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CIM in the context of smart cities: how the interoperability between BIM and SIG can assist the development of smart cities.

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SUMMARY

Nowadays, Smart Cities are one of the most debated and discussed subjects related to urban development. Various technological and innovative processes are being integrated into society's everyday life, aiming at fulfilling the new demands for a sustainable growth that is led by the citizens, by and large. In this context, the infrastructure sector figures as one of the most important points to reach that goal. This paper seeks to study the applicability of the Building Information Modeling (BIM), and of the Geographic Information System (GIS) to Smart Cities, highlighting the main potentialities and challenges of the utilization of these processes. The study will be realized through a literature review of the most relevant works, focusing on the integration of technologies and placing the concepts of City Information Modeling (CIM) in the discussion. It is our understanding that the adoption of CIM concepts by city managers, and by the entire construction sector, could be an important step in the development of Smart Cities around the world.

Keywords: Smart Cities, BIM, GIS, CIM, Infrastructure

1 INTRODUCTION

Over the last few decades, the world has gone through many changes in the context of cities. Urban environments have become more complex, and the dynamics involving its diverse agents became more sophisticated and widespread.

This scenario is joined by the urgent environmental demands, a byproduct of years of negligence regarding the longevity of the resources utilized, and we now face an unprecedented situation, one which makes an urban redevelopment necessary, taking sustainability and the citizens' well-being into account.

The innovative technological processes seek to meet these demands, and to assist public managers and private companies in creating strategies and action plans to bring a new infrastructure to the cities. Thus, the concept of Smart Cities is born.

Studies regarding Smart Cities began in the 90s, and have been advancing throughout time. Recent statistics show that currently there are around 2000 Smart Cities projects around the world, including projects in their beginning and more developed ones. This figure represents a growth of 20% compared to the year of 2015 (NAIDU, 2018).

It is a fact that the idea of technological and more sustainable cities that respect their citizens is well-accepted and studied in academia, however, the biggest challenge is not to pursue the comprehension of the fundaments, but to formulate strategies for the implementation of the concepts, be it in existing cities or in new projects.

One of the ways to start this study is to focus on the aspect that represents urban planning: a city's infrastructure and its components.

The strategic construction of road infrastructures, zoning and division of cities' territories, and the planning of vertical construction (buildings and the like) comprise the main subject this work is based on.

Various technologies have been integrated to the civil construction market throughout history, and the most significant in recent years is Building Information Modeling, commonly known as BIM.

BIM methodology revolutionized the approach to all the processes involved in vertical construction, on small and large scales. The possibility of modeling structures in 3D, the ability to collect data and information to an unprecedented degree, and especially the collaborative way this information is shared, make BIM an unique technology that could potentially be used as a tool in the development of Smart Cities.

However, despite all of these improvements, BIM carries some factors that limit its field of action, making the integration of another technology necessary, one that facilitates the encompassing of these processes for horizontal infrastructures, such as bridges, viaducts, highways, among others. Given this framework, the technology in question is GIS, the Geographic Information System.

GIS is a technology that allows for the collection of geographic and cartographic data that facilitates the mapping and modeling of the territory. This data can be utilized for urban and regional planning.

This paper seeks to dive into the literature related to the subject, aiming at combining the advantages of the BIM and GIS methodologies, which would enable the modeling of information regarding all of the urban infrastructure, be it horizontal or vertical. The means of making these technologies compatible will be investigated, introducing the concept of City Information Modeling (CIM), and relating it to Smart Cities concepts.

2 THEORETICAL FRAMEWORK

2.1 The concept of Smart Cities

Cities are dynamic environments characterized by the actions and the collaboration of multiple agents that interact with each other, and that have specific characteristics that vary depending on the region they find themselves in and also on the level of development they experience in everyday life.

