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BACK TO 4.0:

RETHINKING
THE DIGITAL CONSTRUCTION INDUSTRY

A cura di

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"Energy Management of the Smart City through Information Systems and Models"

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Abstract

Advanced analysis tools to describe the reality by data collection are fundamental for the development of urban strategies for energy management and refurbishment of the built environment. The smart city concept connects the "parts" of the urban "body" to promote a complex energy balance. The definition of the balance focuses on the time schedule of consumption and production. The possibility to store into sinks and extract energy from sources in a coordinated way can effectively introduce the paradigm of a new urban organism with circular and composite interconnections. GIS environment can provide a suitable data management system on which a smart city can be developed: City Models are customizable repository of buildings information coming from different data sources whose the level of detail of the acquired data can radically differs, ranging from open statistical and standard data to detailed and executive files coming from BIM models. Buildings within the city can be described with different accuracy and accordingly the energy results (and possible strategies and associated costs) could delineate dramatically changing scenarios. The paper analyzes the levels of detail of the building models used to provide the energy assessment of a district (as a sample of a methodological approach) carried out following national standards (UNI). A steady-state performance calculation, based on the method implemented into the national regulation, provides the energy outcome. The results change due to the level of enrichment of the GIS model by data collected from different sources and urban policies could benefit from the definition of an effective strategy of organization and data collection framework to develop and adopt this key management instrument. The combination of GIS, BIM and BEM could be the evolutionary scenario pinpointed in this first stage of analysis.

1. Introduction

The attention toward the modelling of urban data at different scale is nowadays more relevant than ever considering the increasing complexity of urban systems: the definition of Intelligent City Management Systems is crucial for an efficient and sustainable service provision, aimed to optimize the consumption of resources and to reduce impacts on natural environment. In this direction, the availability of data on built assets plays a significant role both from an analytical and from a management point of view.

Citywide, fine grain analyses on the existing buildings stock enable policy makers to address urban renovation strategies in a systemic way, rather than leaving this process to the disjointed initiative of single private owners (Thompson et al., 2016). Moreover, real estate and construction sectors are currently undergoing a digital transition in products and processes: buildings are thus evolving from being pure physical products to real service providers that interact with users, offering tailored services and adapting their comfort conditions based on human needs and preferences (Mostashari et al., 2011). Buildings data availability, interoperability and integration are core issues for the smart management of future urban settlements. In particular, the convergence between geospatial data and Building Information Modeling (BIM) is boosted by the need of an integrated approach to the modeling of interior and exterior urban spaces (El-Mekawy et al., 2012), making them more efficient, connected and responsive.

This paper describes how buildings data, when profitably combined together, can supply an informative basis useful to support real use cases, like energy assessment at city and district scale. In the following sections a brief description of the current state of Italian building data is provided, outlining a possible path for the creation of a city-wide Building Information System; also the role of City and Building Modelling in energy-related applications is discussed. Finally, a methodological approach for the development of an energy need estimation at district scale, using georeferenced, integrated building data, is depicted.

2. Integrated Building Data

The collection and organization of building data allows the use of building information for purposes that go beyond the original intent they were created for: the underlying idea is that the same information could be useful in different field of application and data, produced for a specific purpose, may turn out to be useful for other uses. Moreover the support of geospatial technologies and techniques allow not only to combine together all available information on a single building, but to connect them to the surrounding context (other buildings, facilities, morphology, etc.).

The systematization and integration of existing databases concerning buildings were assumed as a strategic activity from different European countries since early 2000s (Van den Brink et al., 2013), (Hawerk, 2001), (Olivares García et al., 2011).

