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City Information Modeling: General Aspects And Conceptualization

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ABSTRACT : *The cities of the 21st century are subject to a large number of problems related to transportation, public safety, land use and occupation, sanitation and water availability etc. These problems are mainly observed in developing countries. Thus, the urban planners and rulers have great challenges to be faced in the planning, management and monitoring of cities. In order to deal with the current and future demands of urban populations, it is necessary to develop new paradigms capable of facing the challenges that are posed. In this context, technologies can be used to make city management more efficient, effective and effective, improving the quality of life of the population. The object of study of this paper is the conceptualization of the City Information Modeling (CIM) paradigm. Based on the critical analysis of the literature, it is intended to discuss the existing concepts for the Modeling of City Information.*
KEYWORDS: *cities, modeling, conceptualization, general aspects.*

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I. INTRODUCTION

The modeling of city information (CIM) is an emerging issue with important issues that still need to be discussed. According to Khemlani [1](p. 1), "[...] there is no agreed-upon terminology yet to refer to the concept of modeling cities". The author refers to it as City Information Modeling. Recently, Tah et al.[2] suggest the use of the terminology Built Environment Information Modeling (BeIM).

In addition to terminology, the concept of CIM is not well established. According to Amorim[3] (p. 89, our translation), "[...] regardless of technological issues, there are some conceptual issues that need to be discussed and deepened by the community involved in the search for a consensual definition." discussion that encompasses the CIM and other concepts related to it. Lima [4], like Amorim [3], also believes that the discussion about the CIM needs to be deepened. Therefore, it will be possible to mature the terminology, the conceptualization, and even the possibilities and limitations of the CIM.

The City Information Modeling is the promise of a new paradigm indicated by different authors as being able to improve the planning of the cities, aiding in the decision making by the rulers, and even, by the citizens, since through the CIM can arise applications for the transport sector, location-based services, etc. [3, 5, 6]. Currently, there are different concepts being used for the CIM, however there is no conceptual consensus in the literature [3, 6]. Finally, this research will seek to contribute with the deepening of the conceptual aspects about the CIM and its discussion.

II. MODELS AND MODELING

The models are used to represent objects, facts and phenomena. Generally, they are simplified formulations for specific purposes, and consequently are less than reality, constituting a homomorphic system of the real world. Thus, it can be said that they do not fully represent a given object, fact or phenomenon. The process or technique of model construction is called modeling [7].

Regarding the purpose, the models can be descriptive, exploratory, planning and predictive. Predictive models can be extrapolated or conditional. While descriptive models aim to explain and understand reality, the exploratory models seek to discover other possible realities. The planning models allow the optimization of variables using the simulation models. In turn, predictive models exist with the intention of predicting the future. While extrapolative predictive models use current trends to project the future, conditional predictive models are based on cause and effect relationships [8].

As for the constitution of the models, they can be physical or conceptual. Physical models have characteristics similar to those of real objects. In turn, conceptual models are based on logical properties and abstractions [8].

Mathematical models can be analytical or numerical. The constitution of verbal models encompasses written or spoken logical discourses. In turn, mathematical models employ mathematical logic and properties. While the analytical models are based on symbology and abstract notation, numerical models are implemented in computers and, therefore, are digital ones [8].

The physical models are subdivided into iconic and analog. While the iconic models have only a different scale from that found for real objects, the analog model uses transformation rules to relate to real objects. Conceptual models may be verbal or mathematical [7,8].

Considering the temporal aspects, the models can be static and dynamic. The static models consider the state of the system at a given moment, and the dynamic models, consider the behavior of the system of interest taking into account the variation of time.

Considering the context of this paper, it is important to emphasize that the representation of the various types of objects in the computational environment constitute numerical models or digital models. In turn, geometric models are representations of the shape of three-dimensional objects in the computer. These models can be edge, surface, solid, or even point (cloud of points). In order to overcome the limitation of the geometric models, procedural models were developed that allow to represent more complex objects, their behaviors and relationships.

In the city information modeling (CIM), 3D numerical models of the city are used, which represent the different types of urban objects (buildings, road system, urban furniture, vegetation, water bodies among others), relationships and behaviors. Each of the objects that constitute these city models have characteristics: geometric (form), graphic (appearance), topological (relationships) and semantics (properties / behaviors).