This dynamism is defined by the quick refinement of urban and environmental planning, which makes the managers in charge search for solutions for these demands in a prompt and practical way. The companies enter the scene in this context, implementing new technologies and processes that are capable of aligning specific solutions for big cities. (SILVA et. al, 2017)

According to Almeida & Andrade (2018, p. 23)

> In parallel, and often due to this diversity in exchange relations, the city, being a physical territory in which expansive dynamics act, answers in its own diverse ways the emergence of new challenges, such as saturated mobility networks, floods, water and energy shortage crises, inefficient handling of solid waste, the decay of urban physical networks, microclimatic imbalance, natural disasters, among others.

Marzouk & Othman (2020) contribute to the discussion by adding other factors, such as issues related to health, traffic, pollution, mismanagement of resources, and deteriorating infrastructure.

This context is a byproduct of an exponential rise of urban population and its complexity, which can be explained by factors such as the rural exodus, and the increasing numbers of immigrants hailing from countries going through social and military struggles. (AMORIM, 2016; MARZOUK, OTHMAN, 2020)

These new challenges to urban planning, and to the pursuit of more sustainable development, aligned with the goals of environmental associations, paved the way to the conception of “Smart Cities”. (ALMEIDA, ANDRADE, 2018)

Given such a complex and overarching subject, the definition of Smart Cities is widely discussed among authors, who present different, but complimentary, views. (YANAMURA, FAN, SUZUKI, 2017)

Cosido, Loucera & Inglesias (2013, p.2) define Smart Cities “as a new living urban-space that in order to perceive, learn, and understand what is happening around the city makes use of a growing ICT infrastructure, and then it can take better and faster decisions based on all the gathered data”.

The authors also point out the existence of a big misconception in thinking that Smart Cities are simply a technological advancement, while forgetting the broad sense that is related to the improvement of resource and sustainability management. (COSIDO, LOUCERA, IGLESIAS, 2013).

This definition overlaps with the concept explained by Yanamura, Fan & Suzuki (2017, p.1463), who say the adoption of the term “smart” aimed at solving quick urbanization, seeking a sustainable development of the city “though the optimal management of the resources and potential, offering a comprehensive higher quality of life to the citizens”.

The UN (United Nations) also characterize Smart Cities describing them as an “innovative city that utilizes ICTs and other means to improve quality of life, efficiency of operations and services, and the competitiveness of cities, while guaranteeing the fulfillment of present and future generations”. (UNION, 2015)

Ben Leitafa (2015, p.2) has a more succinct and practical definition, highlighting that “a city is “smart” when when that city can integrate and synchronize formal leadership and endogenous democratic participation in the IT-based urban ecosystem..”

This concept is similar to the one applied by Harrison (2010), who highlights the usefulness of the technology that utilizes data for the development of the population and of sustainability.

Amorim (2016, p.484) addresses the concept even further:

> Thus, the idea of a smart city fundamentally presupposes: quality of life for all of its residents and visitors, and the unrestricted practice of active citizenship. The adoption of sustainable policies and practices, with the responsible consumption of materials and natural resources, and also food and energy self-sufficiency, as well as environmental damage reduction, are all part of this strategy.

As previously mentioned, the definitions differ in mere details and approaches, and if seen as complementary, they allow for a broad and necessary view for the comprehension of Smart Cities.

A pertinent issue, and one which permeates studies related to Smart Cities is “how to identify them?”. In other words, how can one tell whether a city is smart or not?

Currently there is no standard criterion to determine the "level" of smartness adopted by a city. However, this paper highlights the indicators pointed out by Leitafa (2015) (Table 1) as the most assertive and pertinent in relation to the definitions previously presented.