Differently, building data in Italy are still fragmented in sectorial databases with few interactions between available information. As in foreign states, the cadaster represent the building database "par excellence": formally, this is the only database on buildings available on digital format nationwide. Cadastral data comprises a georeferenced component, mapping cadastral parcels and buildings, connected to semantic data and blueprints describing the characteristic of each single Real Estate Unit (REU). Cadastral identifier are key reference for other external databases, both in public and private sector, dealing with the building: examples are the civil registry, the Energy Performance Certificates (EPC), utilities point of distributions (POD), etc..
The introduction of the Topographic Database (TDB) in Italy represented an important step toward the digital modeling of the built environment: TDB are the new, georeferenced earth surface model, introduced at national level in 2011. In this model accurate geometric data referred real world objects (like street, buildings, rivers, trees, etc.) are coupled with semantic information describing the main feature of each object. Among others, the "Built Environment" theme host geometric and semantic data for every building within an urban settlement, with a geometric accuracy that is generally compliant with a 1:1000/1:2000 cartographic scale. As TDBs are conceived mainly as a cartographic product obtained through aerial imagery, contents are related only to what is visible and recognizable in stereo-pairs images: no information are provided on non-visible part of the buildings (e.g the number of dwellings, floors below the ground, age of construction). Furthermore, no integration with other data sources is required by the current national standards. Nevertheless, the creation of relationships with external archives (especially the cadaster), enriching building-related contents, would enable the use of these tools beyond the simple mapping purposes, laying the foundation for the modeling of building data citywide compliant with international standards (OGC, 2012), (INSPIRE, 2012).
Most of existing information related to buildings, but also concerning building users (residents, workers, customers, etc.), usually refer to one of two main references: these are cadastral identifiers and addresses. Thus the association of buildings in the TDB with these two key reference enables the gathering of the existing informative heritage and the connection on the TDB would enable the generation of a citywide Building Information System, providing a proper basis for the generation of 3D City Models.

3. City and Building Modeling for energy purposes

City Models and 3D cartography in general are tools used in those fields of application related to the study of urban environment and one of the use cases where their potential is exploited the most is in energy applications field (Amado and Poggi, 2012), (Morello and Ratti, 2009), (Nouvel et al., 2014). Particularly interesting is the possibility to develop fine grain analysis investigating the energy need and retrofit potential for every single building within a city or a district (Carrión et al., 2010), (Kaden and Kolbe, 2013).In many studies, the availability of 3D City Models represents a "ready-to-use" package of data to be input in the energy balance, providing information on the characteristics of each building under analysis and on the surrounding built and natural environment. Outputs provide a punctual identification of the better and worse performing buildings, useful to promote efficiency interventions where the energy saving potential is higher. The accuracy of such outputs is strictly connected to the quality of input data, and, moreover, to their level of detail and update.

Furthermore, a structured definition and management of information at building level (i.e. through BIM) enhance an efficient and sustainable asset management.

In fact, among the 25 BIM Uses identified by a research group of Penn State (CIC, 2012), one is related to the energy analysis in design stages. Considering that a BIM Use can be defined as “a method of applying Building Information Modeling during a facility’s lifecycle to achieve one or more specific objectives”, it is significant to carefully create a model, introducing structured information so that it can be used for the estimation of the energetic needs.

Within this scenario, standards and reports have been developed by several organizations and corporations to define guidelines for energy modeling. Among them, Series 10 of Common BIM Requirement 2012 (buildingSMART Finland, 2012) defines the requirements of how information models are used in energy analyses during design, construction and operation. Series 05 of GSA BIM Guide (U.S. GSA, 2014) underlines that the scope and level of detail of energy analysis to be performed depends upon project constraints, performance goals, and project phase.