The emergence of BIM models, and more recently, CIM models, seem to contradict two classical modeling assumptions, which state that 'the model is a reductionist representation of the object' and that 'models are built for specific purposes'. The BIM models and the CIM models are constructed for multiple purposes and seek to be isomorphic, of the objects they represent. Thus, these models are initiatives subvert, to some extent, the idea that the model is less than reality.

III. ABOUT BIM AND CIM

The Modeling of City Information can be highlighted as a new paradigm in development. Although emerging, it is known that its viability depends on knowledge of different areas, such as architecture and urbanism, engineering, geography, computer science and so on[9]. The term CIM was first used by Khemlani[1]. Based on BIM, the author of the blog AECbytes portrays the need to develop a model capable of gathering data from the city aiming to produce a platform with interoperability, collaboration and control to propose solutions for the city.

From 2005 to date, the CIM has been gaining space and different levels of deepening, however, there are important issues that need to be discussed and elucidated, such as what is the CIM? Considering that the CIM is a proposed term with reference to the BIM paradigm, some general aspects will be presented.

BIM can be applied in different phases of the projects, namely pre-construction, construction and post-construction. In 2000, the Architecture, Engineering and Construction (AEC) industry began using BIM in projects. According to Eastman et al. [10](p.13), BIM is "... a modeling technology and an associated group of processes for production, communication and analysis of the construction model." BIM is a well-established paradigm. In this sense, the CIM came from the analogy with BIM, comparing the design of the building with the planning of the city.

Despite the possible analogy between BIM and CIM, it is important to clarify that there are many differences between the building and the city. The urban environment is complex, in it are contained beyond the static models, the dynamic objects. Thus, to analyze the urban reality, among many factors, companies, transportation, and people need to be considered.

IV. PROSPECTING ACADEMIC WORKS

In order to analyze the number of academic papers published on the CIM, surveys were conducted in ScienceDirect, Google Scholar and Scopus for the period from 2005 to September 2018. ScienceDirect has more than 250,000 open access articles. Research can be found in the areas of human, social, exact, biological and health sciences [11]. By using the keywords "City Information Modeling" and performing the search in Title, Abstract and Keywords, a paper was found. The work of Chen et al. [12] is entitled "Automatic building information model reconstruction in high-density urban areas: Augmenting multi-source data with architectural knowledge". Using the keyword "CIM", 864 papers were found in ScienceDirect, however, none of them corresponded to the terminology "City Information Modeling". The papers were related to Civil Integrated

Management, Convective Interaction Media, Complementary an Integrative Medicine, Communication Independence Measurement, Common Information Model and Compact Intensity Modulation. However, all represented by the acronym CIM.

Google Academic has its own tools for researchers to find academic papers such as: scientific articles, books, master's dissertations, doctoral theses, abstracts, pre-publication libraries and content prepared by professional and academic organizations [13]. We found 117 academic papers for the period from 2005 to September 2018 using the keyword "City Information Modeling". As was done in ScienceDirect, using the keyword "CIM", we found work related to City Information Modeling and Civil Integrated Management, Convective Interaction Media, Complementary an Integrative Medicine, Communication Independence Measurement, Common Information Model and Compact Intensity Modulation).

The results of the surveys carried out in the different databases allow us to conclude that there are few academic papers using the term "City Information Modeling" in specialized journals. This was observed through consultation with ScienceDirect and Scopus. The survey conducted on Google Scholar showed a greater amount of work, however, many jobs were found that are not in specialized journals. Most of the works found in Google Scholar are of events (congresses, symposia etc.) or of research carried out in undergraduate or postgraduate courses.

We present below the different concepts found for "City Information Modeling" in the literature. The concepts elaborated by Chen [12], Hisham [14], Gil, Almeida and Duarte [15]andStojanovski [16] will be discussed.

For Hisham [14] (p. 1):

"[...] more recently a new term was coined, CIM or the City Information Model, which aims to transform the urban plannersway of handling their plans just like architects."

The conceptualization presented by Hisham [14] is rather simplistic. Considering that with the CIM the projection of the city will occur in the same way as the design of the building, the author does not take into account the various differences between these activities. One of the important aspects to emphasize is that in the design of the buildings there are a lot smaller restrictions on an urban project. Thus, the complexities of a CIM model were not considered by the author [3].