Table 1 – Smart City indicators

INDICATORS	DEFINITION
Smart people	Social capital boosts this dimension. Smart people are the result of social and ethnic diversity, tolerance, creativity and involvement. Cities may offer online courses and workshops, online assistance for education, and customized programs and services to raise social capital and qualification.
Smart governance	Electronic services, such as electronic government, social media and crowdsourcing, all include their parts in transparent processes of decision-making, which lead to smart governance.
Smart mobility	Urban planning is the best way of reaching smart mobility. It shifts the focus from individual modes of transport to collective ones through the extensive use of Information and Communications Technologies (ICTs).
Smart environment	City leaders can explore opportunities in the areas of construction and energy management. The use of innovative technologies, such as solar power and other renewable sources of electricity, can also improve the natural environment.
Smart living	This last concept involves the improvement of quality of life regarding services, increasing the attractiveness for tourists, and promoting social cohesion and security. Smart living encompasses cultural equipment, electronic health, social services, and public security tools, such as surveillance systems and service networks for emergencies.

Source: Adapted from Leitafa, 2015

The indicators present a way to reach a sustainable and smart development of a city. The necessary tools for this purpose are specifically related to the collection and modeling of data. In the context of infrastructure, there are two tools with great potential to help in this process: Building Information Modeling (BIM) and the Geographic Information System (GIS).

2.3 Building Information Modeling (BIM) - Concepts

The term "Building Information Modeling" is one of the technologies with the biggest potential to be utilized as a tool for the development of Smart Cities. (ALMEIDA, ANDRADE, 2018; MARZOUK, OTHMAN, 2020)

In recent years, the construction industry focused on BIM, and it has been developing countless studies about its benefits and the challenges of its implementation. (MARZOUK, OTHMAN, 2020)

In relation to this concept, authors Wang, Pan & Luo (2019, p. 41) define it as follows:

> BIM, digitally representing the physical and functional Information of construction projects, is essentially a shared database that can facilitate the whole process of managing the building life cycle. BIM has enabled the digital management of the full life cycle of buildings, including the design, construction, operation, management, and maintenance phases of construction projects.

It is worth pointing out the terms used in this definition, a "shared database" and "digital management", that overlap with the concepts of Smart Cities previously described.

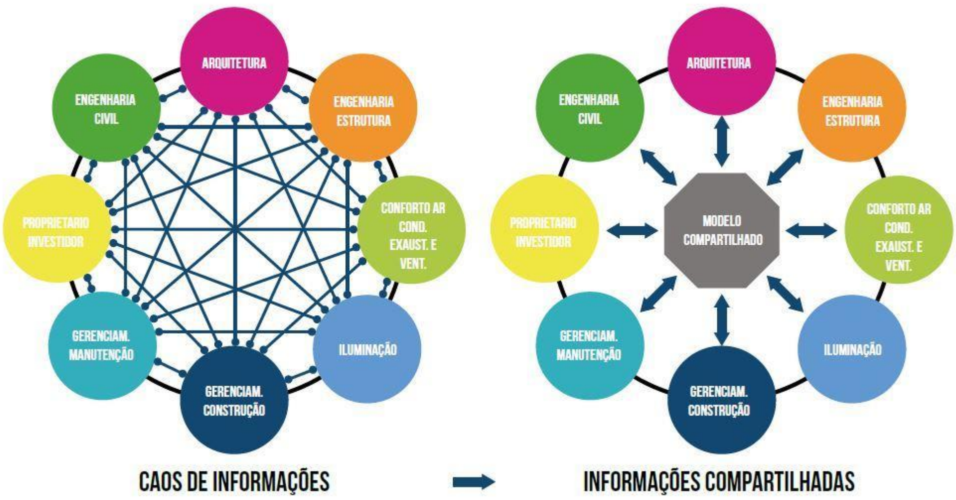
In the same sense, Almeida & Andrade (2018, p.27) bring the term "information modeling" to the discussion, which is where we find the essence of BIM methodology.

According to the authors:

> The term 'information modeling' comes from computer science, referring to system analysis and programming. In these areas, it is viewed as a disciplined approach to analysis that uses programming concepts to produce a clear specification of how an activity operates, that is, how it manages the information. Information modeling proposes a reference framework that highlights in an explicit manner, first and foremost, the association between things.

