

Bright Cities and City Information Modeling

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1 ABSTRACT

The increasing urbanization and above all the increasing demand for more efficiency in energy consumption and in the management of natural resources makes ever more urgent to tackle the construction of buildings and the planning of cities in an innovative and sustainable way. In this perspective, some research lines have emerged referring to the concepts of smart, intelligent, and green/sustainable buildings. Starting from this analysis, the article aims to highlight how it is possible to synthesize both the environmental quality aspects and the integrated control of a building in the concept of bright green buildings, and how thus a wider conceptual reference framework is necessary: identified in the Bright City based on the implementation of a City Information Modeling (CIM). This methodological framework allows managing the urban transformation operations in an integrated way and represents a synthesis of the current paradigmatic references: sustainability, smartness and resilience.

Keywords: city information modelling, bright cities, smart cities, building information modelling, smart building

2 INTRODUCTION

Residential and non-residential buildings are the main energy-consuming within an economy. About 35-40% of the energy produced by the buildings is used for the construction while the remaining part is absorbed for lighting and air conditioning systems (Srivastava et al., 2017). The buildings also tend to consume other natural resources in addition to energy for example land and/or building materials. In order to limit these effects, buildings should be transformed into increasingly efficient environments through the continuous search for reduction or minimization of consumption and waste.

The transformation of buildings into smart, intelligent, and green/sustainable buildings should be accompanied by the improvement of the urban context as well as the change of cities. A city, in fact, should reinvent itself following a design of sustainable development. This improvement, which implies more efficiency and the use of advanced technology, is now a reality in many medium to large urban centers. The need for cities to evolve themselves alongside this direction is the consequence of the growing urbanization of the world population, the increasing demand for energy-efficiency and more in general the management of non-renewable natural resources that tend to be more and more scarce. The regulation of residential and non-residential buildings has also changed, becoming gradually stringent in terms of the required efficiency targets (Buckman et al., 2014).

3 THE GREEN AND SMART BUILDING VS. THE BRIGHT GREEN BUILDING

3.1 Green and smart building definition

The constant consumption of non-renewable resources leads to the rapid depletion of the available resource stocks. Nations, therefore, as well as cities have to use energy in a more efficiently way natural resources. In 2014, the European Commission has issued the Communication “Resource efficiency communication opportunities in the building sector”, whose main object is to reduce the environmental impact of buildings by improving efficiency in resource consumption and competitiveness in the construction sector. These main indications were further confirmed in 2015 in the “Circular Economy Action Plan” where construction projects, which reduce the environmental impacts of buildings and rise the recycling capacity of the different components, are promoted.

If on the one hand buildings may be beneficial protecting people, on the other hand may have negative effects on the environment. For this reason, the literature has identified and developed two different concepts about

buildings efficiency distinguishing in terms of energy and the environment: sustainable buildings (or green) and intelligent buildings (or smart).

The concept of green/sustainable buildings mainly refers to the practice of designing, building, operating, maintaining, renovating and demolishing buildings in order to preserve natural resources, reduce air and water pollution and respect the environment. The principle of preserving the environment which implies the principle of constructing sustainable buildings allows reducing wastes besides consumptions by increasing energy, water and materials efficiency and reducing costs and risks. Sustainable buildings can therefore be an effective instrument to sensitise citizens to the environmental issues and also may represent a real solution to reduce the impact of human activities. If successful, green buildings present a lighter ecological footprint through the promotion of resource conservation and the efficient use of resources. In other words, the plan of green buildings implies the need to find a balance between residential constructions and the environmental sustainability.

As far as the second type of buildings is concerned, Buckman et al. (2014) distinguish between intelligent buildings, smart buildings and thinking buildings according to the increasing interaction of the buildings in terms of the building's ability in reacting, adapting and predicting different events. In 1995, the Conseil International du Bâtiment Working Groups for first defines a building as intelligent in the following: "A dynamic and responsive architecture that provides every occupant with productive, cost effective and environmentally approved conditions through continuous interaction among its four basic elements: places (fabric; structure; facilities); processes (automation; control; systems) people (services; users) and management (maintenance; performance) and the interrelation between them." (CIB, 1995 as quoted by Everett, 2008).

Wang et al. (2012) and McGlenn et al. (2010) instead define smart building as a holistic and integrated architecture or design where the planning as well as the construction of buildings considers smart technologies such as control device, state sensors, etc. and materials used. Moreover, the building should be considered as a unique and integrated system which has the capability to achieve of some predetermined objectives such as: energy and efficiency, longevity, comfort and satisfaction. The continuous flow of information obtained by all the different devices allows these systems to adapt to different contexts as well as to specific variations that can occur in the same context.