From the point of Gil, Almeida and Duarte[15] (p. 143):

“The CIM would extend the use of Geographic Information Systems (GIS) in urban planning as decision support tools[17,18], through the integration with the Computer Aided Design (CAD) to become a design support tool[19,20]”.

According to the text by Gil, Almeida and Duarte [15], the concept of CIM is understood by the authors as analogous to the concept of BIM. As discussed for Hisham [14], the concept proposed by Gil, Almeida and Duarte [15] does not take into account the full extent and expectations of a CIM model.

For Stojanovski[16] (p. 4):

“CIM is a BIM analogy in urbanism. It is a system of urban elements represented by symbols in a 2D space and the 3D spaces within. It is also conceived as 3D expansion of the GIS (3DIS or 3D information system) enriched multilevel and multiscale views, designer toolbox and inventory of 3D elements with their relationship”.

On the conception of Stojanovski[16], it is perceived that the author thinks the CIM as a tool for the urban planningin 2D and 3D. This way of conceptualizing the CIM can also be considered simplistic, since it does not take into account that these tools are important not only for the planning activities, but even for urban management.

More recently, Chen et al.[12] (p. 22) state that:

“A city information model (CIM) contains spatial data and virtual representations of all objects of interest in an urban area. A well-developed CIM can facilitate the work of city planners and urban designers in addressing urban problems such as traffic congestion, accessibility, connectivity, and the potential impact of natural disasters[21].”

Despite the concept of Chen et al. [12] take into account that a CIM model encompasses spatial and virtual data of the city that are useful in urban management, it does not consider the need to integrate the various subsystems and guarantee the interoperability between them.

Regarding the concept of City Information Modeling, Amorim [3] (p.96) states that "[...] a vision of CIM must necessarily contemplate a BIM vision." Moreover, the Author at the same page “[…] The information must be centralized in a single model and will be accessed and transacted between the various subsystems of the CIM and its administrators. However, here lies one of the biggest problems to be faced, which is the integration of the various subsystems and the guarantee of interoperability between them."

V. SMARTCITY

According to European Parliament [22], SmartCity is: "[...] a place where traditional networks and services are more efficient with the use of digital technologies and telecommunications, for the benefits of its inhabitants and businesses." Therefore, the concept of SmartCity aims to improve the quality of life of people from technological infrastructures that provide efficiency in safety, sustainability, transportation, among others [23].

The concept of SmartCity has spread over the last 20 years, both in the literature and in international politics. The idea of SmartCitiesexpanded by the applicability of improved urban management, mobility, economy and, consequently, the quality of life of the people [24].

Information and Communication Technology (ICT) compiles and monitors a SmartCity. One of the key steps in the use of ICT is the collection of data related to the city. From the creation of large data banks to the city, it is possible to provide useful information to governors, entrepreneurs, citizens, and even visitors [24,25].

According to Limet al. [26], the SmartCity concept encompasses very diverse aspects, such as: urban services, sustainable economic growth, high quality of life, conscious citizens, intelligence, integration, intelligent economy, mobility intelligent, learning, preventive maintenance etc.

In the context of this paper, it is important to emphasize that CIM and SmartCity are complementary concepts. While the idea of SmartCity is at the service of citizens and urban administrators, the CIM is focused on the demands of designers, operators, planners, builders, etc. [3].

It is important to note that the concept of smart city is transdisciplinary and involves different areas of application such as intelligent environment, intelligent home, intelligent energy, intelligent building, intelligent transportation, intelligent logistics, intelligent agriculture, intelligent security, intelligent education, intelligent health etc. Smart devices are used to connect public power, entrepreneurs, citizens and visitors, so that there is interaction and data collection aimed at providing quality services.

VI. CITYGML

Having emerged in Germany, CityGML is the result of an initiative of the SIG3D group. Currently, it is developed and officially maintained by the Open Geospatial Consortium (OGC). CityGML is an international standard open and free, in which it is possible to store and exchange urban models. Through it, it is possible to detail in different levels (LoD) the elements that make up the cities, such as buildings, rivers, bridges, vegetation, roads, etc. [27]. Figure 1 shows the different levels of detail offered by CityGML.