Figure 1 illustrates how information modeling is important to the process as a whole. The information is shared strategically with all the parties interested in the project, avoiding noise in the communication and execution flaws.

Figure 1 - Integration of the BIM model



Source: CBIC, 2016

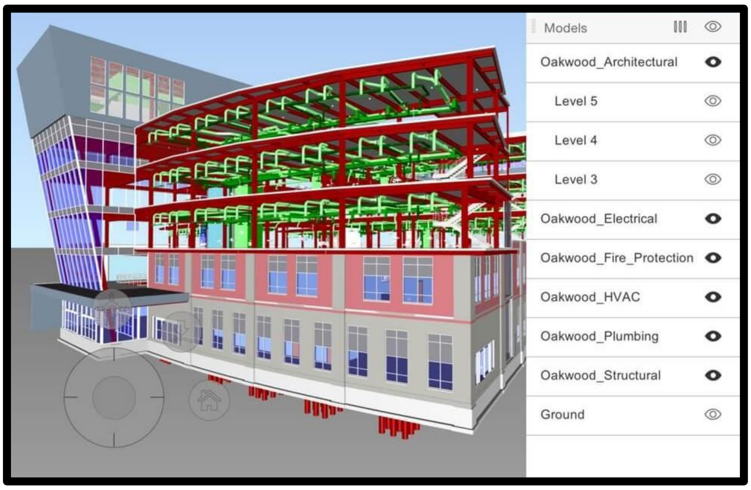
Table 2 presents the main definitions found in literature, which will be the basis for the development of this work.

Table 2 – Definitions of BIM methodology (Building Information Modeling)

AUTHOR	DEFINITION
Andrade (2012)	[...] a process of a project or human activity, or a set of systems, or a methodology, based on the management of the information of a building through a digital model, aiming at collaboration, coordination, integration, simulation, and the optimization of the project, the construction and the operation of the building throughout its life cycle.
Eastman et al. (2004)	[...] involves a revolutionary shift in the manner projects are conceived, how the information about a building is presented, and how this information will be utilized further ahead in construction operations.
Silva et al. (2017)	[...] a software geared for engineers, designers, geographers, and technicians that are involved with civil construction or urbanization, in which its complex database provides a number of tools that streamline the processes of coordination, communication, maintenance, and the analysis of buildings or urban projects.
Deritti (2018)	[...] is a technology that has been disseminated in civil construction as a substitute for Computer Aided Design (CAD). Through BIM, many steps in projects have been streamlined, such as the compatibility of projects from different areas, the budgeting of construction work, schedules and As Built.
Amorim (2016)	[...] an integrated set of sophisticated operations throughout its life cycle, which encompass the most diverse types of numerical simulations, seeking the production of better, more durable and sustainable buildings, through the use of procedural modeling, which incorporates the three-dimensional geometry of objects, their physical properties, behaviors, relations, among other attributes, benefitting the quality of the constructed environment, the reduction of environmental impacts, and the satisfaction of users.
CBIC (2016)	[...] is a set of policies, processes and technologies that, combined, generate a methodology to manage the process of projecting a building or installation, and testing its performance, managing its information and data, utilizing digital platforms (based on virtual objects), throughout its life cycle.

Source: The authors, 2021

Figure 2 – Building model in BIM project



Source: Nakamura, 2019

In its essence, BIM can be a powerful tool in the process of conception of a Smart City. The level of detail generated (Figure 2) and the amount of data provided allow for a thorough management of the processes in the life cycle of a construction, as well as the recording of each corresponding information in a shared database. However, the technology is still very limited when it comes to horizontal expansion, being restricted to vertical infrastructure projects. (MARZOUK, OTHMAN, 2020)

In this context, another technology is brought to the discussion aiming to overcome these restrictions, and to help BIM in the development of cities: the Geographic Information System (GIS).

