The BIM towards the Cadastre of the Future enhanced through the Use of Technology / Il BIM verso il Catasto del Futuropotenziato tramite l'utilizzo della tecnologia

The BIM towards the Cadastre of the Future enhanced through the Use of Technology

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Abstract

Knowing, digitalizing, sharing represent the key concepts of this millennium. The construction and Real Estate sectors have the opportunity to take up this challenge by becoming promoters of intelligent data management that characterize buildings. The Building Information Modelling *(BIM) methodology, strengthened by the unstoppable technological progress, lays the groundwork for re-designing a structured knowledge system of the building heritage. This triggers a new concept of Cadastre of the Future, dynamic and updated, which interrogates the* Big Data *of the buildings according to a multidisciplinary and interoperable approach. The perspective is ambitious, but it is essential to define the correct methodological approach to govern the digitization of built heritage. The setting up of the first experimentations is carried out on the City of Turin. Pursuing the vision of augmented digital city, an interactive map has been created, exploiting new technologies, such as Augmented and Virtual Reality, to enable the dissemination of information to different types of users.*

Keyword: Building Information Modelling, Cadastre of the Future, Big Data, Augmented Reality, Virtual Reality.

Vision and methodological approach

The challenge of digitization that the construction industry is facing is absolutely an opportunity to be seized, but at the same time to be governed, in order to promote effective management of data over time. The *Building Information Modelling* (BIM) methodology, strengthened by the pervasive use of new technologies, represents the new frontier for organizing, exchanging and displaying a large amount of information on buildings, which thus become the reference *Big Data* of built heritage. Thanks to technological innovation and the *Internet of Everythings* (IoT), data interconnection and availability are essential areas of research in the digital age, as they involve various disciplines, even very different from each other, with different levels of maturity. Through the parametric digital models it is possible to arrange all the necessary information about the buildings in a unitary and congruent way, storing datasets that, within an integrated process, can be interrogated with a different level of detail according to the type of user and at the scale of interest. The BIM tools promote the census of buildings, related assets, systems and structural elements, complete with alphanumeric information, as well as geometric, and from external data sources such as photographs, videos, technical data sheets. In this way a real identity card of the building is created, able to evaluate the docu ment status and inefficiencies of the system during its entire life cycle. The vision of the Cadastre of the Future has matured in this context. It is interpreted as a methodological system for

managing information on the built heritage that aims at completeness and usability of data thanks to the typical tools of BIM, not only for tax purposes but also and above all for conservation, management and maintenance at building and urban level. It is not only a matter of storing documents already available, but of setting and planning methods of investigation, in-depth analysis, research and evaluations that can provide a cognitive framework of the built heritage through a rigorous process set up during the start-up phase. This process must then be implemented with data that can be continuously collected over time, with successive and different levels of detail related to different interventions on the building. In this scenario, more than ever, it is worth the concept that those who start well are half of the work and, of course, that if you do not start, you will never reach a result of adequate quality. Waiting to have all the necessary information, would mean continuing to work according to the traditional approach, that is, without a true knowledge of the built knowledge. In this perspective, the involvement of public administrations is undoubtedly essential. Even if with different reaction times, in recent years we have witnessed a growing interest and involvement of public administrations in innovative processes, also through experiences related to European planning, especially focusing on issues related to energy saving, and the dematerialization of information, so as required by the Prime Ministerial Decree 13/11/2014.

