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INTELLIGENT INFORMATION SYSTEMS FOR THE REPRESENTATION AND MANAGEMENT OF THE CITY
Urban survey and design for resilience

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ABSTRACT
Recent emergencies have triggered a series of proposals, revisions and regulatory updates. In Italy, as part of the Italian Decreto Rilancio, a proposal to introduce a compulsory building file seems to have been accepted. If this proposal is followed up, we could soon see the collection of a series of data and information on the building stock of our cities. This contribution defines a proposal for the organisation of this systematic collection, suitably supported by advanced IT tools, to make possible the start of a renewed season of monitoring, management, planning and development of more resilient buildings and cities. The proposed idea is to channel the information and data on individual buildings into a single database that can provide a comprehensive, unambiguous and multi-scalar picture of the urban system.

KEYWORDS
integration of GIS and building models, representation and analysis at the urban scale, integrated planning, BIM, CIM

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Looking at the development and the changes that the urban environment is going to experience soon, it is clear that Italian cities need to be equipped with the technological and digital tools to face the management processes of the emerging model called 'smart city'. Modern cities will have to be able to plan new policies of expansion, conversion, requalification and improvement of the urban environment – starting from principles aimed at environmental, social and economic sustainability – and support the dynamic character of the socio-economic model that distinguishes our era. In this regard, modern 'smart cities' will not be able to do without management tools that provide integration between different methodologies, different technological tools and specific procedures that can provide digital models based on real data, on which to build development scenarios. The proposed idea is to convey the information and data related to individual buildings in a single database that can provide a comprehensive, unambiguous and multi-scalar picture of the urban system: from the individual building, the individual criticalities/opportunities, up to understand the entire urban organism in its entirety. This would allow the promotion of future targeted interventions, but well inserted in a systemic way in the urban and territorial context. Specifically, the discussion will analyze the possibility of managing the existing Italian building stock through the integration of geographic information systems (GIS) and building models (BIM).

With the so-called BIM Decree, Italian Ministerial Decree 01/12/2017 n. 560, in the short term we will gradually come into contact more and more with numerous digital building information models (Building Information Model), models that can monitor and hold together all in the phases of the life cycle of buildings (Fig. 1). As is often the case following traumatic events, the pandemic spread of Covid-19 has triggered a series of proposals, revisions and regulatory updates. In particular, in Italy, as part of the Italian Decreto Rilancio, it seems that a proposal to introduce a mandatory building file has been accepted. If this proposal is followed, soon we could see the collection of a series of data and information on the consistency of the building stock of our cities. This data collection, if combined with the use of BIM integrated with a geographic information system, would make possible the start of a season of monitoring, management, planning and computerized development of more resilient cities. From this point of view, the outline of the building file should contain a description of the building from a technical and administrative point of view, with information relating to the state of fitness, safety, plant equipment, maintenance actions, types of construction and energy efficiency parameters. A mass of data that, if put into a system, can provide, appropriately treated, a solid basis for decision-making.

The reflections towards an increasingly integrated management, and aimed more at the digitization of information relating to the urban environment, would marry the smart city philosophy, also aligned to the regulatory updates mentioned. Considering then that the mandatory BIM will allow to implement and complete the 3D database of the city, it would be appropriate to update and/or create integrated cartographic databases geo-referencing parametric digital models, ensuring a global vi-

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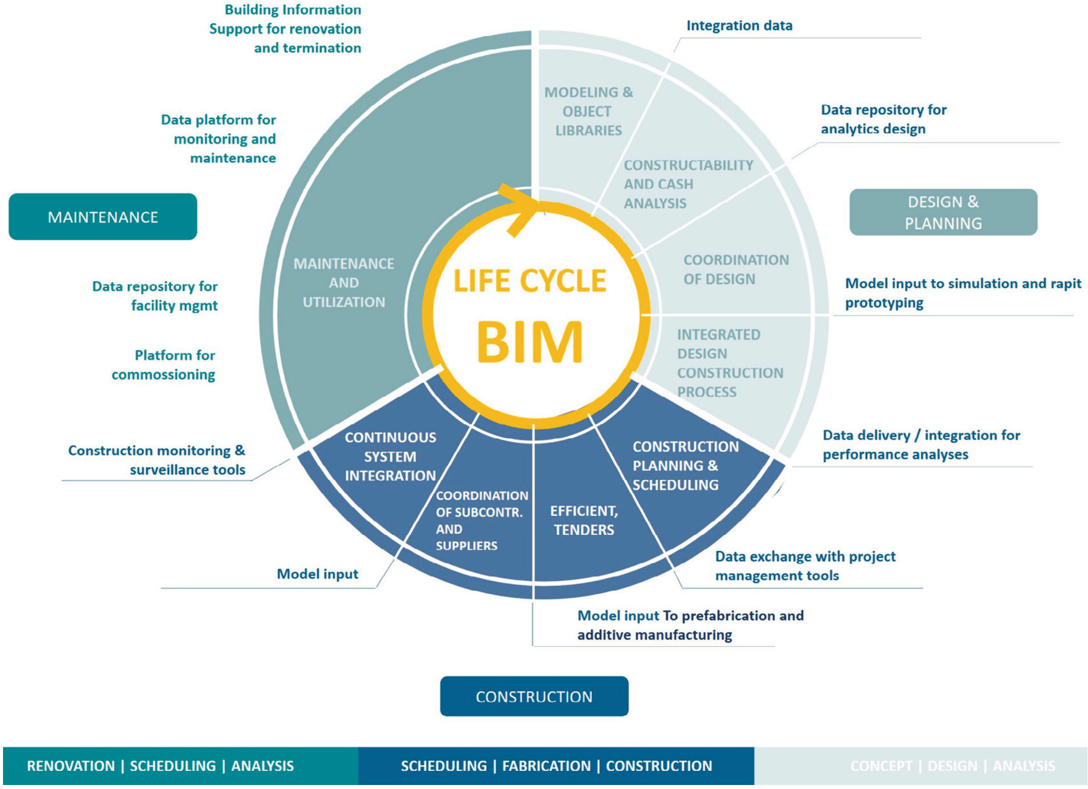

