The Importance of City Information Modeling (CIM) for Cities' Sustainability

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Abstract. The urban population growth has caused an increase of infrastructure systems' complexity and consequences of human activity to the environment. Therefore, it is essential that sustainability concepts are implemented in urban development. This paper presents a study of how City Information Modeling (CIM) can contribute to improve public services and the quality of life of citizens. In order to reach these goals, the authors analyzed the International Standard ISO 37120 (Sustainable development of communities – Indicators for city services and quality of life) and evaluated how data from Building Information Modeling (BIM) and CIM can be used to obtain data for the indicators of the ISO. The study concludes that BIM and CIM models can provide data for 53 of 100 existing indicators in a simpler and more accurate way. This approach can assist the city's managers to take assertive decisions and contribute to improve the evaluation of public services performance.

Keywords: Sustainability, ISO 37120, urbanism, urban planning, BIM, CIM.

1. Introduction

Cities concentrate most of the world population, economics activities and produced assets. The high human activity associated with an extensive urban occupation model has caused severe social and environmental problems, which implicate on sustainability and efficiency deficits and compromises cities' resilience. These are some of cities managers main challenges on the XXI century [1].

According to the United Nations (UN) [2], nowadays 54% of the world population lives in urban areas, despite the differences on urbanization levels between countries. Due to the continuous and intense urbanization process, until 2050 an increase of 2,5 billions people to urban population is expected, by this time 66% of people will live in cities.

To achieve the purpose of this research was important to delineate the concepts of Sustainability, Building Information Modeling (BIM) and City Information Modeling (CIM). It was also indispensable to understand ISO 37120 concepts and proposals in addition to its indicators.

Sustainability is defined as a characteristic or condition of a process or system that allows it to keep constant or stable in the long-term. Therefore, it should exists without producing resource scarcity. In this meaning, when it referrers to the human, take place society, economic, social, cultural and environmental aspects [3].

Riddell [4] wrote that to put the sustainability paradigm into practice, is essential to increase investments and to promote organized growing by the sustainability terms, which involves a strategic decision-making process in order to reach environmental conservation and human development at the same time.

In 1987, the Brundtland Report presented the most accepted definition of sustainable development: “meet the needs of the present without compromising the ability of future generations to meet their own needs” [5]. This definition, from the World Commision on Environment and Development (WCED), changed discussions about development and economic growing. Way beyond of just creating a new term, it was established as a new way of the world challenges to progress.

According to the referred report and Agenda 21 for Sustainable Construction in Developing Countries [3], the sustainable development combines the following dimensions: economy, society and environment. Furthermore, this development “is not the goal, but the process of maintaining a dynamic balance between the demands of people for equity, prosperity and quality of life and what is ecologically possible”. This is a transformation process on which resource exploration, investments and technological development are made according to the future, weighted by the needs of the present.

Building Information Modeling (BIM) is a process involving the generation and management of digital representation of physical and functional features of buildings [6]. This model is based on smart object representation, wich allows a systemized data, attribute and parameter association [7].

Alizadeh, Bajgiran and Nik [8] describes some of the BIM possible application such as 3D coordination, development planning and monitoring, a better project 3D visual understanding, quantitatives and costs evaluation, conflict detection, as built model, bewond other features.

BIM model can support the detailed semantic of building parts or other city functional parts. Technology in this field enables the storage of designing information in the database digital form for timely updating and sharing. It may also make possible the real-time and conforming relationship between data and phenomenon analysis when any data or paremeter is changed [6].

In view of the aforementioned urban complexity grow, professionals responsible for cities infrastructure systems demands new tools for supplying their needs in planning, project, construction, urban equipment management, as well as its restoration. In this context, appliances and technologies has been proposed and implemented to meet urban demands, among then arise City Information Modeling (CIM) paradigm.

CIM is considered more than the merging of all BIM models, once that it represents a superior level of infrastructure network, administration and human activity. This model facilitates visualizing, analyzing and monitoring the urban environment, in order to support project and planning from local to regional overview. Hence, CIM is characterized by a multidisciplinary unification of all spatial data model.

As reported by Amorim [9], in the City Information Modeling concept, agents involved in cities needs to act in a coordinated way on conception, planning, execution, operation, monitoring, maintenance and renovation of the city. These process occurs in a single and shared database, the CIM

model. The main features of CIM paradigm characteristic, in conceitual terms, is the collaborative work and interoperability.

Almeida e Andrade [10] goes enven further in the CIM concept as a computation based knowledge model involving process, public polices and technologies that allows the multiple interested parts to collaborates to development of sustainable, participative and competitive cities.