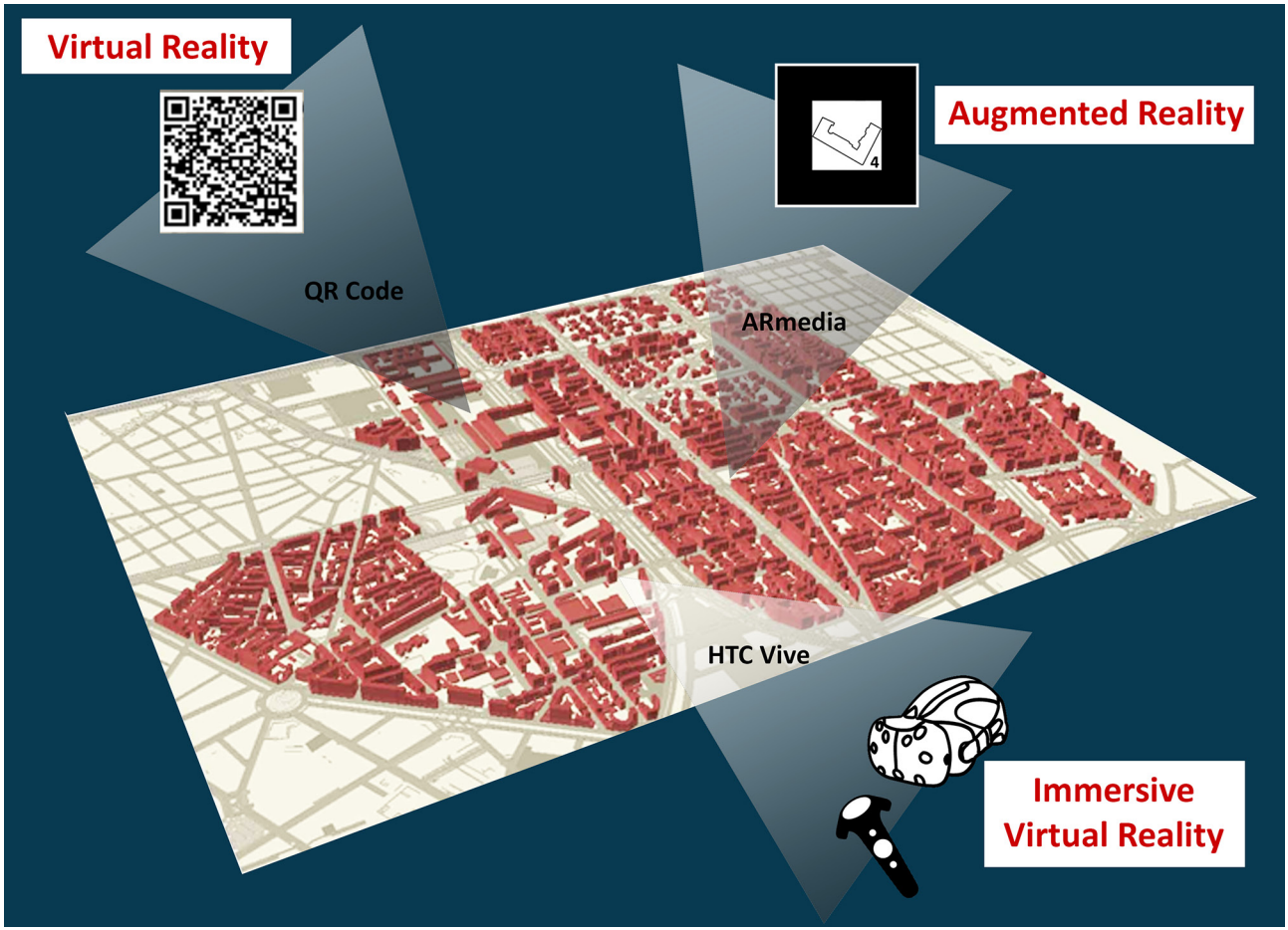
Case study

Preliminary experimentation towards this type of integrated research has been carried out by taking the City of Turin as a case study, putting experiences of data communication conducted within the *District Information Modeling and Management for Energy Reduction* (DIMMER) European project, focused on energy saving at the district scale, and the BIM digitalization of public buildings of the city (ToBIM) into system.
In DIMMER, whose demonstrators were Turin and Manchester [1], the main objective was the implementation of a middleware platform in which geometric and alphanumeric data coming from different domains were integrated *BIM, Geographic Information System* (GIS), *System Information Model* (SIM), IoT. The *District Information Model* (DIM) concept was introduced for the first time. The added value of this type of integration lies in the possibility of inter-exchanging data between the various stakeholders typically called to operate on both the construction scale, such as facility managers, and the urban one, such as energy managers/providers. This information, available through various systems with a web interface, such as platforms and dashboards, is aimed at improving the awareness and collaboration of different types of users on energy efficiency. The visualization of data is also explored through immersive and augmented virtual reality systems, in order to test new communication possibilities (fig. 1). Furthermore, a gamification approach has been adopted to make young people an active part of the awareness process on energy issues.
ToBIM [Osello, Ugliotti 2017] on the other hand, analyzes the most representative public buildings of the City of Turin at a construction level through an investigation process aimed at identifying the basic information necessary to guarantee management and energy monitoring activities in the context of a diversified and extended property portfolio. Re-establishing the knowledge of the artifacts is the setting up of information between the various actors to guarantee the effectiveness of the process, and therefore the analysis and comparison of the data acquired through the BIM modeling (fig. 2).
These experiences led to the creation of an interactive map, described below, which presents a cross section of the city of Turin to be explored through Augmented (AR) and Virtual Reality (VR), as enabling technologies in the communication process.
The main objective is to bring citizens, as well as operators, closer to a new, more reliable and accessible information management approach for buildings and the city, based on a process of intelligent digitization of the built heritage starting from the BIM method.