Fig. 1 | Diagram of the BIM model during the design, construction, and maintenance phases of the building artefact.

sion and monitoring of the city. In this scenario, the spatial context would be managed technically and technologically with GIS tools, a powerful set of tools capable of acquiring, storing, retrieving, transforming, analyzing and reproducing spatial data related to the territory (Burrough and McDonnell, 1986). The difficulty in retrieving data, to date, remains one of the most expensive obstacles in terms of energy and time, making the planning, programming and control of interventions cumbersome. The building file linked to the BIM model, inserted in a GIS environment, available and queryable in the different scales of representation, could instead be a real and new key to solve the problem of 'as-built' documentation (Vacca et alii, 2018), as well as to make the same processes of planning, programming and control of interventions more efficient. An interesting example of urban environment analysis is the Sun Solar City project in Bolzano (Comune di Bolzano, 2013). A WebGIS mapping in which the potential exploitation of building roofs is represented if photovoltaic panels for electricity production were installed there, to reduce per capita annual CO_2 emissions by 80% by 2030.

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The case of asset management[1] | The implementation of the asset management process requires a significant amount of continuously updated information and data related to the different phases of the artefact's life cycle: data related to the design and review phases, correspondence between the actors involved in the decision-making process, maintenance records, information about modifications, and information on maintenance works are necessary to provide asset managers with a complete picture of the extent of the existing data archive for each architectural artefact (Kyle, 2001). This means that building asset managers should use a comprehensive and up-to-date system consisting of a digital data set that reflects the history and current state that has characterized and characterizes their building assets. Data collection is critical to the implementation of an asset management system, and the ability to collect detailed data enables effective asset management (Woodward, 1997; Vanier, 2001).

Building life cycle management needs to be supported by a precise and detailed set of information that differs from that contained within the traditional construction process (Häkkinen, 2007). To be able to analyze and interrogate data and information that characterize buildings within a single environment, it is possible to use work environments that process and make available all the information that characterizes the building in the different temporal phases of the life cycle, from the design, material procurement and construction phases of the building, acting as a collector of all the information needed for operations and maintenance (Howell and Batcheler, 2005; Campell, 2007). A BIM[2] model addresses these needs by allowing different hierarchies of information to be captured and managed depending on the time phase of the building (Fig. 2).

When dealing with the theme of management as a crucial moment for the maintenance and conservation of an artefact, the problem of the organization and diffusion of knowledge represents one of the fundamental methodological and conceptual aspects (Calabrese, 2020; De Pasquale, 2020). The analysis of the traditional procedures leads to an understanding of how the problem has been faced until now considering separately the two fundamental factors: the representation on one side and the description on the other side. Currently, it is no longer conceivable to analyze and manage a building heritage without a series of descriptive data and other data related to representation. In this regard, the BIM represents an immediate and continuous biunivocal contribution between descriptive data and graphic data related to the geometry of the buildings under analysis. It also allows to modify the collected data and to insert them in the database both in the alphanumeric and in the graphic field. On the contrary, the two descriptive frameworks are directly related to each other and therefore, regardless of whether the modelling or the changes occur in one framework or the other, they are updated automatically and simultaneously in both.

The tools to support the management of the built heritage | When you need to manage an existing building, or better still with an asset composed of several buildings, often fragmented, you have to face a series of problems quite different from those that must be

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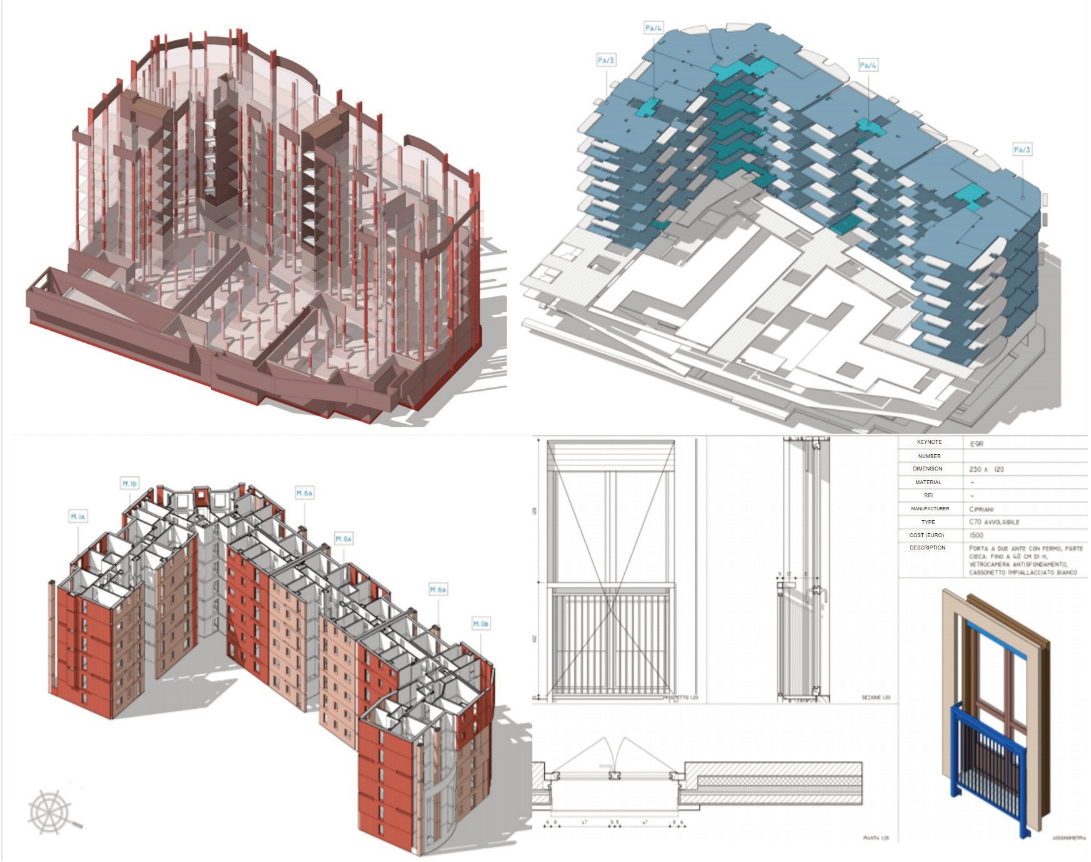