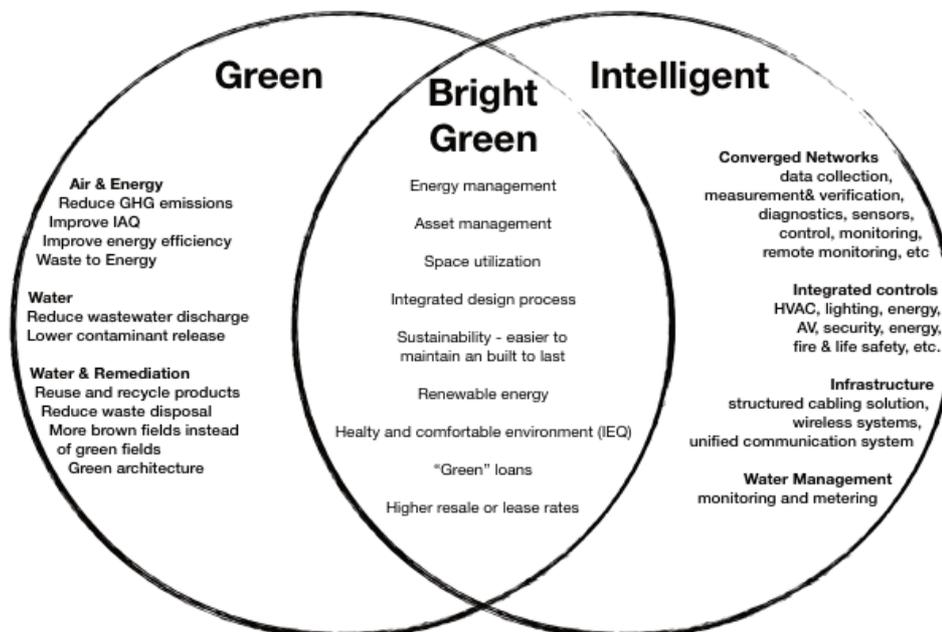


Fig. 1: Intelligent, Green and Bright-Green Buildings divided by "skills" and fields of interest. Source: CABA (2008)

If on the one hand the green buildings definition includes aspects such as energy efficiency, ventilation and water recovery, as well as all the staff regarding the optimization cycle of rubbish and reuse of wastes, on the other hand, smart buildings description regards the ability to integrate the building network, the integrated monitoring of HVAC (Heating systems, Ventilation and Air Conditioning), the electronic and safety devices, and finally the infrastructure and water management. It is thus evident that the concepts of smart and green

buildings, even if not coincident, present an overlapping area, defined as bright-green buildings (CABA, 2008), which includes topics such as renewable energy, environmental and indoor quality of residents, sustainability and energy management (see Fig. 1).

3.2 The bright green building

A bright-green building is therefore a building that is both intelligent/smart and sustainable. This kind of building is, in fact, a structure that uses both technology and processes to create a building that is safe, healthy and comfortable as well as to increase productivity and well-being of residents. It also provides timely and integrated system information so that owners can make smart decisions about operations and maintenance activities and develops an implicit logic that effectively evolves with changes in owners' needs and technology. In this way, a bright-green building guarantees intelligent and continuous maintenance operations and is designed, built and managed with minimal impact on the environment, conserving resources, increasing the efficient use of energy and creating healthy environments for the occupants. In other words, this type of building are structured to satisfy the needs of the present without compromising the needs of future generations. In bright-green buildings, completely networked systems transcend the simple integration of independent systems to achieve the interaction between all the systems, which, working in an integrated way, optimize the performance of the building and create an environment favourable for achieving the specific objectives of residents. In addition, fully interoperable systems in these buildings tend to work better, cost less for maintenance and leave a smaller ecological footprint than single utilities and communication systems (CABA, 2008). The evolution of these concepts as well as the prompt realization within a building is so rapid that what until a few years ago was seen as a future (Fig. 2), the Net Zero Energy Buildings or the Eco-districts, today is already a reality.