Cognitive survey preparatory to the definition of the BIM contents in the perspective of the Cadastre of the Future

Searching and analyzing existing information related to buildings is the first step in digitalizing built heritage. Starting from the experiences carried out in the aforementioned projects, it has been proved that information management is lacking in procedures and tools that guarantee their uniqueness and reliability. In fact, often *As-Built* documentation is paper-based or not updated and more digital versions are available, as well as the fact that the informa-

Fig. 1. DIMMER: investigation on urban scale visualization mode (graphic eleboration by the authors).



tion characterizing the building envelope or inventory of components is completely lost over time. Extending the analysis to the entire building process, it is evident that the most significant problem that afflicts the construction industry is the lack of information during the life cycle of buildings. The accuracy and completeness of the knowledge of the artefact is a key factor that profoundly influences subsequent investigative activities [Simeone et al. 2014]. In fact, any planning or maintenance intervention is based on what is known of that object. The scarce availability of resources, time and money, to find adequate information involves evaluating interventions based on assumptions that may lead to operating problems and consequent cost increases. The lack of data, or the exchange of information from one stage of the process to another and from one subject to another, represents a cost, which was quantified for the first time for this sector in December 2004 by the *National Institute of Standards and Technology* (NIST) [2] at $ 15.8 billion, of which two thirds are attributed to the *Operations & Maintenance* phase [NIST 2004]. Starting from this critical situation, the BIM can on the one hand constitute the instrument that becomes an integral part not only of the design and construction but also of the management of the building, on the other the method of data exchange between the various subjects involved, limiting the dispersion of information and the resulting costs. The digitalization activities of the building heritage must therefore be conducted in such a way as to guarantee knowledge, organization, sharing and usability of the information, which become the key to the success of this type of initiative. The modelling activity is aimed at returning a representation of the actual state of the buildings, where the added value is configured in the possibility of populating the database with information of interest for different types of users, from the citizen to the building manager, from the energy manager up to the city planner. At building level, the aspects considered mainly refer to the functional decomposition of the building, explaining typological and quantitative information regarding the composition of the envelope (opaque and transparent surface, materials), spaces and equipment, and technological systems. Parametric models must be set up in such a way as to provide significant information in real time under ordinary management and maintenance, but even more so in emergency conditions to design correct architectural, structural interventions and systems operations. The potential lies in the fact of being able to investigate the buildings not only as a function of what is visible, but above all of what is not. This aspect is particularly significant for the planning of ordinary and extraordinary maintenance of technological systems and for verification of structural or seismic stability. Consider, for example, the great advantages in case of seismic, alluvial, or fire events, in being able to have virtual models accessible by professionals in which to quickly find reliable information and technical data on the building. It is essential then to relate these data on the one hand with the intended use, occupation and usage profile of buildings, on the other with the urban/district context in which they are located. The data must be cross-examined in order to refine the level of detail of the surveys and assessments, promote more realistic optimization scenarios according to the actual characteristics of the site. It is very different, in fact, to compare the high energy consumption of a building, in consideration of its extension (e.g. one level or high vertical development), of the specific function (e.g. school or police headquarters), of the opening period (e.g. limited opening or H24), of the types of lighting devices present (e.g. dated or last generation), and of the possible presence of specific equipment (e.g. computers or laboratories), compared to not having any reference information. Furthermore, the planning of any efficiency enhancement measures must be the result of a careful evaluation of the cost-opportunity balancing, ie technological-plant engineering solutions actually applicable also in consideration of the structural and use capacities.

Also in *Smart City* perspective, it is very important to know the real situation of the heritage, in consideration of the activities of territorial planning, management and energy efficiency, therefore the information collected on a building scale must necessarily be correlated with the urban territory. BIM offers a broader perspective to analyze the heritage of the city, promoting tools for asset management that can be integrated with GIS systems in order to enrich spatial information with those on individual buildings. This, currently in the phase of experimentation and research, would allow an efficient and effective management of the facilities at the district/city scale, evaluating not refurbishment operations but also optimizations of systems networks and energy consumption. BIM data, combined with other datasets thanks to ICT, promote a dynamic cross-sectional vision of heritage. Building managers, thanks to these tools, could access real-time information on the building and its components, making accurate assessments of the operating conditions of the assets, allowing better usage.