Fig. 2 | The project information within the BIM model (graphics by A. Alberti, 2014).

faced during the design and construction phases. Among the main difficulties, the management of information to be historicized and the plurality of technical and non-technical users involved in management and maintenance operations play a fundamental role. The two problems exposed can be solved by linking the BIM model of one or more buildings to a database or building management systems, such as BMS (Building Management System) and CAFM systems – Computer-Aided Facility Management (Dejaco, Re Cecconi and Maltese, 2017), or by linking the BIM model to the CIM[3] (City Information Modeling) model of the city in which it is inserted. The City Information Modeling represents the 3D model at the urban scale of the city, which within it collects the BIM models of individual buildings, the open-source information made available by the Municipality, related for example to public spaces, such as green and infrastructure networks, data related to roads, and also integrates within it all the information generated and implemented by the IoT through the sensors installed within the city territory (Fig. 3).

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By linking BIM to CIM, users are provided with an interactive environment, rich in information and data, which can be communicated through ad hoc elaborated representations, such as 3D city models, alphanumeric graphs, thematic tables, etc., where the information in addition to being accessible to all, can be analyzed, queried and shared in real-time (Hisham, 2018). Internationally, some cities, such as the city of Singapore, are implementing CIM models of the city's urban fabric to improve land management and planning. The Virtual Singapore[4] project aims to collect in a single environment all the information related to the buildings and the context in which they are inserted: a dynamic three-dimensional model of the city area is being created, connected to a collaborative data platform, where all users, can enter data and BIM models of the buildings, to obtain a single working environment for public agencies, private citizens and researchers (Fig. 4).

The implementation of a CIM realized through the contamination of public and private information, as in the case of the city of Singapore, has great potential to address problems related to city planning and management both at the urban scale and at the architectural scale, related to the individual building. From a first analysis, depending on the type of user, the following advantages can be highlighted: a) professionals and Public Administration operators have the opportunity to collaborate in the decision-making process on urban planning, through the use of the data that populate the platform, which are dynamic, since they are constantly updated, returning a reliable snapshot of the urban and building fabric investigated; b) citizens have the opportunity to check in real-time the updates related to their real estate assets and receive timely feedback from the agencies and competent bodies in case of need; In addition,

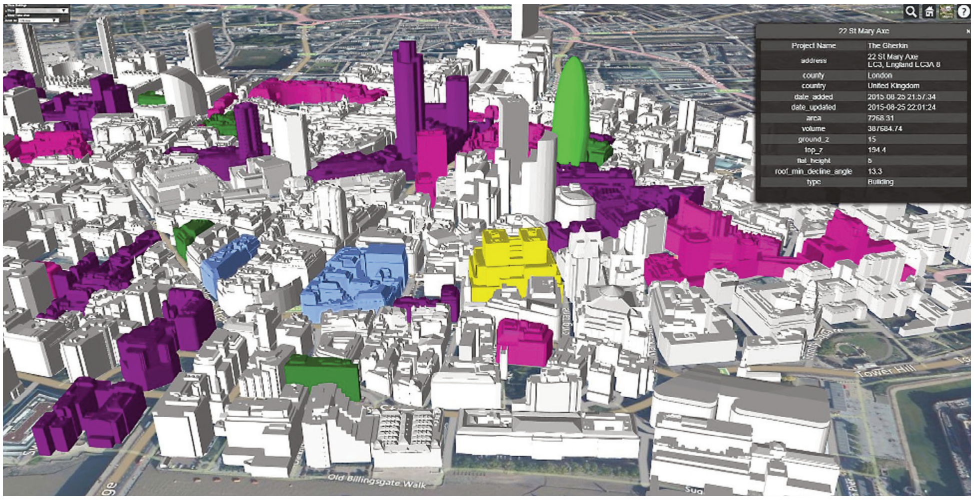

Fig. 3 | Example of visualization of a CIM model (source: geospatialmedia.s3.amazonaws.com/wp-content/uploads/2018/05/CIM1.png).

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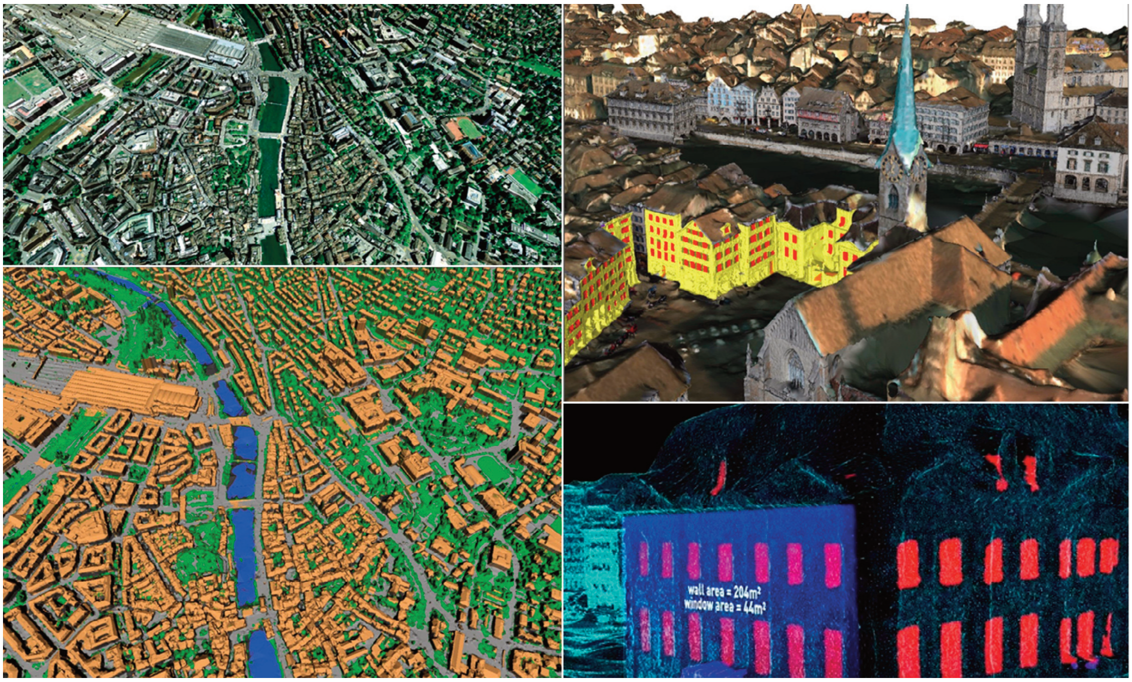