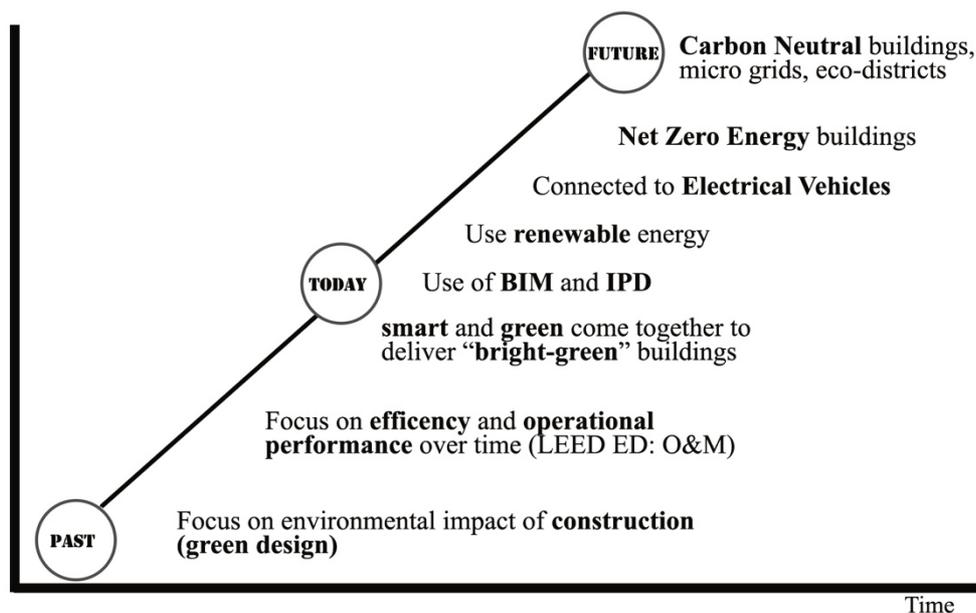


Fig. 2: Evolution of green buildings. Source: Schenider Electric (2008)

3.3 The bright green building within the European institutional framework: Level(s)

The outlined evolution has been obtaining an ever greater affirmation, not only at the level of consensus and sensitivity of the population but also at the political level. The European Commission presented the pilot phase of Level(s)¹ on September 28th 2017, a new EU framework for sustainable buildings, which will allow transforming the construction sector. It is an open source scoreboard developed in close collaboration with leading players such as Skanska, Saint-Gobain, the Sustainable Building Alliance and Green Building Councils. It is the first instrument of this type designed to be used throughout Europe and aimed at facilitating the transition to the circular economy. Level(s), as result of an extensive consultation with firms and the public sector, is based on performance indicators covering issues such as greenhouse gas emissions,

¹ see for more details: <http://ec.europa.eu/environment/eussd/buildings.htm>

resource efficiency, water efficiency, health and comfort. It aims to create a common language that defines what a sustainable building is in practice without limiting itself in considering only the consumption of energy.

Level(s) focuses on the main aspects of a building's performance, serving as a guide for those who want to build in a more sustainable way. These aspects include: the greenhouse gas emissions during the entire lifecycle of the building, the efficient use of materials in terms of a circular and resource economy, the efficient use of water resources, the healthiness and comfort of spaces, the adaptation and resilience to climate change, and finally the cost and value of the entire lifecycle of the building. Each Level(s) indicator is designed to link the impact of the building with the EU's priorities for the circular economy. This framework actually expands the construction sector program by contributing to achieving sustainable development goals of the United Nations.

Both the design of buildings with low or near zero consumption characteristics which implies the energy redevelopment interventions to bringing existing buildings closer to the concepts of quasi-zero energy and the planning of energy districts on which are based an eco-friendly smart city show greater limitations and greater difficulties. These are related to the lack of a technology which permits to analyse at the same time the interactions among multiple elements such as for example: buildings, energy generation systems, variable thermoelectric users, variable climatic conditions, the presence of renewable sources, problems of performance constraints, possible design solutions characterized by innovative materials and technologies, regulatory assessments economic and financial indicators related to smartness.

In the market, as a result of extensive international research, there exist several software environments which allow analysing in-depth the energy performance of a building-plant complex (ESP-r of the University of Strathclyde, Energy+ of the US Department of Energy, TAS, etc.). These softwares allow evaluating parametrically the effect of redevelopment interventions and allow considering polygeneration and distributed generation in real buildings (in this direction an example is the ODESSE - ENEA software). What is missing is a general framework of analysis of the problem which goes beyond the single building. It is relevant to consider the context in which a building is included i.e. The analysis of the neighborhood. Thus, the various buildings that compose a neighborhood should be interconnected with energy generation and/or distribution systems networks in order to form a bright core - efficient, sustainable and smart - following a design based on a synergistic approach. From this point of view, Italy has an important tradition of urban regeneration implemented in the last forty years in the historic centers and in the disused areas, but the dimension of this opportunity is still far from the needs of today.

A warning sign on the much work that remains to be done, in particular with reference to the ex-ante evaluation of urban redevelopment and transformation projects, lies in the data illustrating the strong social changes taking place in the central urban areas (loss of functions and inhabitants), the continuous occupation of new land up to the saturation of some territorial areas (valley bottom, coastal areas and periurban areas), the relocation of production and service activities. The growth model adopted after World War II has caused a deterioration in the environmental quality of cities and neighborhoods, where beauty and identity typical of our history have been lost, making districts that are increasingly suffocated by cars, without public spaces where citizens may meet or walk, and finally, where the energy inefficiency of the houses has turned into a further economic burden for the weaker social groups. Not to mention the cancellation of important and valuable natural and agricultural environments.