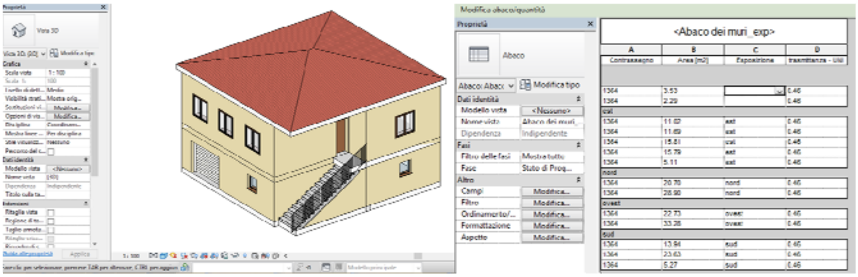

Figure 1. Modelling ad-hoc parameters for energy analysis

Accordingly, as operating into the Italian context, in order to perform energy analyses under steady-state conditions, information to be modelled has to be defined since the beginning, by adding ad-hoc parameters to building elements and by defining their possible values. Therefore, a rigid structure of information has to be defined for properly modelling building elements and spaces. Beyond the structure of the database, also the enumerated values for every field of the database have to be listed. In this way, once the database is exported from the BIM authoring tools, specific rules and calculations can easily be ran in ad-hoc spreadsheets (Figure 1). As an example, by enumerating the values for the adjacent environment of each wall and by storing its thermal properties in the database, it is possible to evaluate the heat loss coefficient for transmission.

In this way, by setting ad-hoc parameters in the BIM environment and by defining appropriate rules in the datasheets, it will be possible to extract schedules from BIM models and use them in tools for energy analyses under steady-state conditions.

Moreover, in order to perform dynamic energy analyses, simplified analytical models could be created and processed by suitable tools. In fact, BIM models could be the starting point for the creation of Building Energy Models (BEM). Great attention has to be focused on the exchange of information between BIM and BEM models (Ciribini, 2015) and to the reliability of energy performance evaluations through different BIM and BEM models (De Angelis et al., 2015).
Therefore, a great attention has to be paid to the creation of the models in order to satisfy defined model uses and to perform energy analysis at different levels, with different accuracy and purposes (energy labelling, refurbishment strategies, cost optimal analysis optioneering).
The convergence between City and Building Modeling is an advantageous evolution of two sectors dealing with the management of built environment: traditional and new data are gradually unified digital ecosystem, easing the development of Intelligent City Management System.

4. A GIS-BIM approach to citywide energy assessment

In order to test the usability and to demonstrate the potential of a georeferenced, integrated information on buildings in a practical use case, Politecnico di Milano and University of Brescia are focusing on the implementation of a district-wide heating energy need estimation: assuming current TDB contents as rough informational basis for energy modeling, the study aims to progressively evaluate the benefits related to different levels of data enrichment. Starting form rough TDB data, building information are integrated initially with semantic data coming from other existing datasets and furtherly with geometric data coming from BIMs. The final aim of this work is to measure improvements in assessment accuracy related to a progressive data refinement and, at the same time, evaluate costs and efforts required for the realization of such refinement.
The methodological approach described in the following sections is currently being developed and defined through the testing on two Italian case study areas, located within the municipality of Melzo (Milano Province) and Gavardo (Brescia Province). Thanks to agreements between the university and two local authorities (Melzo municipality and Comunità Montana Valle Sabbia) the research group assume the point of view of a public administrator, accessing to priviledge relevant databases whose contents are commonly not available to users for privacy reasons: sensitive data were omitted before data processing.

5. Methodology

As previously stated, analyses are computed as TDB contents are progressively enriched: for each step of data integration a specific Data Package (D.P.) is created. As a progressive enrichment, each further Data Package acquire contents coming from the previous steps.

DATA PACKAGE 1

The D.P.1 comprise only rough TDB data and a list of assumptions is adopted in order to complete the energy assessment. As mentioned in section 2, building data in TDBs refer to those characteristics that are visually recognizable through stereo-pair images, whose metric accuracy depends on the ground sample distance: building geometries are reported as above ground envelops composed by one or more building parts with different elevation reference and height. Roof shapes are hardly comprised in current TDBs and buildings height corresponds to the eave height. Hence, geometric appearance of buildings within the TDB refers to the so called "block model". Semantic contents from the TDB also indicate the main use of each building within a city: this is a broad information as it does not consider minor functions (e.g. commercial activities located on the ground floor of an apartment building) whose energy consumption patterns may differ from the main one.