Fig. 4 | Some visualizations of the Virtual Singapore project: from the analysis of roofs with solar panels to the identification of routes without architectural barriers (source: www.nrf.gov.sg).

Fig. 5 | Some images related to the City Model of the city of Zurich: the project developed by ETH scientists was realized through the combination of millions of images and videos (source: ethz.ch).

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within the model at urban scale it is possible to evaluate the accessibility to public spaces, through the visualization of geometric data of the land, you will then have the identification and visualization in real-time of barrier-free paths for the disabled and the elderly; c) researchers and scholars will have the opportunity to query the system and create ad hoc thematic tables, in order to display information related to specific analysis, such as the analysis of the potential production of solar energy. The implementation of a CIM model today is, therefore, an instrumental prerequisite for the realization of sustainable city development, as has been widely documented by many scholars (Fig. 5).[5]

The realization of the file of the building: an example of case applied to the public heritage | Models are built to better understand and communicate complex realities: the organization and processing of data and information of the studied system need to build models capable of understanding and correlating document types, defining a series of attributes and qualities useful to the knowledge of the investigated area. During the design process, many models are built, for example, the architectural, structural and energy model, each of which represents, from a precise point of view, a semantically complete view of the system. In addition to being a fundamental aid to understanding, modelling is also a communication mechanism that allows different expertise to interact using a common language and to break down complex problems into smaller, manageable portions. The project modelling process provides an infrastructure and a set of methodological tools for understanding basic concepts and determining how and when a specific model, a precise view of the system, should be implemented and with what level of detail.

The application of the theoretical principles of the research to a significant case study, such as the social housing building designed and managed by ATC – Agenzia Territoriale per la Casa del Piemonte Centrale, consisting of 78 dwellings, built along the axis of Spina 4, in Via Fossata in Turin (Alberti, 2014; Fig. 6) was fundamental for the applied experimentation from which the problems to be solved and the proposals for innovation emerged (Fig. 7). This methodological approach will allow the subsequent export of the innovative results obtained to other public or private realities that daily manage huge real estate assets (Pesce, 2019). Today, BIM systems make it possible to draw great benefits from a wide-ranging evaluation of the interventions that can be programmed on public and private building stock, and therefore to analyze the effects that these interventions have in terms not only of architecture but also of urban planning. Through this tool, it will be possible to monitor the building resources and the prefiguration of architectural and/or urban planning solutions, to allow preventive evaluations of management and construction hypotheses.

From BIM to the Digital Building File | The Building File was introduced at the end of the ’90s with the Draft Law n. 4339-bis 30/11/1999 entitled Provisions on the Reg-

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ulation of the Construction Market and the Establishment of the File of the Building. Within article 1 are collected the definition and contents of the file[6]. In February 2019, the Government introduced several new features on its contents: starting from the assessment of vulnerabilities from natural hazards to get to the reconstruction of the history of each building, analyzing the interventions of seismic and energy adaptation, to collect within a single document all the information to date in possession of different entities. The new demands have pushed the scientific community to look for possible solutions to draw up the document with the help of virtual work environments that contained within them all the data of the building during its entire life cycle. The BIM, in its meaning of AIM model, represents a possible answer to the new needs: the elaboration of the digital building file, in BIM environment, requires the definition, structuring and hierarchy of the data that characterize the artefact to translate them into informative attributes associated with the elements that make up the model. The same possibility of communicating information and data with different representations, such as two-dimensional, three-dimensional and abacus graphic representations (Fig. 8), will allow to dynamically manage information and data useful for the realization of parts of the file. The possibility of managing information related to spaces, with the automatic mapping of areas and destinations of use, finds multiple functions within the building file: from the management of areas for leases to the mapping of destinations of use up to the analysis of the exploitation of spaces (Fig. 9).

However, although the use of BIM for the realization of the digital building file turns out to be very easy and immediate, the BIM environment still turns out to be too rigid for the temporal management of the building process, and the realization of the project phases, turns out to be insufficient for the daily management of the building[7]: to meet this need it would be necessary to create a temporal phase for each day. It is possible to overcome this system rigidity by connecting the BIM model to a database or to a building management tool, such as BMS or CAFM, working environments in which the time attribute can be easily managed. The BIM model can be connected to the database through API[8], Application Programming Interface, creating a bidirectional link between the two working environments, which will allow for up-to-date and aligned working environments. If you connect model and database to a web service created ad hoc, i.e. a software able to share data between different systems that allow the exchange of data between the BIM model and web pages, you can create an interface for consulting data that is more immediate in updating and reading by various users (Fig. 10).

Conclusions | The contribution is intended as a brief overview of integrated tools capable of combining, integrating and exploiting the full potential of existing representation and monitoring systems. The conventional approach foresees the application of information systems – BIM and GIS – mainly in a sectoral way, addressing specific areas and departing from the principle of globality of the 'smart city' model. Promoting a combined use of these approaches, and thus outlining the features of the method-

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Fig. 6 | Two images related to the building site of the residential building in Via Fossata in Turin (source: www.atc.torino.it).

Fig. 7 | The complete architectural model of the building for residential use of the ATC, located in Via Fossata in Turin (graphics by A. Alberti, 2014).

ology, would open the door to new design and planning methods capable of integrating interventions on a building and urban scale in a systemic way, favouring the interoperability of information (Avena, 2020; Mangon, 2020).