In order to measure and to drive performances of city services and quality of life, the ISO 37120 (International Organization of Standardization), known as "Sustainable development of communities – Indicators for city services and quality of life", establishes a holistic and unified urban environment approach, as concerns to its sustainable development and resilience. Thus, this International Standard has indicators which presents a uniform assessing procedure, as well as the procedures how its indicators should be measured [11].

These indicators are structured around themes, according to cities sectors and services provisions. They are organized in Core Indicators and Supporting Indicators. Due to indicators consistency and comparability over the time and from a city to city, the referred International Standard assists cities to monitor its performance achievements. Moreover, beyond the comparison of several measurements, ISO 37120 enables experiences and good practices sharing between cities. By this way, it contributes to planning the public policy of the city once it considers the current resource consumption and its consequences [11].

The Core Indicators are considered fundamental for driving and assessing the performance management of city services and quality of life, while the Supporting Indicators are not mandatory and promotes the best practice.

This paper is consequence of a research developed at Porto's Superior Institute of Engineering (ISEP), Portugal. It's goals were to study BIM and CIM, as well as to evaluate the feasibility of BIM and CIM tools implementation on cities' management to reach sustainability concepts through a more efficient governance of resource and services. The International Standard ISO 37120 (Sustainable development of communities – Indicators for city services and quality of life) was analysed and its indicators were evaluated to understand which data can be obtained from BIM and CIM models.

2. Methodology

Books and scientific publishings were selected at Google Scholar, ScienceDirect and Scientific Electronic Library Online to compose the bibliographic review of this research project. It was addressed the following subjects: sustainability, urban planning, sustainability assessment methods, Building Information Modeling (BIM), Geographic Information Systems (GIS) and City Information Modeling (CIM).

Then, the author carried out an in-depth study of the ISO 37120 (Sustainable development of communities – Indicators for city services and quality of life), which aimed to detect the indicators that can be apprised based on data provided by BIM of edifications and by a CIM model of city.

3. Results

The Core Indicators and Supporting Indicators of ISO 37120 are essential for assessing and guide the performance management of cities' services. Several indicators are arranged into 17 themes related to different cities' sectors or services [6].

The Table 1 highlights the International Standard themes and specifies the number of Core and Supporting Indicators in each one of the themes. The following table also presents the amount of indicators that could be answered by data from BIM, CIM and other database. The indicators identified as "BIM" and "CIM" can be provided by data coming from BIM or CIM models, while the indicators classified as "Other", means they can not be provided by BIM or CIM data.

Table 1. Number of ISO 37120 indicators by theme.

	Indicators		Indicators by data origin		
Theme	Core	Supporting	BIM	CIM	Other
Economy	3	4	0	0	7
Education	4	3	0	0	7
Energy	4	3	1	6	0
Environment	3	5	0	7	1
Finance	1	3	0	0	4
Fire and emergency response	3	3	0	2	4
Governance	2	4	0	0	6
Health	4	3	0	0	6
Recreation	0	2	0	2	0
Safety	2	3	0	4	1
Shelter	1	2	0	0	3
Solid waste	3	7	3	7	0
Telecommunication and innovation	2	1	0	2	1
Transportation	4	5	0	4	5
Urban planning	1	3	0	3	1
Wastewater	5	0	0	5	0
Water and sanitation	4	3	5	2	0
Total	46	54	9	44	47

The Table 2 provides a description of each theme compatible with BIM or CIM models.

Table 2. ISO 37120 themes and its compatibility with BIM and CIM.

Theme	Analysis
Energy	How much electricity is consumed in order to reach a desired management level of generation, consumption, as well as conservation of electricity. It is also relevant to say that any kind of electricity generation have some level of environmental impact [6]. A CIM model, containing the electrical network, will be a good data source for six indicators of this section. The city model will be able to provide important information about electricity generation, transmission and consumption in real time on an accurate way. Furthermore, the BIM model of public buildings can make available it's useful area to calculate these buildings consumption per year.
Environment	Measuring particulate matter concentrations, greenhouse gases emissions and noise pollution, which can lead to significant human health effects besides environmental impacts [6]. It is possible to use city CIM model as a source to answer the current theme indicators, because atmospheric pollutant, as well as, noise pollution monitoring stations could report directly to CIM databank, that is, continuously feed the city CIM model with air quality measurements. By this way, the manager will have a wide, integrated and real time view of environmental conditions in different city location, besides that answer to eight ISO 37120 indicator of this theme.