Given these characteristics, in the D.P.1 coarse TDB are mainly manipulated in order to derive the main geometric data to be used as inputs in the energy balance spreadsheet. First of all a 3D reconstruction of each building is processed extruding each building part for the relative height. Consequently, the following parameters can be extracted directly from the TDB for each building:

- Gross volume, obtained as the sum of the volume of each building part composing the building;
- Outer surfaces (roof surface size; horizontal surfaces, with outdoors or ground boundary conditions; facades dimensions and orientation).

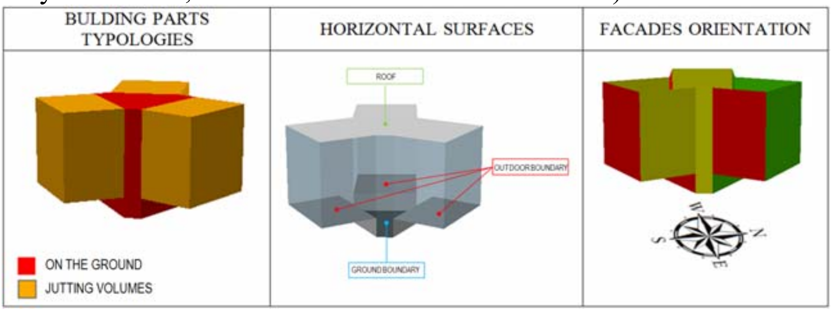

Figure 2. Buildings geometric data extraction

Computable parameters are listed below:

- Number of floors, derived assuming a constant storey height. As the constant storey height is an assumption, the number of floor calculated might differ from the actual building;
- Surface-to-volume ratio;
- Gross heated area, obtained as the sum of each building part footprints multiplied for the number of floor calculated;
- Net heated surface, computed subtracting a standard wall thickness corresponding to 15% of the gross floor surface;
- Net heated volume, computed multiplying the Net heated surface for a local standard net storey height;

- Window surface, computed using the local standard window/floor surface ratio, equally applied to all facades orientation.

Semantic information extracted from the TDB refers to the main use specified for each building: the assumption adopted is that all analyzed constructions host exclusive functions.

As described before TDB do not provides information about the year of construction of each single building: nevertheless this information is essential for the determination of the constructive and thermal characteristics of buildings and buildings components. For this purpose, thematic maps available in public administrations at different levels , like land use cartographies (realized for environmental monitoring purpose) and historical analyses on the progression of the urbanization process occurred along time (contained in municipal Urban Plans), are crucial in order to overcome this lack of information and to estimate an approximate construction period for each building analyzed.

DATAPACKAGE 2

In the D.P.2 TDB data processed for D.P.1 are semantically enriched with other data coming from existing archives. As previously stated, no connection with external data sources is implemented on the TDB. Nevertheless, cadastral identifier and addresses are key reference able to relate buildings in the TDB with many relevant databases: in order to include external data in the energy calculation, the association between buildings in the TDB, cadastral IDs and addresses need to be implemented.

Starting from TDB data, consistency between buildings in the TDB and cadastral parcels have to be created through a geometrical re-definition of buildings geometries considering cadastral boundaries and the attribution of the related identifier. At the end of this processing all existing information connected to the cadastral references (e.g. Energy Performance Certificates, thermal plants data, residents data) are automatically georeferenced and linked to the related building in the TDB. For what concern address-related data, building address is an essential information to relate assets to social and economic data referred to users behaviors, preferences and needs, but in this specific work it is crucial as it enables the georeferencing of actual consumption data.

So, in the D.P.2 data computed in D.P.1 are integrated with semantic data coming from other sources. Thus, new acquirable data for each building concern:

- the actual number of floors, below and above the ground;
- the number of dwellings;
- the distinction between heated and non-heated portions of a building (e.g. garage and attics);
- the different uses within the same building (e.g. for buildings with shops at the ground floor and residential unit on upper storeys);
- the actual year of construction (or the construction period) for each specific building, when Energy Performance Certificates reporting this information are available;

- the number of people and families living inside each buildings and demographic data concerning residents age;
- the yearly electricity and gas consumption registered in the previous year.