2.4 Geographic Information System – Concepts

GIS are digital systems based on geography, cartography, and remote sensing technology. They manage spatial information related to the surface of planet Earth, and reproduce this information in platforms and specialized softwares. (WANG, PAN, LUO, 2019)

Naidu (2018, p.6) points out:

> GIS was fundamentally created as a framework for catching, putting away, questioning, dissecting and showing geologic referenced Information yet with the headway in the web, portable innovation, GIS rose as a wide term and a total bundle, which can allude to various present day advances and propel forms and turn out to be more standard that grows learning of the urbanization and associations among individuals.

GIS is not a recent technology, however, it has been changing and being developed throughout the years. (NAIDU, 2018)

Nowadays, it is essential to the urban and regional planning of cities. The systems consist of a digital database that can be utilized for numerous purposes, in which spatial coordinates are the common reference point. (DERITI, 2018)

A broad and precise definition is described by Amorim (2015, p.92), who says:

> GIS are specified, projected, and implemented to represent one or more real life systems. GIS can be developed to withstand actions of planning, management (operation and maintenance), and the monitoring of all urban systems, such as security and public policies, and infrastructure systems, like telecommunications, public transport, and sanitation, or social systems like education and health, among others.

Another important point is the integration of GIS with the Information and Communications Technology (ICT), which enabled the production of quantitative and qualitative analyses of vast territories. (CORREA, SANTOS, 2015)

These concepts bring out important aspects, given it is essential to remember that the focus on planning and on the management of territory is one of the pillars of a Smart City. (WANG, PAN, LUO, 2019)

Therefore, it is important to link the various GIS interfaces to the processes during the conception of a Smart City. Table 3 describes how this should occur, listing the main items and related examples.

Table 3 – Application of GIS tools on Smart Cities

ITEM	DESCRIPTION
Spatial Planning	An existing city can focus on smart management of solid waste using big data and GIS
Gis-Ict	Continuous flow of data and information: connecting departments and concerned parties
Collection	Digitalization of geographic data, spatial databases, supplying critical data for the management of "smart" cities.
Processing	Management of data in real-time, maintenance of open data protocols, integration of service-oriented architecture (SOA) to a data service architecture that does not leave room for data silos.
Communication	A bidirectional flow of information between participants, concerned parties, and citizens.
Analysis	Analysis of structured (digitalized) and unstructured (social, surveys) big data to analyze in real-time.
Decision-making Based on Data	The 'always on' ecosystem allows for real-time management and decision-making.

Source: Deogawanka, 2016

It is clear that GIS enables the strategic use of the geographic data collected in various fronts, not limiting itself to the spatial planning of a city.

3 METHODOLOGY

The methodology employed in this work consists of an exploratory literature review.

A literature review is defined as an investigation and gathering of the main papers about a subject that have been published. (LAKATOS & MARCONI 1987)

In research, any material of relevance and quality in its content was considered, including books, magazines, articles, bulletins, papers, theses, dissertations, among others. Literature was limited to the period between 2010 and 2020. In total, there were 21 works included in this review.

Firstly, Smart City concepts were emphasized, focusing on the establishment of the indicators to understand what makes a city smart.

In a second moment, the research focused on conceptualizing Building Information Modeling (BIM), gathering various definitions that could add to the discussion.

As a complement, works related to the Geographic Information System (GIS) were read, gathering its main characteristics and aspects.

As a result, the definitions of BIM and GIS were compared, looking for the precepts of their compatibility, and to understand how and what it means to develop City Information Modeling (CIM).

Lastly, the pretext for CIM was compared along with Smart City indicators, trying to understand which points the system could benefit in the development of smart and sustainable solutions for cities.

4 RESULTS

4.1 Interoperability between BIM and SIG – Potential Benefits Found

The interoperability between the BIM and SIG systems proved to be possible and promising to the cities' urban development. But, before that, it is important to understand the scales in which each technology operates in this context.