Table 2. ISO 37120 themes and its compatibility with BIM and CIM.

Theme	Analysis
Fire and emergency response	Evaluating city number of full-time and volunteer firefighter, once fire response is a fundamental service to protect life and property of city citizens. It is also considered the number of fire related deaths, natural disaster related deaths, as well as the response time for emergency and fire departments from initial call [6]. Among the CIM model analytical possibilities is the creation of time response maps, from the first call, considering a great part of real obstacles and variables. Those data could help the city's manager to get a handle on citizens' security and safety threats.
Recreation	Calculating the area of public indoor and outdoor recreation spaces per capita. This aspect is very important in developing countries, once it promotes citizens' welfare and community sustainability. The ISO also notice that the need of public recreational spaces varies depending on local climatic and cultural conditions [6]. Those areas could be delineated using aerial photography and/or land use maps. As previously mentioned, a CIM model would contain city's zoning maps and all public properties well modeled. The CIM model could process all recreational areas and deliver proper and precise data for these indicators.
Safety	Number of police officers, homicides and crimes against property, as well as response time for police department from initial call. Theses indicators reflects the personal safety sense and can effect on investments [6]. Similarly to "Fire and emergency response" theme, the CIM model will allow the creation of time response maps by the police corporation. In addition, homicide data, especially crime locations, could be reported directly to CIM model, which would create a crime spots map throughout the city and even respond to four of the five indicators in this section.
Solid Waste	The population attendance by the regular collection of solid waste and it's final destination, as well as the production and recycling of hazardous waste. This is due to the contribution of solid waste systems to public health, local economy and environment [6]. Thus, the BIM models can provide information about the building solid waste production, answering three indicators of the theme. The CIM will respond to the other seven indicators.
Telecommunication and innovation	The number of internet connections, cell phones and landlines are analyzed, since these aspects reflects the city's connectivity at global level, which contributes significantly to economic development [6]. The records of internet and landline services are maintained by the companies that provide these services, which can supply the CIM model. Therefore, anyone applying the ISO 37120 should only consult the CIM model, not being necessary to collect information with companies for two of the three indicators. Thus the implementation time of this standard can be optimized.
Transportation	This topic considers the size of transport networks, number of cars, motorcycles, amount of public transportation travels and transportation fatalities, as well as city's commercial air connections. These aspects provide an insight into the transport systems efficiency and policies, traffic, congestion, public transport usability and urban form [6].

Table 2. ISO 37120 themes and its compatibility with BIM and CIM.

Theme	Analysis
	CIM will allow the modeling of the city's transport infrastructure, by the way that the networks length will be one of the possible data deliveries. The International Standard establishes that this information can be obtained using computerized mapping, thus, with the CIM it will be possible to evaluate four of the nine indicators in this section.
Urban Planning	Green areas, number of planted trees, irregular and/or illegal properties areas sizes and the employment/housing rate. The first two aspects are directly related to urban climate and quality of life improvement, in addition to atmospheric pollutants retention. The following two issues are associated with social welfare, human health and economic development [6]. In this theme, the CIM can be used as a data source for three indicators assess, since green spaces modeling will provide their areas and trees planting may be registered in the CIM model. ISO 37120 states that informal establishments identification must be carried out with aerial photographs and/or land use maps and that areas shall be calculated using GIS. As previously seen, in the "State of the art", both procedures can be performed in the CIM methodology by an automated and simplified way.
Wastewater	Wastewater collection and treatment. The first one is a city indicator of health, cleanliness and quality of life. The sanitary wastewater treatment indicates the local development level, community health and water quality management efficiency [6]. In this meaning, the wastewater system model may respond to all indicators in this section. Because, the CIM will contain information on each wastewater connection, residential or not, from the BIM models of buildings, as well as data related to this water transportation and treatment.
Water and sanitation	Potable water access, improved water and sanitation, water consumption, interruptions and losses in supply. These aspects are directly related to health, quality of life and local development [6]. BIM models will be able to respond about access and consumption of potable water (five indicators), since these quantitative ones belong to buildings operation phase. The CIM model will provide data on interruptions and losses in potable water supply (two indicators), since these data will be monitorable and analytical, once the water distribution system is modeled.

4. Conclusions

The City Information Modeling (CIM) is essential for the implementation of sustainability concepts in cities, thus collaborating on the fulfillment of the established goals in several international agreements concerning the reduction of human activity on the environment. In addition, the establishment of economical systems guaranteeing fair access to the resources and promotion of human development by fair and cohesive societies.