The coordinated use of information technologies for data and information management guarantees the restitution and monitoring of the human environment in the form

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of a dynamic inter-scalar model. These representations would provide a concrete opportunity to serve the programming, planning, design and control of urban development interventions. By aligning with European directives, which promote the use of BIM methodology as a single tool for design, it demonstrates by extension the possibility of using privately produced models, not only to manage and monitor the building stock but also to plan future urban development according to the principles of sustainability. In fact, it would provide a tool that is consistent with the Smart City model, capable of reducing the timescales of the various processes, guaranteeing a more detailed level of information and ensuring the possibility of putting together elements that are difficult to compare. The parametric information model simultaneously 'records, archives, preserves' and 'represents, simulates, prefigures'. It does so at the same time as we operate, reflecting changes and variations in real-time. For this reason, a substantial part of the time dedicated to setting up the model is devoted to the study and preparation of the graphic codes and the sensitivity of the representation.

But the model also has limitations. One has to think about the boundaries of the model and keep them in mind. It does not operate in the round on the building process. An example: the first boundary is related to the use and implementation of the model in its geometric aspect, these are only open to a certain kind of skills; if I have to intervene in a designed way on the form, attributes and relations of the model, I have to have a certain skill. The first boundary is therefore related to 'competence', 'I must know how to do'. How can this first boundary be overcome? The preparation of the process must involve skills that do not necessarily have to operate directly on the geometric component of the model. I have to make the system 'more democratic', i.e. open up the BIM model to skills that might otherwise benefit from it.

A second edge of the boundary concerns this next aspect: from the moment in which I face a great cost for the production of the model (in terms of resources, tools and procedural apparatuses that govern the information flows), this must reverberate its effects, it must be reflected, in its use as widespread as possible (in the project, in the construction site, in the life of the work, in the file precisely); it is necessary to amortize the investment, and we do this at the moment in which we make the model accessible, appropriately approximated and reduced to only the aspects of interest) to the activities of maintenance and management of the built environment: we dilute the cost of building the model, we amplify its benefits. Finally, the digital information model presents, in this rapid and non-exhaustive treatment, another important margin of its boundary, connected to the risk of proliferating the number of parameters that must be associated with it, with a consequent reduction in the overall efficiency of the process.

Therefore, the need to overcome these limits becomes imperative, by associating another paradigm to the object-oriented one, the relational one, linked to the management of databases (Zhang et alii, 2009). This is the meeting point between model and database, this is the challenge that the setting up of a shared system of knowledge must face: the virtual exploration of the artefact within shared environments, such as

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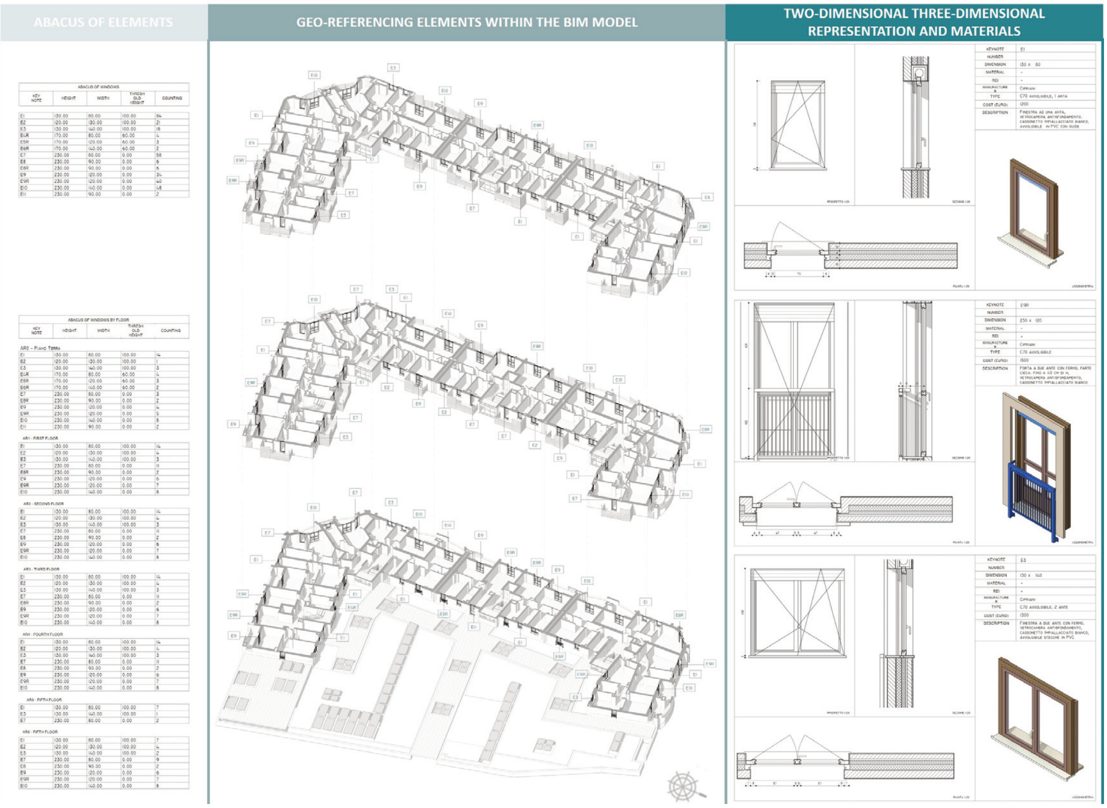

Fig. 8 | Example of the possible representations of the elements in the BIM environment: abacus of the external doors and windows, visualization of the elements within axonometric cutaways of the building levels and bi-dimensional and tri-dimensional representation of the doors and windows (graphics by A. Alberti, 2014).

the 'network', requires the identification of representation techniques dedicated to the interaction between professional and artefact: the possibility of exploring the model in spatial-perceptual terms (central projection) does not necessarily translate into speed and ease of access to the individual parts and therefore to the documents related to them. The information apparatus, in particular, that relating to the internal spaces of the artefact, is often more simply accessible by using parallel projections and planes that cut through the object (sections) or appropriate methods that allow parts to be made transparent for others. These aspects, which can be defined as navigation and data access within information systems, must also respond to standardised methods and procedures, and this is a frontier for future development.