Knowledge of built heritage must be brought back not only as a sum of individual buildings, but as a structured whole of buildings, facilities, infrastructures and all that constitutes a district/city. It is a matter of setting up a system of knowledge aimed at increasing safety, quality and optimization also in economic terms and maintenance planning.

The role of representation in the process of communicating information

To enrich the vision of the Cadastre of the Future, which queries Big Data for a better knowledge of the territory and the city, new solutions are experimented that combine representation with the needs of knowledge. In fact, it is noted that greater information and innovative and technological means of communication, including *Information and Communication Technology*, are required to have a substantial urban culture progress [Colletta, 2017]. This new communication setting enables a number of new possibilities to learn, plan, design, monitoring and creating strategies at the city level.
The central idea is to build an augmented digital city, which exploits the potential of the BIM methodology to establish a structured cognitive system of buildings, which can be integrated with other applications and dynamically interrogated through new communication technologies (fig. 3). This process involves the overlapping of digital content from a two-dimensional static representation aimed at increasing the perception of the built environment and the available information superimposing/replacing the reality. In this way, the link with information can be always

Fig. 2. ToBIM: Methodological setting of BIM models (graphic eleboration by the authors).

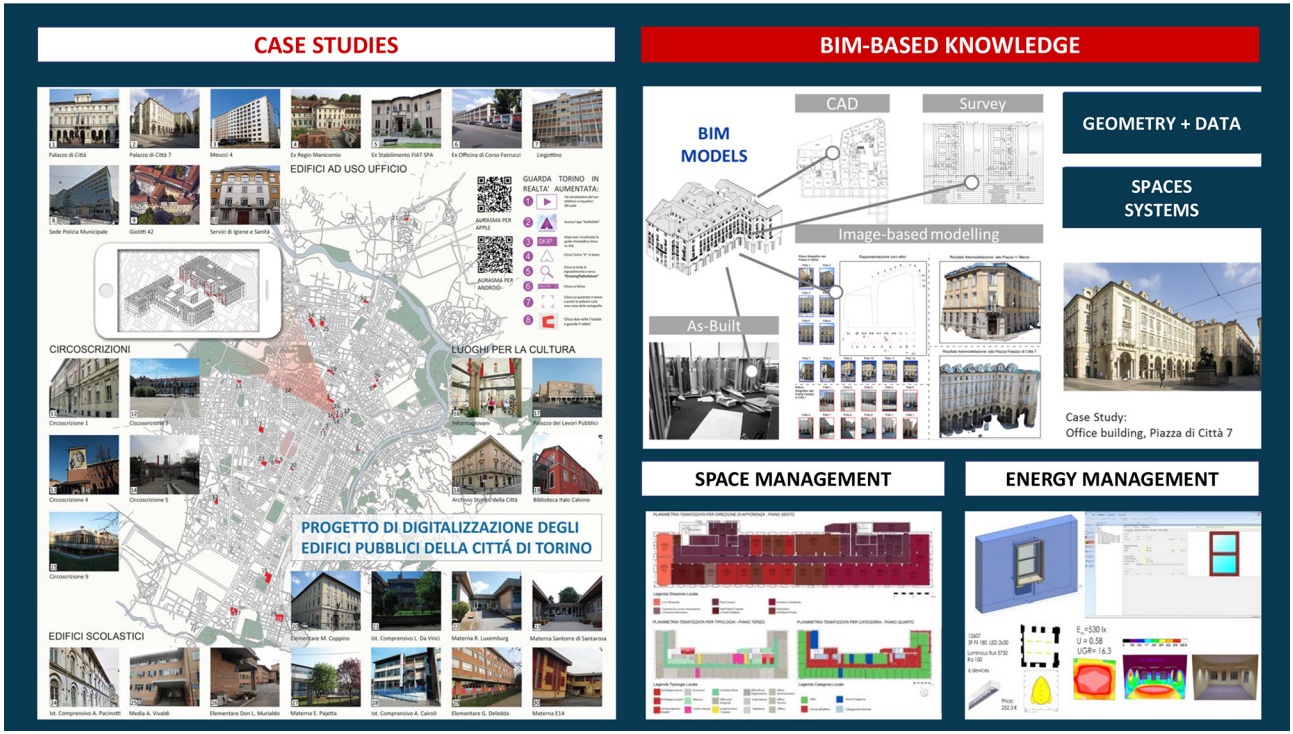
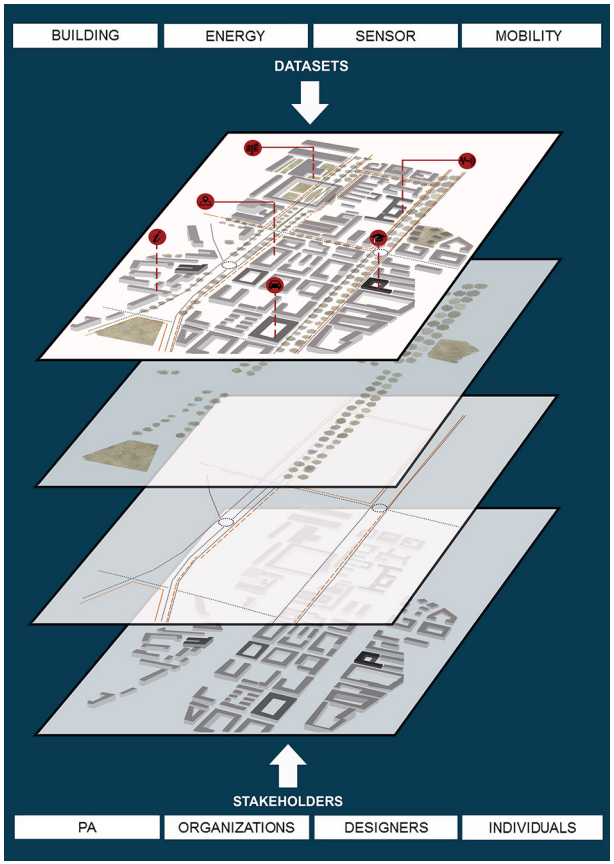