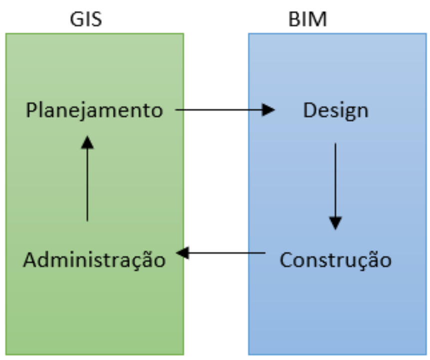
Figure 3 – Model of BIM-SIG Hierarchy

Source: Almeida, Andrade, 2015

Based on the model exemplified by Amorim & Andrade (2015), SIG acts on the territorial scale both in the macro level (world) and the micro level (lot), while BIM takes effect in the data put in these territories through the construction of buildings.

Another important point is to understand that the integration between these technologies is not built in a linear way, as some might think, but rather in a cyclic way, making the flow of available information continuous. Andrews (2019) proposes a simplified model of this integration (Figure 4), making it clearer.

Figure 4 – BIM-GIS Interaction



Source: Adapted from Andrews, 2019

With the concepts of action scales and flow of processes, it becomes noticeable how broad this integration is. The action areas are exemplified in Table 4, based on the studies of Wang, Pan & Duo (2019).

Table 4 – Action areas in the BIM-SIG integration

ACTION AREAS	APPLICATION
Data integration	The BIM-SIG integration allows for the assimilation of big data into the planning and monitoring processes, therefore optimizing the solutions to possible problems and unforeseen situations that may occur during and after constructions.
Urban Governance	The representation of information in 3D models of the constructions and the territory in which they take place makes the analysis of possible natural disasters ahead of time viable, such as floods that could damage the buildings and be a hazard to the population.
AEC Projects' Life Cycle (Architecture, Engineering, and Construction)	The BIM-SIG integration is applied throughout the life cycle of an AEC project, in which the planning and management of the scope are done in a complete way, covering the control of the physical financial agenda, the thorough survey of the materials, and the simulation of the entire construction process, avoiding possible reworking situations.
Energy efficiency	During the enterprise's planning phase, various reliable methods are simulated and verified regarding their energy efficiency. The use of a RDF (Resource Description Framework) can effectively determine the specific energy data of the construction.

Source: Adapted from Wang, Pan & Duo, 2019

The application of these concepts generates the so-called Sustainable Environment of Construction. (WANG, PAN, DUO, 2019)

With the action areas established, the study now faces the integration models that can be followed. These models are based on the most relevant references, and vary depending on the objective and hierarchical place that each technology holds on the process.

Table 5 – Applicability modes of BIM-SIG

INTEGRATION MODES	DESCRIPTION
Mode 1 – BIM as a main resource with the support of GIS	For example, in the field of architectural estate, a database of buildings and historic sites is established mainly by BIM, and the immersive environment of historic buildings can be explored for digital reconstruction, preservation and interaction. A GIS model is used to supply additional data. Furthermore, the technology of integrated delivery based on BIM can be used for smart management of MEP systems in the operational and maintenance phases, through which an algorithm that converts BIM information into GIS maps is used to digitalize information related to MEP and to integrate them in an as-built model.
Mode 2 – GIS as a main resource with the support of BIM	GIS can offer project participants spatial data on construction projects, and be the driving force for the interoperability of data information of other modeling softwares, such as BIM data, the data information can be directly imported to a GIS [15]. For example, a GIS can be used for spatial planning before construction to facilitate the modeling of the surface, and for different forms of geospatial analysis and database management, and the addition of BIM models can simulate the construction professional connecting execution schedules with three-dimensional models to visualize the sequence of construction and to guarantee safety.
Mode 3 – BIM and GIS equally involved	To achieve interoperability between the BIM and GIS models, rules of mapping between IFC and CityGML are created, which represent applications in two different domains, to

	guarantee a precise mapping between the two models and to achieve their integration [25]. In order to solve practical problems, such as the execution of energy modeling in a communal scale, we need to integrate data about the size of urban communities that comes from GIS models and from individual buildings derived from BIM models.