DATAPACKAGE 3

In D.P.3 data collected in the previous D.P.s are furtherly enriched with data coming from BIM models.

The database of BIM models could be enriched with information collected during on-site visits, gathered through on-line documents (i.e. Cened and Curit regional websites) or retrieved from on-line services for visualizing maps and views of every location (i.e. Google Maps).

Detailed data concern:

- detailed shape of the building and its elements;
- heated and non-heated volumes of buildings (thermal zones); net and gross heated area;
- for each surfaces (i.e. wall, floor, roof and window): area, exposition, adjacent environment (i.e. outside, against the ground, toward non-heated space), thermal properties (i.e. thermal transmittance, solar heat gain coefficient);
- length of thermal bridges;
- information on mechanical equipment;
- information related to shading elements and obstructions to solar access of the buildings.

Some parameters could be the same among D.P.2 and D.P.3, however the accuracy of the data differs. As an example, in D.P.2 thermal transmittance has been set depending on the year of construction, while in D.P.3 it has been evaluated considering the thickness and the properties of each material.

6. Further works and expected outputs

As previously mentioned, the research described in this paper is still in progress. The definition of a simplified method for the inclusion of solar gains, considering shadows produced by surrounding buildings and land morphology is still in progress for D.P.1 and 2; also the analysis on thermal plants data is currently underway.

For the Gavardo case study all available building data have been acquired: data pre-processing aimed to create connection between TDB, cadaster and addresses is currently in progress.

Meanwhile, first attempts were carried out for the Melzo case study, where the harmonization process between TDB, cadaster and addresses were already computed (Guzzetti et al., 2012). The outputs, obtained using the three Data Packages described, will be compared with real consumption data and the accuracy in energy analysis will be measured as soon as consumption data will be provided. This will enable considerations both on the improvement in estimates precision related to a progressive data refinement and on the efforts required for the realization of such refinement, determining the optimal trade-off between costs and benefits of data integration.

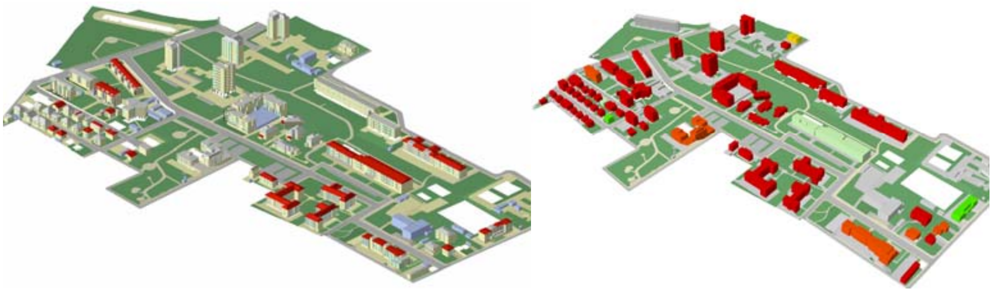

Figure 3. City Model of the Melzo case study, integrated with BIM data (on the left), and related buildings energy classification (on the right)

7. Conclusions

The presented paper aims to gather available and relevant data for all buildings within a city: the results will be a "ready-to-use" package of information that might be used for the development of applications and in the realization of analyses at city scale, orienting public policies and highlighting new possibilities in constructions market.
The European Directive on energy efficiency requires progressive higher thresholds of energy saving and to promote, define and control urban interventions and policies for energy enhancement is fundamental to achieve European environmental tasks.
A citywide Building Information System would allow to characterize the quality of the built assets and to relate buildings having specific features with natural and built environment surrounding. The core of the issue is the building that it is not only considered as a physical object but as central reference for everything that relate to it, like utilities, taxes, energy performance, users, etc. The integration of building data and the introduction of an interoperable framework would allow optimizing the informative heritage available, reducing redundancies and improving the usability of data for applications and analysis.