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ABACUS OF ROOMS | DESTINATIONS OF USE - ROOM SQUARE METRES - ROOM CUBIC METRES - TYPE OF FINISHES

PLAN OF ROOMS | GROUND FLOOR

N°	DESTINATION OF USE	AREA OF THE ROOM	VOLUME (H=2.70m)	PERIMETER	WALL FINISHING	FLOOR FINISHING
A000	SCALA A ANDRONE	46.0 M^2	124.2 M^3	46.22 M		
A1_A	DIS	3.6 M^2	9.6 M^3	7.74 M	LIME PLASTER	PORCELAIN TILES
A1_B	B	7.4 M^2	20.1 M^3	11.39 M	LIME PLASTER	PORCELAIN TILES
A1_C	S+K	15.1 M^2	41.0 M^3	16.21 M	LIME PLASTER	PORCELAIN TILES
A1_D	LM	15.5 M^2	41.8 M^3	16.10 M	LIME PLASTER	PORCELAIN TILES
A2_A	DIS	4.2 M^2	11.3 M^3	8.92 M	LIME PLASTER	PORCELAIN TILES
A2_B	B	7.0 M^2	18.8 M^3	11.23 M	LIME PLASTER	PORCELAIN TILES
A2_C	K	8.8 M^2	23.7 M^3	12.63 M	LIME PLASTER	PORCELAIN TILES
A2_D	M	17.9 M^2	48.2 M^3	18.10 M	LIME PLASTER	PORCELAIN TILES
A2_E	R	1.0 M^2	2.6 M^3	4.20 M	LIME PLASTER	PORCELAIN TILES
B000	SCALA B ANDRONE	43.6 M^2	117.8 M^3	49.66 M		
B1_A	DIS	6.7 M^2	18.2 M^3	12.34 M	LIME PLASTER	PORCELAIN TILES
B1_B	B	7.5 M^2	20.2 M^3	11.90 M	LIME PLASTER	PORCELAIN TILES
B1_C	S+K	16.9 M^2	45.5 M^3	16.85 M	LIME PLASTER	PORCELAIN TILES
B1_D	LM	14.9 M^2	40.2 M^3	15.88 M	LIME PLASTER	PORCELAIN TILES
B1_E	R	1.3 M^2	3.5 M^3	4.77 M	LIME PLASTER	PORCELAIN TILES
B2_A	DIS	6.0 M^2	16.2 M^3	11.08 M	LIME PLASTER	PORCELAIN TILES
B2_B	B	8.2 M^2	22.1 M^3	12.60 M	LIME PLASTER	PORCELAIN TILES
B2_C	K	9.1 M^2	24.6 M^3	12.34 M	LIME PLASTER	PORCELAIN TILES
B2_D	M	16.7 M^2	45.1 M^3	17.03 M	LIME PLASTER	PORCELAIN TILES
B2_E	R	2.4 M^2	6.5 M^3	6.31 M	LIME PLASTER	PORCELAIN TILES
B3_A	DIS	6.1 M^2	16.4 M^3	11.24 M	LIME PLASTER	PORCELAIN TILES
B3_B	B	7.4 M^2	20.1 M^3	11.81 M	LIME PLASTER	PORCELAIN TILES
B3_C	M	21.4 M^2	57.7 M^3	22.32 M	LIME PLASTER	PORCELAIN TILES
B3_D	R	2.0 M^2	5.3 M^3	5.80 M	LIME PLASTER	PORCELAIN TILES
B4_A	DIS	3.5 M^2	9.3 M^3	7.61 M	LIME PLASTER	PORCELAIN TILES
B4_B	B	6.8 M^2	18.3 M^3	10.93 M	LIME PLASTER	PORCELAIN TILES
B4_C	S+K	14.3 M^2	38.6 M^3	16.05 M	LIME PLASTER	PORCELAIN TILES
B4_D	LM	14.2 M^2	38.5 M^3	15.55 M	LIME PLASTER	PORCELAIN TILES
B4_E	R	1.1 M^2	3.0 M^3	4.42 M	LIME PLASTER	PORCELAIN TILES
B5_A	DIS	7.0 M^2	19.0 M^3	12.87 M	LIME PLASTER	PORCELAIN TILES
B5_B	B	7.5 M^2	20.2 M^3	11.60 M	LIME PLASTER	PORCELAIN TILES
B5_C	S+K	14.5 M^2	39.1 M^3	15.40 M	LIME PLASTER	PORCELAIN TILES
B5_D	LM	14.9 M^2	40.3 M^3	15.62 M	LIME PLASTER	PORCELAIN TILES
B5_E	R	1.7 M^2	4.6 M^3	5.27 M	LIME PLASTER	PORCELAIN TILES

APARTMENT AREAS | ACCOMMODATION AREA - LEVEL

HOUSING ABACUS

NAME	AREA	LEVEL
AR0 – GROUND FLOOR		
A1	53.64 M^2	AR0 – GROUND FLOOR
A2	49.07 M^2	AR0 – GROUND FLOOR
B1	58.50 M^2	AR0 – GROUND FLOOR
B2	51.99 M^2	AR0 – GROUND FLOOR
B3	45.71 M^2	AR0 – GROUND FLOOR
B4	47.87 M^2	AR0 – GROUND FLOOR
B5	55.72 M^2	AR0 – GROUND FLOOR
C1	47.22 M^2	AR0 – GROUND FLOOR
C2	83.19 M^2	AR0 – GROUND FLOOR
D1	56.78 M^2	AR0 – GROUND FLOOR
D2	66.23 M^2	AR0 – GROUND FLOOR
D3	60.83 M^2	AR0 – GROUND FLOOR
D4	74.44 M^2	A AR0 – GROUND FLOOR
AR0 - PIANO	751.21 M^2	

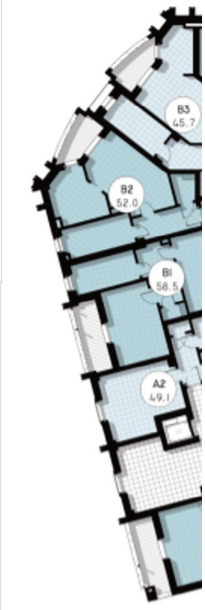

Fig. 9 | Abacus of rooms and abacus of accommodations in the BIM environment (graphics by A. Alberti, 2014).