Fig. 3. Idea of augmented digital city (graphic eleboration by the authors).



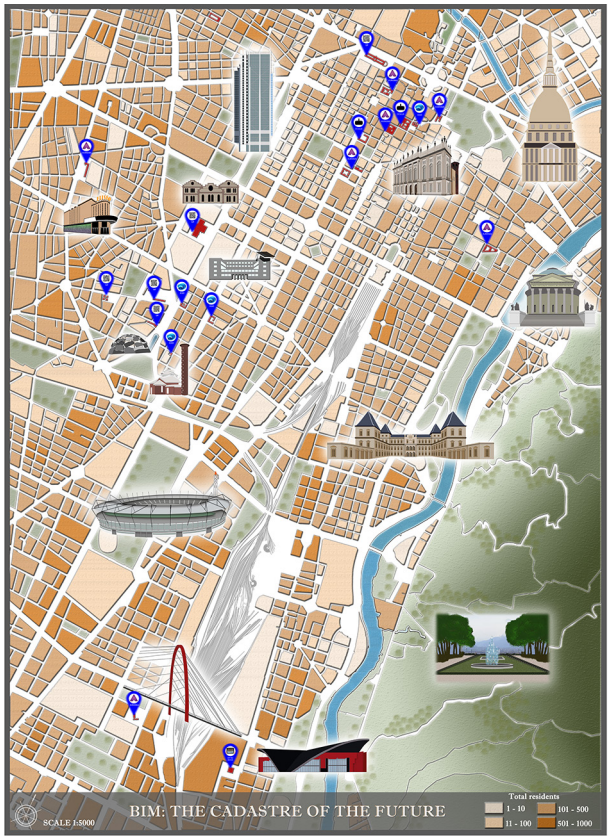
kept up to date, despite the graphical representation may be exceeded in the course of time. In this vision, many subjects (individuals, organizations, sensors, PA) can add digital informative layers in real time to the representation. Through the use of Augmented and Virtual Reality, it is possible to establish new modes of interaction that allow a greater number of users to access technical-information contents. It can therefore be said that the AR and VR combine to define a new model of augmented city in the era of *Smart Cities*, thanks to the use of objects that become speakers and provide access to information. AR begins to spread in the entertainment field, but, in reality, the focus is on infotainment that combines the quantity and quality of information to be used in a specific context with the simplicity of any capacitive surface associated with the use of a camera and a dedicated management system [3]. It is a visual content management 2.0 that adds new levels of information in real time and with high interaction rate using all types of mobile devices, including wearable technologies. Currently this type of communication is widely used in museum and tourist area, to make specific information available on certain objects/points of interest. The approach is participatory and links all the components of the supply chain, through tools and devices with which users are confronted daily even in private context. The traditional representation must now find the right balance with the digital evolution to extend the possibilities of dissemination of data. Sharing information and visualizing it in a simple and direct way is the enabling factor to fully exploit the potential of BIM, facilitating its use and display at different levels, from designers, operators and managers, from the building to the district and city. Actions aimed at increasing users' awareness exploit new technologies by promoting applications, interactive maps and virtual tours aimed at bringing citizens closer to a new approach to managing information about buildings and the city, based on a process of intelligent digitization of heritage built. Outlined the research objective, an interactive map of the City of Turin has been realized as preliminary application, which proposes a new system of representation and interrogation of the buildings starting from the technical cartography (fig. 4). The city map becomes, therefore, the large multimedia container where every entity that constitutes the built heritage is questionable, compared to the layer made up of the parametric digital models. For illustrative purposes, the map has also been proposed in large dimensions, through an installation of 52 sqm presented du-