The BIM and CIM models shall enable the observation of cities' development in real time with better accuracy and readiness through the automatization of 53 of the 100 indicators of the international ISO 37120 standard. Despite the submission so that the international standard is annually executed, the urban manager will be able to monitor the several aspects of development in their city in smaller intervals, according to their seasonality.

As examples are the evaluation of the consumption of energy and water, the production of solid waste and wastewater, witch are influenced by climate change, reflecting the seasons, beyond other factors. Another influence is the rate of urban occupation in different periods of the year. In other words, a touristic city during high season will present a bigger water and electricity consumption and consequently, bigger solid waste and sewer production.

The Building Information Modeling (BIM) and City Information Modeling (CIM) will also contribute to increase the accuracy of results submitted to ISO 37120, the sharing of good practices among cities with comparable development in a global scope: cities considered comparable in the profile indicator basis, also included in the international standard. Thus, the comparison is not only restricted to cities of a same state or country.

The CIM paradigm — as an approach to a global model of the city — will also be formed by the incorporation of BIM models of constructions. In this way, all data related to cities will be available and attached to the georeferenced representations of the constructions in the CIM databank. Thefore, it will be possible to obtain information directly from the virtual model to monitor and evaluate the performance of public services, besides responding to ISO 37120 and collecting information to subsidize more assertive and efficient decision-making.

The set of BIM model, for instance, will be able to provide the estimated production of sewers based on the number of wastewater producer installations, such as toilets, sinks, showers, drains, etc. Therefore, from the CIM it will be possible to respond to all indicators from the "Wastewater" section, as the percentage of people served by wastewater collection, the residual waters which does not receive treatment and the percentages of wastewaters that receives primary, secondary and tertiary treatment.

Besides, the management of urban infrastructure in accurate and georeferenced data shall allow bigger accuracy in the identification process of the root causes of many problems, resulting in more assertive actions for the improvement of the urban infrastructure subsystems. This will reduce the need of corrective maintenance, bringing forth resource savings for the towns, as well as improvement in the provision of public services for the population.

Considering the potential contributions of CIM on urban management, it is suggested that future studies shall intensify discussions and seek to explore the details of this new paradigm, from the fusion of the BIM methodology with the GIS (Geographic Information System) to the energetic enforcement of the existing sharing and representation protocols.

5. References

[1] Ministério do Ambiente, Ordenamento do Território e Energia 2015 *Cidades Sustentáveis 2020* (Lisbon: Direção Geral do Território)
[2] United Nations, Department of Economic and Social Affairs, Population Division – UN/DESA/PD 2014 *World Urbanization Prospects: The 2014 Revision, Highlights* (New York: United Nations)
[3] International Council for Research and Innovation in Building and Construction – CIB; United Natios Programme, International Environmental Technology Centre – UNEP-IETC 2002 *Agenda 21 for Sustainable Construction in Developing Countries: a discussion document* (Pretoria: CSIR Building and Construction Technology)
[4] Riddell R 2004 *Sustainable urban planning: tipping the balance* (Bodmin: MPG Books Ltd)
[5] Bruntland G H 1987 *Our Common Future: The World Commission on Environment and Development* (Oxford: Oxford University Press)
[6] Xu X, Ding L, Lou H and Ma L 2014 *From Building Information Modeling to City Information Modelin* (ITcon: ISSN 1874-4753) Vol. 19, p 292-307
[7] Brigitte G T N and Ruschel R C 2016 *Modelo de informação da construção para o projeto baseado em desempenho: caracterização e processo* (Porto Alegre: Ambiente Construído) p 9-26 Available at: http://dx.doi.org/10.1590/s1678-86212016000400102

[8] Alizadeh K M, Bajgiran J S and Nik E R 2016 *Building Information Modeling (BIM): A Study to Prioritize Applications, Risks and Challenges* In: International Conference on Industrial Engineering and Operations Management (Kuala Lumpur: IEOM)
[9] Amorim A L 2015 *Discutindo City Information Modeling (CIM) e conceitos correlatos* (São Paulo: Gestão e Tecnologia de Projetos) p 87-99. Available at: http://www.revistas.usp.br/gestaodeprojetos/article/view/103163
[10] Almeida F A S and Andrade M L V X 2018 *Considerações sobre o conceito de City Information Modeling* (São Paulo: inSitu)
[11] International Organization for Standardization – ISO 2014 *Sustainable development of communities: Indicators for city services and quality of life* (Genava: ISO)

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