3.4 Building Information Modeling

For what concerns the management of built environment, and buildings in particular, the availability of an integrated system of knowledge is the basis for a smart assets management.

In this perspective in 2014 the Juncker Commission set the Digital Agenda as a priority and a number of initiatives to make the EU a world leader in information and communication technology has followed. This includes increasing digitalization in cities and the built environment. A latest example for this strong engagement is the Digital Cities Challenge. The 15 cities selected in 2018 receive coaching and facilitation from high level experts to easing their digital transformation journeys. The process of city's digitalization consists mainly in supporting cities in the use of new technologies for delivering services for their citizens.

Since 2014 (2014/24/EU DIRECTIVE) the European Commission has prompted the diffusion of the Building Information Modeling (BIM). The main reasons that have led a growing number of governments to invest in Building Information Modeling approach are:

- the need to enhance public spending, in terms of allocating resources according to the quality of the final result;
- the internationalization of companies and professionals who can operate in a global reality;
- the need to converge towards sustainable interventions. All this is possible only with a decision-making process at the basis of the design as much as possible "informed".

BIM is a radically innovative strategic methodology that has the ambition of profoundly transforming the construction sector. It is configured as the keystone in the process of the construction sector's digitalization. It is a real paradigm shift as it creates the conditions for multi-criteria analysis, that allows to balance different specialist skills, needs and requirements, often in contrast with the evaluation of different scenarios and intervention strategies, identifying the combination that maximizes the quality of the results.

So BIM is a collaborative approach that can facilitate cooperation and enables better information-sharing and management and communication between the different teams involved in a construction project. All teams contribute information and benefit from the information inputted by others: silos are therefore eliminated. This system 'democratizes' knowledge and allows for more collective decision-making. BIM's common language and common semantics therefore allows service providers to collaborate across complex projects across the city, and also means that all team members are working to the same standards.

In traditional building processes, key project and asset knowledge is often lost between stages, when one team hands over to another; BIM can stop this from happening by centralizing all information, so that all resources are shared, and standardizing procedures and benchmarks. This way, expertise is consistent and consolidated, and all relevant information and errors are integrated into one platform so that they can be solved systematically by developers and management. This then allows them to conduct performance analysis more effectively and carry out more accurate assessments of the condition of the involved assets - seeing exactly how the buildings at hand are operating and where any efficiencies can be made, enabling better usage and utilization of assets and resources.

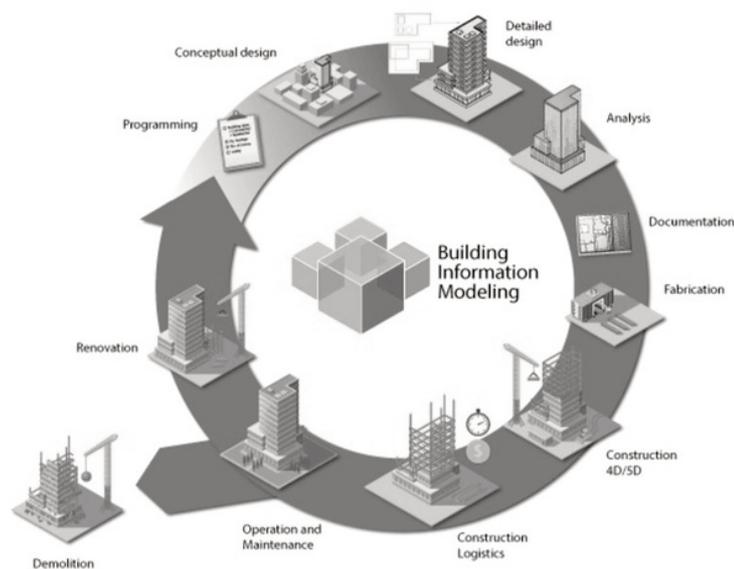


Fig. 3: Bim Lifecycle. Source: <https://cadoutsourcingservice.quora.com/Building-Information-Modeling-BIM-Life-cycle-and-Facilitates-Management>

BIM collects data into one platform that can be shared among all - this includes the public. Not much BIM is currently open-source, but in the cases where it is, it allows the community to fully engage in the physical transformation of their city, giving them access to information usually only held by those directly involved in the design and construction process.

The real added value of BIM is obtained when this methodology is implemented within the entire lifecycle of buildings (Fig. 3):

- Project planning (standards, data inclusion, finances and property, etc.)
- Project design (construction materials, geophysical conditions, etc.)
- Project implementation (safety regulations, contracting, quality management, scheduling, etc.)
- Asset management (supervision, facility management, ownership documentation of repairs, life-data analysis, etc.)

One of the main obstacles to the diffusion of this new process approach is linked to the bad interpretations of it. The general concept of BIM is often associated with a simple evolution of three-dimensional CAD modeling.