ring Made Expo 2017. The user is directed to move freely in the space of the map by initiating a stimulating and at the same time unexpected cognitive experience between the buildings and the neighborhoods of the city. Places of historical interest are reported in order to guarantee orientation, while the focal points of interaction are clearly identified and define the type of digital content exploited. The principle is to create a series of touch points that act as a trigger to increase the perception of space. Several options for AR and VR visualization are offered in order to establish an interactive relationship with users.

Fig. 4. Turin BIM Interactive Map (graphic eleboration by the authors).

Making information usable through innovative technologies

The digital revolution, in all its ramifications, and the massive advent of innovative technologies, have generated a new organizational method, able to renew relationships and collaborations among the various stakeholders, focusing on new research and experimentation methodologies in the field of data integration and exchange, organized according to the information levels of which the intelligent city is composed.
In fact, new technologies can play a fundamental role in generating new synergies within the Real Estate sector, within an integrated process aimed at continuously enhancing and managing the property information involving public administrations, professionals and the private sector. Thanks to Augmented and Virtual Reality, in fact, it is possible to access more easily the information that defines the city and the built heritage. The use of these technologies facilitates communication, sharing and collaboration among different actors involved in different ways and at different times in the cognitive process (fig. 5). According to this approach, changes the way in which the city and the user can exchange information, through the definition of new rules and processes, in order to cooperate jointly towards the shared digitization of built heritage. The new technologies, in addition to ensuring greater accessibility of information, allow us to bring users closer to a greater awareness of the territory around them. For this purpose, three technologies have been analyzed in detail: AR, VR and 3D printing, to assess the degree of interaction with the user and identify the best solutions in the field of knowledge, dissemination, management and maintenance.
Through the Augmented Reality tools it is possible to increase the two-dimensional representation, by superimposing



digital contents, or information layers to a real scenario, by reading a marker using a smart device. There are numerous applications available in the market. Among these, the Aurasma application was used, which makes it possible to associate multimedia contents such as illustrative videos, drawings or websites/web platforms to an image such as the building's footprint. Framing the buildings represented on the map through the dedicated application, the user can view significant information of a specific building, facilitating the cognitive process involving the user in an interactive way. Specifically, considering the divulgative purpose addressed to the citizen, videos and descriptions which highlight the historical, architectural and functional characteristics of the buildings are recalled in the map. Similarly, QR Codes are used. They are experimented to connect information relating to systems, structural, compositional and historical features, as well as rendered stereoscopic views that allow a semi-immersion inside or outside buildings or parts of cities. Through the same procedure it is possible to recall specific technical, maintenance or management contents of interest to the individual categories of professionals. In this way, information is made available in the place and at the time when it is needed. Consider, for example, the relapse in the maintenance field, for which it provides the possibility to recall technical sheets of the components, maintenance procedures, or technical information on the field simply using a smart device. In addition, applications such as BIM viewers can be called up, allowing you to visualize even very complex and heavy models of buildings on mobile devices quickly, without the need for modeling software or being an expert in using them. The ability to access web viewers, such as Autodesk A360 viewer, allows you to start a real on-line query of information related to each individual object.