Source: Wang, Pan & Duo, 2019

The development of perfect interoperability between the systems is called City Information Modeling (CIM). According to Amorim (2016, p.486), "SIG and BIM must converge aiming at total compatibility between them in the upcoming years", and this will be the starting point to the "data structures and software platforms that will enable future applications of City Information Modeling through CIM tools".

4.2 City Information Modeling (CIM)

City Information Modeling is a very recent matter in the world. With the advent of Smart Cities and with the further development of BIM and SIG-based softwares, CIM has been becoming more of a reality.

Authors Almeida & Andrade (2018, p.27) exemplify important aspects related to CIM, highlighting the term "collaboration".

> The tone of the CIM concept proposed here resides in the term 'collaboration'. In practice, collaboration is intrinsically related to communication and interoperability, and for them to work with more efficiency, an agreement between the bases of information that were adopted is essential. Therefore, here we emphasize the importance of the ontological approach regarding the city information modeling.

Therefore, it is defined that CIM exists to integrate Smart Cities' urban data, and to later model them, making it different from a fragmented city. (ANDRADE, ALMEIDA, 2017).

For the sake of definition and conceptualization, based on the relevant literature, the present work proposes the following precepts:

Table 6 – CIM definition by author

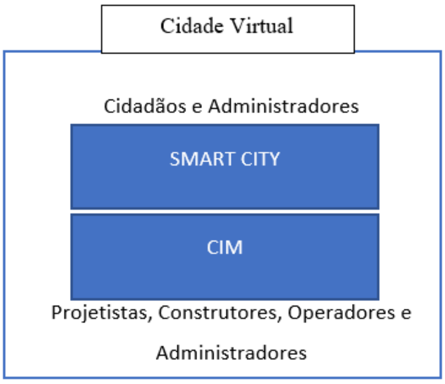
Authors	Definition
Almeida & Andrade (2019)	A knowledge model based on computer science involving processes, policies and technologies, and that allows for multiple concerned parties to collaborate on the development of a sustainable, participatory and competitive city.
Thompson Et Al. (2016)	[...] a transversal and holistic approach to the generation of models of spatial data in which the integration, application and visualization of city data are used to manage and to mediate the demand for land, property and environmental resources; its objective is to balance the need of various concerned parties, aiming to provide sustainable and livable cities where citizens play an important role in its governance.
Beirão (2011)	[...] a platform for project, analysis and the monitoring of cities. It gathers georeferenced information with specialized analysis and project tools. The project tools are generative, to allow for the generation of transformation scenarios. The analysis tools associated with the project tools allow for the analysis (calculate) indicators of support to the decision, objectively evaluating the quality of the solutions generated
Correa & Santos (2015)	It constitutes a new paradigm to think, plan, build, operate, and manage a city's assets. The information regarding the assets must be properly represented in a three-dimensional and georeferenced model, and must serve as a basis to the planning of the expansion, or for the recovery of public spaces, for the preventive maintenance of the infrastructure, and as a basis to simulate scenarios with new public policies. The computational tools associated with CIM will constitute a platform for the city's transformation into a Smart City
Gil, Almeida & Duarte (2011)	A system based on an urban projecting method that integrates the steps of formulation, generation, and evaluation of urban projects supported by the CAD and GIS platform.
Silva et al. (2017)	An extension of BIM applied to neighborhoods or entire cities. Its overall goal is to make the integration of models elaborated in BIM platforms possible, in a manner that creates a digital replica of the city, which can be used as a basis for analyses and sophisticated simulations