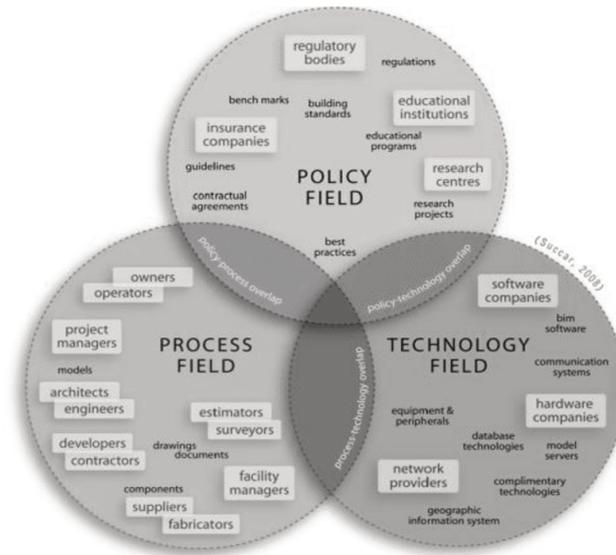


Fig. 4: The three fields of BIM. Source: Succar, 2009

The schema in Fig. 4 shows how the field of application of the BIM is not limited to the adoption of new technologies and new modeling software.

“BIM is not a thing or a software, but a human activity that involves ultimately a vast change in the processes of the building industry” (Eastman et al. 2011).

The BIM methodology starts from the development of a three-dimensional parametric model, the virtual twin of the building, within which all the information concerning its life cycle is capitalized and organized. So, the technology field includes the adoption of BIM analysis and modeling software, the adoption of an adequate hardware and network infrastructure, the adoption of an information database system and so on. The field of processes includes a reconfiguration of the role, the areas of work and the relationship of the actors that revolve around the project, the construction and the management of a building. The political-institutional field includes an essential evolution of the entire legal-normative area linked to the construction sector. BIM is often considered through the lens of a single field of interest and not through the consideration of all its fields.

This methodology can be very effective in the management of public procurement focused on building and infrastructure - whether a road, tunnel, bridge- since risks of failure should be significant. The development of the informative model allows us to have a virtual prototype (digital twin) on which it is possible to carry out simulations, tests and controls before the construction process. Through BIM, any potential errors or incidents can be flagged up well before anything can actually go wrong.

4 TOWARDS A NEW PARADIGM: THE BRIGHT CITY

At urban level, the development of a city may not nowadays disregard from technology. Therefore, it is somewhat surprising that despite the strong push towards new technologies adoption few cities worldwide are actively engaging in adopting new tools and strategies.

Although Level(s) represents an important step forward for European cities, we are not yet in the presence of an integrated decision-making model. What is missing is a shared conceptual framework that allows evaluating the technological solutions with respect to the impact they have on the entire urban system.

The smart city paradigm (Giffinger et al 2007, Etzkowitz and Lydesdorff, 2000, Neirotti et al 2014, Mundula, Auci and Vignani 2016, Mundula and Auci 2017) can be a useful starting point for analyzing bright-green buildings in a wider perspective. Considered firstly as a concept related to the energy efficiency of cities has gradually widened to include social, environmental, institutional and economic aspects. By retracing the evolutionary line of green buildings ideally, we can find an analogy with the same concepts applied to cities. In the face of a first period in which the dominant paradigm was that of the sustainable city, then the smart city was increasingly established, until it found a form of synthesis in the "smart and sustainable city" (ITU, 2016). Looking to the future, however, and considering the growing importance of a third strand, that of resilient cities (Pickett et al., 2014), we should take into consideration that overlapping area between these phenomena which, paraphrasing the terminology used for buildings, we could define "Bright" the cities whose main objective is to combine aspects of sustainability, resilience and smartness.

As for smart cities, also for bright cities there is the problem of their shared definition that allows the measurability of the phenomenon and therefore the impact assessment of the hypothesised solutions. Whatever the dimensions and the indicators chosen to define them, it will be necessary to establish the functional relationships between the urban and the building scale, in order to understand (and therefore to take into account in the selection phase) the effect of the solutions adopted at the most minute level (building) on the whole system (the district and/or the whole city).

If the concept of bright cities were to be considered an invariant with respect to urban typology and morphology, one would lose sight of the main characteristic of cities, that is, of being composite structures whose basic building blocks are represented by buildings and neighborhoods. This fact would make it difficult to assess (in terms of increase in performance) the specific technological solutions for buildings that today seem to be those that have the greatest potential in terms of increasing energy efficiency. This situation therefore requires a methodological and operative approach to maintain a logical-functional connection of bright buildings with the definition of brightness at the level of a urban system.