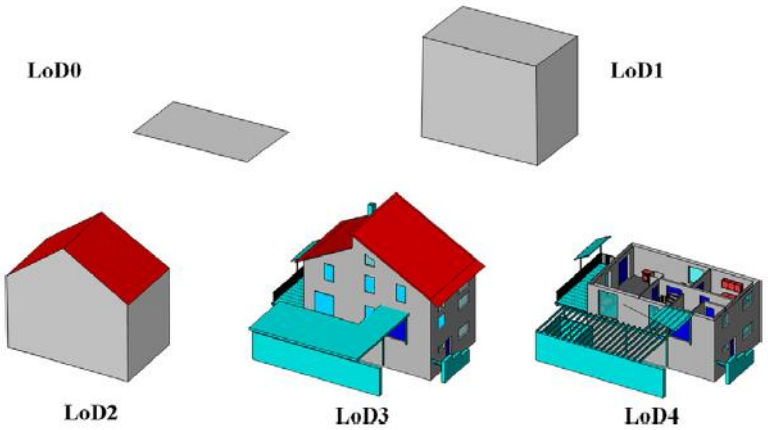

Figure 2: CityGML detail levels
Source: Gröger and Plümer [27].

In LoD0, the building is represented by horizontal polygons (2.5D) with height corresponding to the roof level or height of the footprint level. More broadly, it is a digital terrain model on a regional scale [28].

In LoD1, the building is represented as solid blocks without a roof. For LoD2, the roofs and their main protrusions and recesses (local scale) are taken into account. With LoD3, rich detail architecture can be observed through openings (doors, windows, etc.) and texture application (local scale).Finally, LoD4 considers the detailed modeling of the exterior and interior of buildings [28]. In CityGML, you work with a set of files in XML format and also with image files for texture.

VII. IFC

In 1994, the Industry Alliance for Interoperability (AIA) began the creation of the Industry Foundation Classes (IFC). IFC started from a consortium of companies interested in sharing data from open-source and non-proprietary buildings. Therefore, the data format was created to allow the sharing and exchange of data of the buildings for thefiles of different formats that would be used by the interested parties [29]. The consortium was transformed into the International Alliance for Interoperability in 1997, after which it was renamed "buildingSMART". In order to make IFC the only open world standard for BIM, IFC 1.0 evolved into IFC 4, an international standard for ISO 16739: 2013 (E). After approximately 6 years of development, the IFC4 was launched in 2013 [3].

In order to contribute to the improvement of the sustainability, quality and costs of built environments, buildingSMART is a non-profit organization that proposes the sharing of building and infrastructure data of the city in an open and neutral format. In addition to building modeling, the IFC5 will include the modeling of urban elements such as: canals, roads, viaducts, etc. That is, through it, it will be possible to model components of urban infrastructure. It is believed that IFC5 will not yet cover all objects of the city's scope, however, this new standard emerges as a possibility to make CIM models a reality. Given the timeframe required for the development of IFC4, it is believed that the launch of IFC5 will not occur in a short period of time. After its launch, it will be necessary to wait for softhouses to implement IFC5 in an appropriate file format for modeling data of cities [3, 29].

The buildingSMART encompasses professionals from different areas, such as Architecture, Engineering, Construction and Operation (AECO). Therefore, architects, software developers, engineers, government agents, universities, etc., contribute to more integrated and effective operations involving buildings and urban infrastructure [29].

VIII. CONCLUSION

The prospects of population growth for the next decades and environmental degradation make the problems that cities face even more complex. 3D numerical representation of cities is a fundamental step for 3D Geographic Information Systems (3D GIS), and therefore, for urban management. Given the importance of spatial databases and the need for accurate studies and simulations on acidity, the emerging paradigm, called City Information Modeling, should be discussed and explored in order to verify its potential contributions to improving the quality of life in cities.

City Information Modeling is the promise of a new paradigm.The3D numerical models of the city are used to represent the different types of urban objects.We shown that there are different concepts being used for the CIM, however there is no conceptual consensus in the literature.

Given the importance of spatial databases and the need for accurate studies and simulations on acidity, the emerging paradigm, called City Information Modeling, should be discussed and explored in order to verify its potential contributions to improving the quality of life in cities.

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