Source: The authors, 2020

It's possible to conclude that CIM can play a role in the Smart Cities model, because the union between BIM and SIG allows for the achievement of a complete efficiency in all urban infrastructure systems, and also in the related and dependent processes of this infrastructure. Another important point is the technological compatibilization with other information and communications technologies (ICT) that CIM can provide, which are the essence of the development of Smart Cities. (AMORIM, 2015)

Aiming to reproduce the concept of CIM application in Smart Cities in a simplified way, the following model is proposed (Figure 5), which is based on the Amorim (2015) studies and portrays exactly how compatibilization should be understood.

Figure 5 – Smart City-CIM integration model



Source: Adapted from Amorim (2015)

4.3 Main difficulties related to the BIM-SIG integration

Currently, the biggest challenge to the application of the interoperability between BIM and SIG is the convergence of informations. Because they are created following different standards, there is a risk of losses and failures when data is imported and exported. (DERITTI, 2018)

The standard language used by SIG systems is Geography Markup Language (GML), standardized by the ISO 19136:2007. As reported by Correa & Santos (2015, p.9), GML is "a codification in XML for the transport and storage of geographic information, including spatial and non-spatial properties of geographic characteristics". Within the GML are InfraGML and CityGML, which pertain to the modeling of infrastructures and bridges. (CORREA, SANTOS, 2015).

The language used in BIM softwares is the Industry Foundation Classes (IFC), which is defined by Correa & Santos (2015, p.4) as a "data model that seeks to represent all components or objects relevant to the built environment". It enables the transition of models between different BIM softwares that are in the market. According to the authors, the language "consists of 766 entities ranging from the characterization of the place to be undertaken to the elements that represent the walls and windows of a building."

Both systems can be efficient and sophisticated at their proposals, although there are some differences that make the communication between them harder.

Table 7 — Comparison between IFC and CityGML

IFC	CityGML
Semantic objects focus on the buildings' construction and project, therefore providing construction elements such as beams, slabs and walls, which typically occupy the border between different spaces and simultaneously are part of the building's outer border.	Describes how buildings are observed and used. Therefore, the objects wall and ceiling are defined for a single environment
Geometric representation: csg	Geometric representation: B-Rep
Focus on the building	Objects related to transport, surface, or water resources
A single lod (even though it may contain more than one geometric representation)	Multi-resolution representation

Source: Correa & Santos (2015)

According to Wan, Pan & Luo (2019), in spite of this challenge, some studies on the subject proved to be very promising regarding BIM's IFC language being converted into a superficial GIS model through the transfer of high level geometric and semantic information obtained from BIM for a geospatial environment.

The same authors reveal that different developers are currently working on a unified construction model that incorporates CityGML and IFC. (CORREA, SANTOS, 2015; WANG, PAN, LUO, 2019)

In this sense, another point that would be useful is the "establishment of a common conceptualization of CIM that would allow for multiple researches and platforms in development to communicate with bases in common, so emergencies could be addressed in a systemic manner". (ALMEIDA, ANDRADE, 2018)

5 CONCLUSION

It is clear that GIS can be the solution to the limitations of BIM application and vice versa. Altogether, the technologies can be a big step to the constitution of a Smart City, where the gathering, management and analysis of spatial information on different levels are possible (Urban Infrastructure and Vertical Constructions). (WANG, PAN, LUO, 2019)

Currently, the ISO (International Organization for Standardization) 19166 (B2GM) already exists, which will study the BIM-SIG integration, addressing topics such as mapping development, and guidelines for the flow of information between SIG and the IFC language, which is used on BIM. (JANECKA, 2019)

With this standardization, it is expected that the communication between softwares from both systems becomes simplified and easily accessible. This allows for the development of infrastructure projects with a high level of detail and sophistication, integrated to information technologies (ICT) and big data systems, processes that are essential to Smart Cities.

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