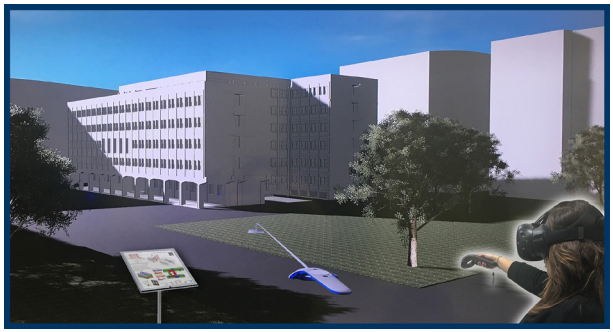
In addition to tools already available on the market, it is possible to create and customize specific applications, useful for managing and displaying detailed information for certain categories of users or professionals. In this way the knowledge of the individual building and the availability of data, facilitates the information process necessary to improve the relationship between user and building, as well as the maintenance and management of each indi-

Fig. 5. Technologies used in the Interactive BIM Map of Turin (graphic eleboration by the authors).

vidual building component. A very useful and interesting application to facilitate this cognitive process is the one experimented '*ad hoc*' for the Firman. In this case, the user through virtual joysticks on the screen of the mobile device, can move within the virtual environment and search for information of interest with respect to fire-fighting equipment, such as fire extinguishing equipment, or to safety procedures. The objects that can be interrogated can be identified by means of flashing devices that intensify the brightness as you approach it. It is possible to display different information depending on the user.
For example, the maintenance technician can access the procedures related to the testing or ordinary maintenance of the extinguishing means. The rescuer, on the other hand, may be interested in viewing the correct location of the means in the floor and their range of use. While the user working in the building can view emergency exits, safe places and assembly points to be reached in case of need. For its conformation, the app is useful during the training phase of rescuers and can be consulted on the way to reach the place of the intervention, so as to know the building beforehand and study the best intervention strategy. Thanks to Virtual Reality, on the other hand, it is possible to view three-dimensional high resolution environments and objects, with which the user can interact in real time, move freely through special devices, which guarantee a sensation of immersion and presence in the reconstructed environment. The tested applications concern the use of *Oculus Rift* and *HTC Vive*. The *Oculus Rift* allows a virtual immersion inside the single building and the possibility to interrogate the objects present. In addition to the classic navigation of the building, it is possible to superimpose information, functional, maintenance and logistic contents. In fact, thanks to this technology it is possible to visualize what in reality is hidden, such as the systems network and the structural part of the entire building or in correspondence with a specific equipment/component. It is possible to recall the related technical data sheets, energy documentation, technical details, or refer to maintenance procedures useful in case of inefficiencies In the case of historical buildings, the use of Virtual Reality, also allows to recall historical-artistic information, through documentation, audio or visual overlays. The use of the viewers allows you to take virtual tours, through which you can get in touch with a large amount of information. In addition to the *Oculus Rift* technology, the market offers new platforms for immersive visualization, not only for simple three-dimensional models, but also for BIM models with the relative geometric and alphanumeric properties of each building component. The *HTC Vive*, make it possible a total immersion of the user that can navigate within the city or a building, thanks to the predisposition of our virtual cognitive (fig. 6). Once the devices are worn, ie the viewer and the controllers, users can interact directly with the space around them and query the objects in the city, obtaining the necessary information (fig. 7). The technological innovation put in evidence, in addition to exploiting the potential of digital, provides new tools such as 3D printers able to faithfully reproduce the building virtually realized, in order to increase the visual and cognitive perception of the user. In this way, it is

Fig. 6. Alphanumeric properties visualization of the BIM model through Virtual Reality (graphic eleboration by the authors).

Fig. 7. Virtual city tour by HTC Vive (graphic eleboration by the authors).