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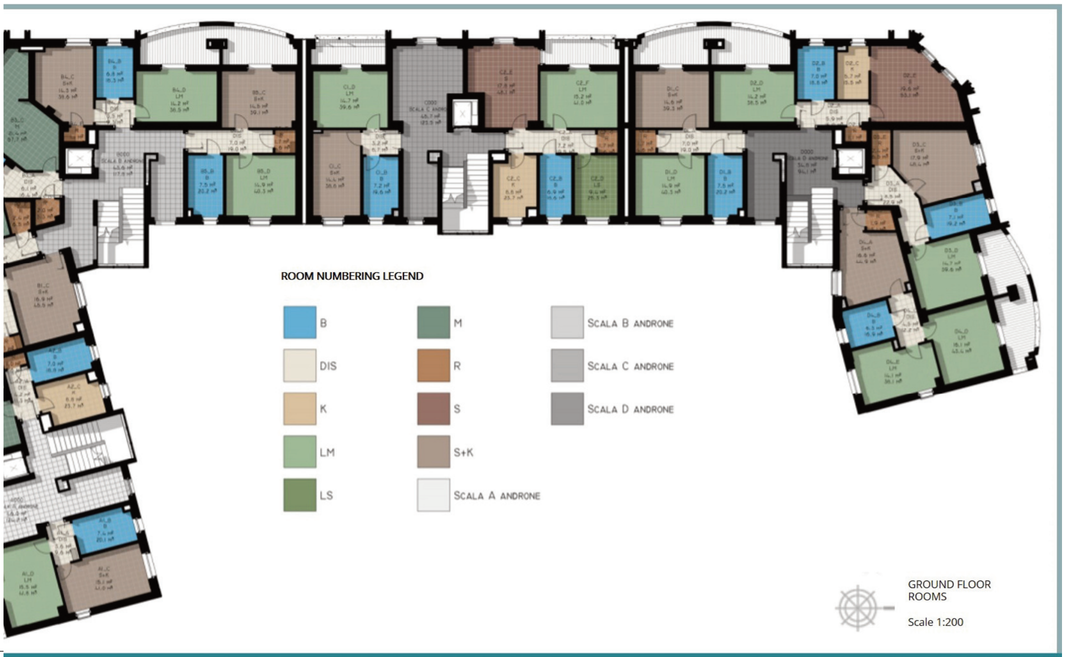