4.1 City Information Modeling

The bright city concept is a reaction to the growing challenges that urban centers are facing. Environmental degradation, increasing economic inequalities, as well as growing populations may exhaust social and physical infrastructure and increase the need of improving the operational, service and energy efficiency of cities, rendering them better places to live for all.

Bright Cities require knowledge-based and performance oriented approaches to urban design and planning. This means that stakeholders from different backgrounds and domains of expertise are involved bringing and sharing multiple levels of information, at multiple scales of analysis and intervention.

An answer to these requirements could be found in a relatively new adaptation of BIM approach: City Information Modeling - CIM (Xun et al., 2014). CIM goes one step further than BIM, integrating the information provided by BIM into wider city planning and development. The modeling of urban information at different level, from single building models to city-wide models, is the central idea of many smart city projects developed in different domains and it refers to internationally recognized data structures (Gröger et al. 2012). From this point of view, City Modeling and Building Information Modeling are converging research areas that take advantages from a reciprocal interchange: the georeferencing of Building Information Models enables their location within a City Model, where each asset might be analyzed considering the surrounding built and natural environment; in turn, city and district models might be enriched and refined with data coming from BIMs, providing a finer grain base for territorial analysis and enabling the extension of facility management applications at urban scale (Kang & Hong 2015; Rafiee et al. 2014; Donkers et al. 2015; Tobiáš 2015; Hijazi et al. 2010):

- CIM represents higher level networks of infrastructure, governance and human activity and ultimately forms the structure that holds all BIM models together;
- CIM allows the description, visualisation, analysis and monitoring of the urban environment to support urban design and planning from the very local to the regional;

- CIM meets the needs of the various stakeholders with specific design and decision support tools;
- the backbone of CIM is an integrated, cross-disciplinary, spatial data model based on open standards.

City Information Modeling is a BIM analogy in urbanism. It is a system of urban elements represented by symbols in 2D space and 3D space. It is also conceived as 3D expansion of GIS (3DIS or 3D information system) enriched with multilevel and multiscale views, designer toolbox and inventory of 3D elements with their relationships (Stojanovski, 2013). CIM focuses primarily on the use of digital information for the purpose to assist in planning and analysis of a city. This can include real-time monitoring or simulation in the planning process. There, leading companies in BIM software have already experimented to develop and expand their software with a CIM portfolio (these are exemplary Autodesk and Bentley). These softwares allow the analysis of 3D City through 360 Degree views. An example is Berlin. Based on a concept by Virtual City Systems a 3D Model of Berlin has been developed.

CIM and the bright city are intertwined. CIM supports cities in dealing with the challenges that growing urbanization poses (the impacts of climate change, ageing infrastructure, housing affordability, traffic growth and congestion, lack of communication or cooperation between different industries) through improving their operational efficiency, facilitating multi-stakeholder cooperation and cutting costs. CIM is at the core of the bright city, in that it fosters improvements in energy and cost-efficient buildings, facilitating more sustainable urban development, and is key to tackling the challenges mentioned above in the following ways: centralizing information and placing it in context; increasing collaboration and cooperation; minimizing risk; empowering citizens; improving productivity, efficiency and results; making cities more environmentally and socially sustainable.

CIM allows for infrastructure (whether already built, or in the construction or design phase) to be modelled in accurate geospatial contexts at the city-level. Anyone working on a project using CIM can access information about any aspect of the infrastructure being built and use it for any purpose - whether finding out property-specific information about a material being used or modeling an alteration to the original plan. CIM is thus in some senses a platform, not only allowing all stakeholders to access all they key information about a project in one place, but also to accurately model the project in its local context.

The smart 3D models enabled by CIM encourage the harmonization of services; a lot of the geospatial data involved in these models is constantly being collected from sensors planted everywhere - on infrastructure, CCTV cameras, throughout the road network - although it is of course combined with existing GIS datasets for even more context. Aggregating and using data from different areas of the city - and different public service departments - fosters a working-together approach, allowing not only the coordinated design of individual buildings, but also of whole districts, facilitating integrated services and coordinated maintenance programs for certain assets.

Currently CIM is already used by the insurance and industry to assess the impact of natural disasters, such as floods, earthquakes or storm events, on buildings and districts; city councils and other companies can use it for the same purpose. This kind of scenario modeling allows for an analysis of the impact of certain events on existing assets and, in turn, its impact on public safety.