8. References

1. Amado, M. and Poggi, F., "Towards solar urban planning: A new step for better energy performance" Energy Procedia, 30, pp.1261–1273 (2012)
2. buildingSMART Finland. "Common BIM Requirement 2012-Series 10: Energy Analysis", Finland (2012)
3. Carrión, D.; Lorenz, A.; Kolbe, T.H. "Estimation of the energetic rehabilitation state of buildings for the city of Berlin using a 3D city model represented in CityGML", Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., XXXVIII-4/W15, 31–35 (2010)
4. CIC Research Group, Department of Architectural Engineering, The Pennsylvania State University. "BIM Project Execution Planning Guide-Version 2.0", USA (2012)

5. Ciribini, A.L.C., De Angelis, E., Taglaibue, L.C., Paneroni, M., Mastrolembo Ventura, S., Caratozzolo, G. “Workflow of interoperability toward energy management of the building” ”, ISTEA Conference on Environmental Sustainability, Circular Economy and Building Production (2015)
6. De Angelis, A., Re Cecconi, F., Tagliabue, L.C., Maltese, S., Pansa, G., Torricelli, A., Valagussa, S., “Reliability of energy performance evaluations through different BIM and BEM models”, ISTEA Conference on Environmental Sustainability, Circular Economy and Building Production (2015)
7. Guzzetti, F., Marchetti, M., Pasquinelli, A., “Development rights management through GIS technology: the case study of Melzo (Milan)”, Proceedings of the International Conference INPUT (2012)
8. Hawerk, W., “ALKIS - Germany’s Way Into A Cadastre For The 21st Century”, FIG Working Week (2001)
9. INSPIRE - Infrastructure for Spatial Information in Europe, 2013. Data Specification on Buildings – Technical Guidelines (D2.8.III.2_v3.0) (2012)
10. Kaden, R. & Kolbe, T., “City-Wide Total Energy Demand Estimation of Buildings Using Semantic 3d City Models and Statistical Data”. ISPRS Annals, II(November), pp.27–29 (2013)
11. El-Mekawy, M., Östman, A., Hijazi, I., "A Unified Building Model for 3D Urban GIS" ISPRS Int. J. Geo-Inf.1, no. 2: 120-145 (2012).
12. Morello E. and Ratti, C., “Sunscapes: ‘Solar envelopes’ and the analysis of urban DEMs,” Comput. Environ. Urban Syst., vol. 33, no. 1, pp. 26–34 (2009)
13. Mostashari, A. et al., “Cognitive Cities and Intelligent Urban Governance”, Network Industries Quarterly, 13, pp.4–7 (2011).
14. Nouvel, R., Zirak, M., Dastageeri, H., Coors, V. and Eicker, U., “Urban energy analysis based on 3D city model for national scale applications”, 5th German-Austrian IBPSA Conference, pp.83–90 (2014)
15. Olivares García, J. M., Virgós Soriano, L. I.and Velasco Martín-Varés, A., 2011. 3D Modeling and Representation of the Spanish Cadastral Cartography, 2nd International Workshop on 3D Cadastres 16-18 November 2011, Delft, the Netherlands (2011)
16. Open Geospatial Consortium, “OGC City Geography Markup Language (CityGML) En-coding Standard”, OGC 12-019, Version: 2.0.0 (2012)
17. Strzalka, A., Bogdahn, J. and Eicker, U., “3D City Modelling for Urban Scale Heating Energy Demand Forecasting”, Ashrae Hvac&R, 17(4), pp.526–539 (2010)
18. Thompson, E. M., Greenhalgh, P., Muldoon-Smith, K., Charlton, J. and Dolnìk, M.“Planners in the Future City: Using City Information Modelling to Support Planners as Market Actors”, Urban Planning, Volume 1, Issue 1, Pages 79-94 (2016)
19. UNI/TS 11300-1:2014
20. U.S. General Services Administration Public Buildings Service, “GSA BIM Guide Series 05: BIM Guide for Energy Performance”, USA (2014)
21. Van den Brink , L., Stoter, J. and Zlatanova, S., “Establishing a national standard for 3D topographic data compliant to CityGML”, International Journal of Geographical Information Science (2013)