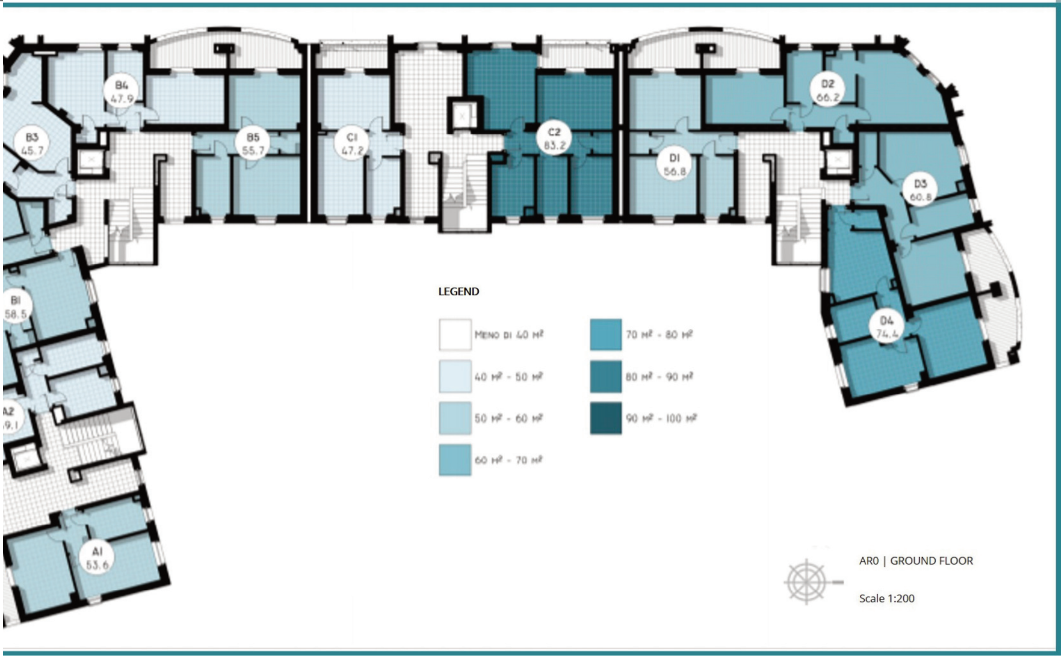

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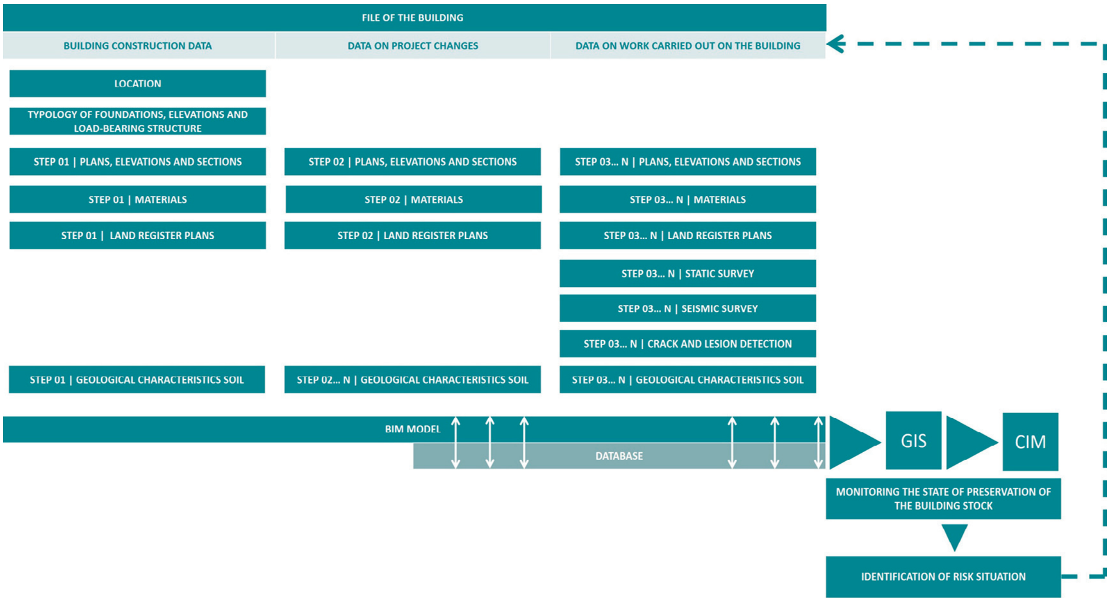

Fig. 10 | The artefact file: from BIM to CIM, with database and GIS support.

itage', 'From BIM to the Digital Building File' by M. Vozzola, the paragraph 'The realization of the file of the building: an example of case applied to the public heritage' by M. Lo Turco and M. Vozzola, and finally the 'Conclusions' by M. M. Bocconcino.

Notes

1) Asset Management is a term that refers to the management of assets, whether this is understood as asset management, resource management or administration of assets. The meaning we refer to in our text is the management of real estate assets.

2) At least 30 definitions and interpretations can be associated with the term BIM (Building Information Model) in the literature (Matějka and Tomek, 2017). As presented within the study conducted by P. Matějka it is possible to define three categories to classify the meaning of BIM. The first category corresponds to the basic understanding of BIM as a 'product', understood as a virtual building model, and the acronym BIM is interpreted as both Building Information Modeling and Building Information Modelling. The second category associates the definition of BIM with the introduction of a new 'method' of working, understood as a set of tools and processes for workflow management. The third category defines BIM as a 'methodology' for managing a building throughout its life cycle.

3) The term CIM was first introduced by Khemlani (2016) envisioning a digital representation of the city that would effectively support decision-making and analysis during natural disasters. It was later taken up first by Xu et alii (2014), who define CIM as a system for efficient city management to achieve real-time, centralized, and accessible sharing of information about various urban systems to improve the overall efficiency of urban management; and then by Amorim (2016) introduces City Information Modeling (CIM) as a system focused on city management, building design, planning, and monitoring, and is addressed as supporting the management of smart city infrastructure (de Souza and Bueno, 2019).

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4) The Virtual Singapore project is available at: nrf.gov.sg/programmes/virtual-singapore [Accessed 25 November 2020]. Virtual Singapore includes 3D semantic modelling of buildings and infrastructure, including detailed information such as material representation; geometric attributes of terrain, water bodies, vegetation, transportation infrastructure, etc.

5) For example, in addition to the case of the city of Singapore, we cite the study by Dantas, Sosa and Melo, 2019.

6) The Italian Draft Law n. 4339 bis, of 30/11/1999, 'Disposizioni in materia di regolazione del mercato edilizio e istituzione del fascicolo di fabbricato' (Provisions on the regulation of the construction market and the establishment of the file of the building), in Article 1 states: 1) It is established, concerning each building, the file of the building. This file is prepared, updated no more than ten years and kept by the owner or administrator of the condominium. On the file are noted the information relating to the building of identification, design, structural, plant, to achieve a suitable framework of knowledge from, where possible, the construction phases of the same, and are recorded changes made compared to the original configuration, with particular reference to the static components, functional and plant. 2) The production of the file of the building, duly updated, is a prerequisite for the issuance of permits or certifications of municipal jurisdiction relating to the entire building or individual parts thereof. At the time of the conclusion or renewal of lease agreements, as well as in case of alienation of the building or individual building units is made, by the owner and the administrator of the condominium, a declaration about the fulfilment of the obligations under this law. 3) The compilation of the file of the building provides a qualified technician based on technical-administrative documentation provided by the owner or administrator of the condominium or, if necessary, after the acquisition of additional knowledge, surveys and measurements. 4) The acquisition at public offices, at the central and local level, of the technical-administrative documentation necessary for the preparation of the file of the building, takes place without charge for the party concerned. For more information, see: senato.it/leg/13/BGT/Testi/Ddlpres/00004628.htm [Accessed 25 November 2020].

7) BIM technology is based on the 3D modelling of the building and the possibility of expanding the representation of the building to 4D, 5D, 6D and 7D, as also defined within the UNI 11337 standard. In particular, the dimensions added to the 3D model can be summarized as: 4D – Temporal Management – the introduction of the time factor, allows to plan the phases of life that characterize the artifact; 5D – Economic Management – the quantification of costs: through the 3D model and 4D it is possible to have control over the costs in the different phases of life of the building; 6D – Life Cycle and Maintenance – the management of the artifact during the phases of the life cycle, useful for the evaluation of the components that constitute the artifact: from systems to finishes; 7D – Sustainability – Sustainable Development – with this dimension there is the possibility to introduce the analysis of energy consumption of the building; analyzing from the earliest stages of design the energy performance that allows to adopt more efficient and effective technical solutions in order to obtain a manufactured product with the lowest energy consumption and ensuring the sustainability of the project (Barbagallo, 2018).

8) To link the BIM model to the database, it will also be possible to use plugins made ad hoc by the different software houses – for example for BIM models processed in Revit Architecture, it will be possible to use Revit DB Link, which allows managing a relationship between a Revit project and a Microsoft Access, Microsoft Excel or ODBC database.

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