Another potentiality of CIM is about the community and social engagement. It can be used to engage the public and communities in the assessment of their future built environment needs, helping local authorities to make better decisions concerning planned infrastructure investment, building design and location. Moreover, the different type of projects that can be delivered through BIM offer cities lots of opportunities to link different planning approaches and different citizen uses and needs. An example is the mobile apps Toolz, a virtual reality map which offers models of urban areas which can be adapted virtually by the community to 'test' out urban design solutions. Sharing resources and increasing cooperation CIM not only saves time and money and optimizes results, but even improves public services through better integrating them with real time information and analysis - a key feature of the bright city. Greater coordination across community stakeholders and different governmental departments also means that local projects and initiatives can be better deployed.²

² An example is San Francisco's Smart Park system, where coordination across city departments under the umbrella of one tool (the smart parking solution that collects data from parking spaces and other city infrastructure, includes smart parking meters and payment services, and more) has allowed the city to implement a flexible demand-response pricing

Bright Cities aim to use data to orchestrate their communities' quality of life, and their safety and security, above and beyond economic opportunity. CIM offers them a way to do this. For instance, optimized simulation of energy analysis, especially across whole districts, would lead to lower energy demands from the built environment and help lower greenhouse gas emissions. The ability to visualize how a whole city ecosystem is functioning in real-time, also allows those managing these systems (whether micro or macro) to adjust resource and energy-usage accordingly, or set up flexible models of consumption that respond to trends that longer-term data reflects. City Information Modeling can integrate the information provided by BIM for city planning and development and lift smart city development up to the next level: the bright cities. The potential of CIM as support in planning future cities regards the contribution to better informed decision-making by planners, the accessibility of data, the accuracy and consistency of data manageability, and the integration of data into contemporary spatial planning and governance. The sustainable urban future of the cities can be delivered by making use of these data, interpreting them (Thompson et al. 2016) and ultimately developing policies.

5 CONCLUSIONS

Technological evolution is increasingly daring. The proposed solutions, even when aimed at a more efficient use of resources and a greater ability to respond to stress and shock that cities are facing, could achieve a sub-optimal result if not framed in a broader strategic framework. The sum of many uncoordinated initiatives does not generate necessarily an optimal solution. Rather, this must result from a logical framework of reference that constitutes both the target to be achieved and a system for assessing the choices. The framework of the bright city, proposed in this paper, although still at an embryonic stage and therefore needs to be deepened, can represent the answer to the challenges (environmental, social and economic) that our communities are facing. Some pioneer cities have gone beyond the simple use of BIM and are now using intelligent modeling for city's development. The shift towards digitizing the whole city is opening up new opportunities to link urban planning and urban design. CIM is the next step: developing a digital DNA of cities, or a 'digital twin'. CIM can be used to provide simulation of traffic flows, congestion, energy use and provision, smart grids, linking different data sets from BIM modelled construction sites in order to facilitate wider city development, and so on. So, CIM is able to accelerate the adoption of the bright city framework in our cities. The digitization of cities and their services is at the heart of the bright cities concept, and this digitization will rely heavily on CIM as we move into the future. CIM approach is the enabler of the bright city, and, in time, will hopefully help to accelerate planning and connectivity for more livable, sustainable, and interconnected cities. As bright cities need intelligent infrastructure, CIM can optimize not only the planning and construction of buildings, but also support the changing of the entire process of urban planning.

6 REFERENCES

- BUCKMAN A.H., Mayfield M., and Beck S.B.M.: What is a Smart Building? In: Smart and Sustainable Built Environment, Vol. 3, Issue 2, pp. 92-109, 2014.
- CABA: Bright Green Buildings: Convergence of Green and Intelligent Buildings. In Sullivan, F. (Ed.), Continental Automated Buildings Association (CABA), Ottawa, pp. 1-220, available at: www.caba.org, 2008.
- CONSEIL INTERNATIONAL DU BÂTIMENT (CIB) Working Group W098. Intelligent and responsive buildings, Toronto, 1995
- DONKERS, S., Ledoux, H., Zhao, J., and Stoter, J.: Automatic conversion of IFC datasets to geometrically and semantically correct City GML LOD3 buildings. pp.1-20, 2015.
- EASTMAN, C., Teicholz, P., Sacks, R. and Liston K.: BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors. Hoboken: John Wiley and son, Inc., 2011.
- ETZKOWITZ H. and Leydesdorff L.: The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. In: Research Policy Vol. 29, Issue 2, pp. 109-123, 2000.
- EVERETT, R.: The 'building colleges for the future' program. Delivering a green and intelligent building agenda". In: New Review of Information Networking, Vol. 14, Issue 1, pp. 3-20, 2008.
- GIFFINGER R., Fertner C., Kramar H., Kalasek R., Pichler-Milanović N. and Meijers E.: Smart cities. Ranking of European medium-sized cities. Centre of Regional Science of Vienna. Available at "<http://www.smart-cities.eu/>"h. Vienna, 2007
- GRÖGER, G., Kolbe, T. H., Czerwinski, A., & Nagel, C. (2008). OpenGIS city geography markup language (CityGML) encoding standard, version 1.0. 0.
- HIJAZI, I., Ehlers, M., Zlatanova, S.: BIM for Geo-Analysis (Bim4Geoa): Set Up of 3D Information System with Open Source Software and Open Specification (Os). In: KOLBE T., König G., ed. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences pp. 45-49. Berlin, 2010.

model for parking that both works for the city (cutting down parking fraud, gathering more data, cutting carbon emissions) and citizens (making it easier to pay for parking, or cheaper if they choose certain spots or time of the day).