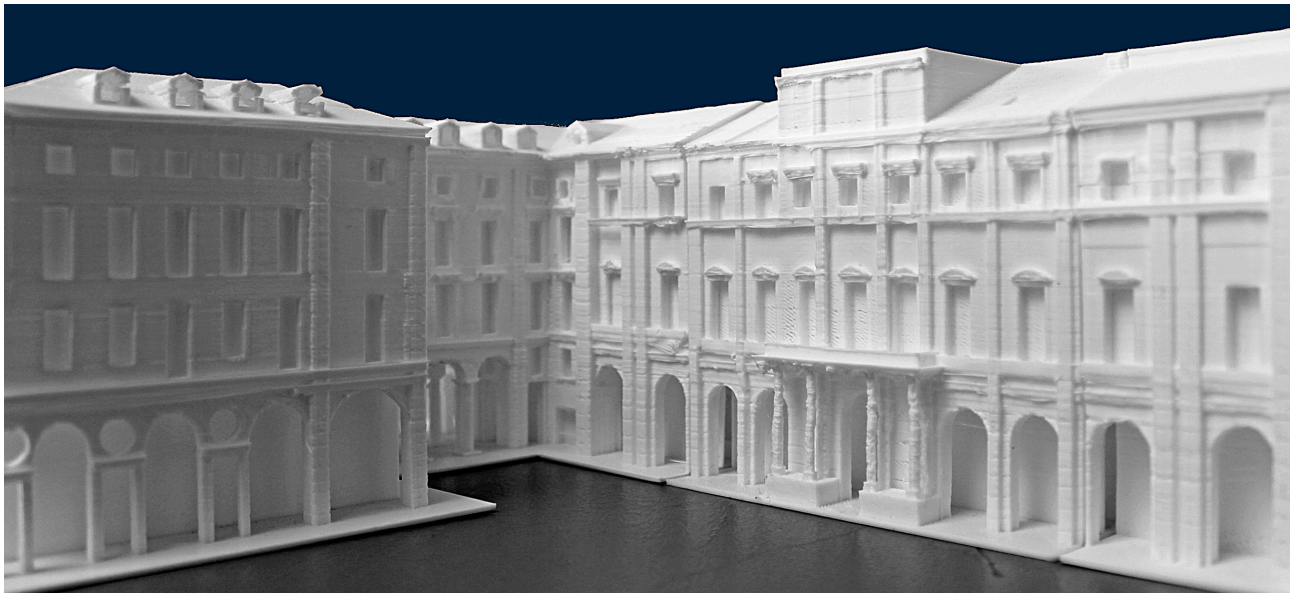


immediately possible to have a reference that is not only virtual but also real. Some of the most representative BIM models of the city, including the Town Hall (fig. 8), the new Unico headquarters of the Piedmont Region, have been reproduced through the 3D printer, providing further concrete and tangible reference points to the interactive map. They, although simplified in their geometry to facilitate the printing process, add new perspectives to the map, generating an additional information layer. The choice of including three-dimensional elements, further underlines how the digital revolution imposes a representation that immediately refers to reality and to simple yet effective communication tools.

Conclusions

It must be clear that, even if there is a cost in the digital re-organization of the data relating to buildings on a BIM basis, there is certainly a cost due to the dis-organization of the same and the procedures, tools and organizations that manage them. The ability to dream must allow us to go towards a Cadastre of the Future based on the BIM census of buildings and infrastructures that make up the city, dynamic, always updated and implemented over time. The task is not simple, especially as regards the level of reliability of the data, but it is still necessary to start with a precise program for the future. The BIM must be used to ensure the overcoming of the current difficulties in obtaining design, structural, systems and environmental information, with the aim of constantly updating the knowledge of the building and its essential components in order to allow the management of buildings based on integrated data and interoperable information systems. This digitalization operation must be thought of as an opportunity for rationalization and formalization of a process of knowledge and maintenance of built heritage. In this context, the case study of the City of Turin illustrated represents a virtuous beginning that must be implemented over time, not only to complete the digitalization of the city's heritage, but above all to make the BIM methodology, based on sharing of data that must always be updated, correct and certain. To build the Cadastre of the Future it is necessary to start a radical cultural change that involves the use of BIM models not

Fig. 8. Turin City Hall: 3D printed maquette of the BIM Model (graphic eleboration by the authors).



only as a simple three-dimensional graphic representation, but as a real alphanumeric database that must be used in an interoperable way among the different users. The tools currently on the market become the starting point for experimentation and for new reflections where the 'I' of 'Information' of BIM is the fulcrum of the debate to find effective solutions to be applied to the entire building supply chain. The digital revolution, made possible by the ongoing technological evolution, must become the opportunity for a true information revolution (fig. 9).

The authors shared the contents, critical analyses and operational practices of this research. In detail, Anna Osello was responsible for vision, methodological approach and description of the case study, Francesca M. Ugliotti for the preliminary studies for the definition of BIM contents for the Cadastre of the Future and for the role of representation in communication of gathered information (the latter with Daniela De Luca). Daniela De Luca studied how to use information by means of innovative technologies. The conclusions were collectively shared.

Notes

[1] Cfr. <http://www. dimmerproject.eu/public-deliverables/> (accessed 2018, March 18).

[2] <https://www.lagospm.com/03-benefits/articles/NIST.pdf> (accessed 2018, February 10).

[3] Cfr. <http://www.internet4things.it/smart-building/realta-aumentata-una-tecnologia-tantissime-applicazioni/> (accessed 2018, February 2018).

Fig. 9. The building heritage object of the digital and information revolution (graphic eleboration by the authors).

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