City that predicts users' needs autonomously in order to provide the optimal comfort condition with the smaller resources consumption.

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