- KANG, T.W. and Hong, C.H.: A study on software architecture for effective BIM/GIS-based facility management data integration. In: *Automation in Construction*, Vol. 54, pp. 25–38, 2015.
- MCGLINN K., O'Neill E., Gibney A., O'Sullivan D. and Lewis D.: SimCon: a tool to support rapid evaluation of smart building application design using context simulation and virtual reality. In: *Journal of Universal Computer Science* Vol. 16, Issue 15, 2010.
- MUNDULA L. and Auci S.: Smartness, City Efficiency and Entrepreneurship Milieu. In: CARVALHO L. C. (ed. by): *Handbook of Research on Entrepreneurial Development and Innovation within Smart Cities*, IGI Global, 173-198, 2017.
- MUNDULA L., Auci S. and Vignani D.: Defining Smart Cities: A Relative and Dynamic Approach. In REAL CORP 2016. *Smart Me Up! How to become and how to stay a Smart City, and does this improve quality of life? - Proceedings of 21st International Conference on Urban Planning, Regional Development and Information Society*, 213-222, 2016.
- NEIROTTI P., De Marco A., Cagliano A.C., Mangano G. and Scorrano F.: Current trends in Smart City initiatives: Some stylised facts. In: *Cities*, Vol. 38, pp. 5–36, 2014.
- PASQUINELLI A., Mastrolemo Ventura S., Guzzetti F., Ciribini F.: City intelligence information modeling. in: *places and technologies 2016 - conference proceedings of the 3rd international academic conference on places and technologies*. Available at https://re.public.polimi.it/retrieve/handle/11311/1012549/142791/PT2016_PMGC.pdf
- PICKETT S.T.A., McGrath B., M.L. Cadenasso, and Felson A.J.: Ecological resilience and resilient cities. In: *Building Research & Information Journal*, Vol. 42, Issue 2, pp. 143-157, 2014.
- PICKETT, S.T., McGrath, B., Cadenasso, M.L., and Felson, A.J.: Ecological resilience and resilient cities. In: *Building Research & Information*, Vol. 42, Issue 2, pp. 143-157, 2014.
- RAFIEE, A. Dias, E., Fruijtier, S., and Scholten, H.: From BIM to Geo-analysis: View Coverage and Shadow Analysis by BIM/GIS Integration. In: *Procedia Environmental Sciences*, Vol. 22, pp. 397–402, 2014.
- SCHNEIDER ELECTRIC: *Smart Building*. In: <https://www.slideshare.net/seindia/presentation-se-smart-buildings>, 2008.
- SRIVASTAVA A., Singh P., Janhavi N.N., Singh A.: *Green Buildings: Eco-friendly Technique for Modern Cities*. In SHARMA P., Rajput S. (ed. by): *Sustainable Smart Cities in India*. The Urban Book Series. Springer, Cham, 2017.
- STOJANOVSKI, T. *City Information Modeling (CIM) and Urbanism: blocks, connections, territories, people and situations*. In: *Symposium on Simulation for Architecture and Urban Design*, 2013, San Diego.
- SUCCAR, B.: *Building Information Modeling Framework: A Research and Delivery Foundation for Industry Stakeholders*. In: *Automation in Construction*, 2009.
- THOMPSON E., Greenhalgh P., Muldoon-Smith K., Charlton J. and Dolnik M.: *Planners in the Future City: Using City Information Modeling to Support Planners as Market Actors*. IN: *Urban Planning (1/1)*, pp. 79-94, 2016.
- TOBIAS, P.: *An Investigation into the Possibilities of BIM and GIS Cooperation and Utilization of GIS in the BIM Process*. *Geoinformatics FCE CTU*, 14(1), p. 65, 2015.
- WANG Z., Wang L., Dounis, A.I. and Yang R.: *Multi-agent control system with information fusion-based comfort model for smart buildings*. In: *Applied Energy* Vol. 99, pp. 247-254, 2012.
- XUN Xu, Lieyun Ding, Hanbin Luo, Ling Ma: *From Building Information Modeling to city information modeling*, *Journal of Information Technology in Construction (ITcon)*, Special Issue BIM Cloud-Based Technology in the AEC Sector: Present Status and Future Trends, Vol. 19, pg. 292-307, <http://www.itcon.org/2014/17>, 2014.