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Impact of Big Data from BIM and GIS on Smart Urban Futures

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Abstract: It is estimated that more than 70% of the world’s population will live in urban areas by 2050. The implications and impact of such growth on natural resources, the economy, and ways of living in current cities are still being assessed as there is an urgent need to develop solutions that can support a sustainable growth. While the potential of big data on the development of solutions appears to be taken for granted, its clear application is yet to be explored in the context of cities governance and design. Urban and rural areas will be further examined, and their boundaries are inevitably to be diluted in the future providing for new ways of living, working, doing business and connecting.

This paper will investigate the use of big data in smart urban futures by exploring the potential of information in support of ecological smart urban corridors development. Through a comprehensive literature review on existing data and information systems such as BIM and GIS and their integration, the paper will analyse the current role of Big data in planning and decision-making and smart cities design.

The results will provide for a clear vision of present data use and potential application in the visualization and design of smart urban futures.

Keywords: Smart Urban Corridors, BIM, GIS, Big data.

1 Introduction

Today, across the world there are more people living in cities than in rural areas. Cities and conurbations increasingly play a major role in driving economic growth and improving the overall quality of human settlements. More job opportunities are generated, and facilities operate more efficiently than in rural regions due to agglomeration and industrialization. A large population sharing infrastructure allows more sustainable growth and concentrated governance permitting for more organized planning. However, cities are facing challenges of rapid urbanization, changing demography, deprivation, insufficient service coverage, inequality, and climate change. Parallel to this, disruptive technologies are evolving at a fast pace and play a major role in how we use an perceive our cities.

This paper intends to explore the role of Big data from GIS and BIM systems in identifying the ecological principles to develop Green and Blue infrastructures for Smart Urban Futures. Through a thorough literature review it explores the potential of smart and disruptive technologies and human and ecological interactions in creating smart networks between existing urban settlements and the rural landscape through the development of ecological urban corridors.

The overlaying patches of different rural and urban areas are increasingly complex and require different approaches and ways of thinking. The trends in city development are now established around economics, nature, the search for a new urban lifestyle and new approaches to governance that serve the multitude of variables and everyday disruptions that cities face.

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Currently, analysis and visualisation of urban data, infrastructure, processes, and inhabitants present an overwhelming problem for monitoring, analysis, planning and decision-making in smart cities projects (Song et al. 2017). This problem hinders the capabilities of cities to properly respond to fast changes in world events, environmental challenges, and economic demands (Sassen, 2018). In the future, the key to accessing data for any urban feature will be to identify the specific location, things and timing of events to create plans which relate to the people who will be affected in that city (Albino et al, 2015). However, understanding existing and available data is of utmost importance for authorities, stakeholders and communities to make informed decisions for future urban growth; the necessary data visualization to support such processes and engage with all partakers has yet to be explored.
Methodology applied to develop scenarios of ecological urban corridors has greatly evolved from being based on either qualitative or quantitative combined with spatial analysis (Peng et al. 2017). Big data from GIS and BIM systems can support the identification of ecological principles to develop smart urban green and blue corridors. Their role in smart urban futures development presents a challenge given their historic environmental and socio-economic characteristics but also an opportunity to explore an innovative multi-inter-disciplinary approach to urban planning. Supported by big data analysis, visualisation and modelling communities, decision-makers, stakeholders and academics engagement is paramount in this process but only possible if the existing data is readable by all. Visualisation and modelling of big data analytics may provide for the support required to engage in innovative approaches to urban planning and decision making in the development of smart ecological urban corridors identifying environmental, liveability and economic drivers and enablers that establish a set of principles to guide the development of existing waterways.

2 Methodologies

This paper was developed based on a thorough literature review according to the guidelines by Gough et al. (2017) and use is made of the digital library databases: Springer, Science Direct, Google scholar, IEEE Xplore and ACM library.
Several types of documents were reviewed including articles, reviews, conference proceeding papers and book chapters. Significant research publications were obtained on Green and Blue Urban corridors historic development and methodologies, Geographic Information Systems (GIS) and Building Information Modelling (BIM) integration, Cities Information Modelling (CIM), Big Data and Big Data Analytics for a considerably large period of 20 years from (1999–2019).

3 Smart Ecological Urban Corridors in Perspective

The concept of ecological urban corridors first appeared in the field of biology. With the increase in human demands and the scarcity of resources, the concept has gained a prominent role in the rapid urbanization and regional integration in connectivity green corridors in the city and intercity. The urgency in which cities grow and need to take over the existing rural areas is increasing at a fast pace due to the population growth and exodus to the urban areas (Seto et al, 2013: U.N., 2018).
The rapid development of urban expansion leads to biodiversity loss and landscape fragmentation. Some argue that it is necessary to focus on urban ecological corridors at a larger-scale of urban and rural space level and its ecological social, cultural and other features began to be a widespread concerned (Che, 2001: Rouget et al, 2006). The urban ecological corridor meets the needs of residents towards the recreation of an ecological green living open space. The term is usually defined through a linear or ribbon ecological landscape that provides the functions of natural habitat, green open space or human habitat isolation in the context of an artificial eco-environment of a city or urban area (Noss & Harris, 1986). With the paradigms of economic development and ecological protection with the burst of urban environmental problems and the increasing human ecological demands, the efficient construction and management of urban ecological corridors is seen as a possible way to resolve the contradictions in the process of rapid urbanization.
There are several classifications of urban ecological corridors, and these vary according to their structure or function. In terms of structural function they include river corridor (MIng et al, 2009: Peng et all, 2017); green transportation corridor (Zong et al, 2003); biodiversity conservation corridor (Li et al, 2009): heritage corridor (Kong et al, 2005); and more recently the recreation corridor which is the result of urban residents needs for green open space and recreational space (i.e. walking and cycling).
In terms of functional classification there is a continuum between ecological urban corridors and communication corridors. The first can be defined as barrier corridor, impeding the material, energy and information from flowing and by doing so protect special species from external interference thus conserving the biodiversity (Noss & Harris, 1986: Peng et al, 2017). These can cause natural habitat fragmentation, reduce landscape connectivity and increase local species extinction conversely, they can create ecological constraints of urban expansion and prevent urban sprawl such as London, Seoul and Beijing greenbelt constructions (Gant et al, 2011: Yang and Jinxing, 2007). The second, promote the flow of important

channels for the water, nutrients, energy, plants and animals thus increasing the connectivity possibilities between important patches. The two functions are not definitive and can ensued simultaneously in ecological urban corridors.

The idea behind urban development is interlinked with the way technology is shaping our present and dramatically impacting on our future. The ubiquitous infrastructure is considered an enabler of smart urban development (Anttiroiko, 2013: Kitchin, 2014: Albino et al, 2015). Technology has an impact on developing urban infrastructure, planning, water supply, public transportation and environmental protection (Anttiroiko, 2013: Kitchin, 2014). It is not about digital cities anymore but smart urban development (Anttiroiko, 2013). Complex information systems require an innovative approach to urban development (Anttiroiko, 2013: Kitchin, 2014). But what do we do with these complex systems and the information generated by them?

Blue and green corridors are urban corridors developed around watercourses, flow paths and surface water ponding along with the green infrastructure that typically accompanies urban blue corridors (Gaston et al, 2013: Li et al, 2017). The dynamic linkages and ecological relationships of both with the urban environment create an area of multifunctional use (URS, 2011: Li et al, 2017).

The key drivers in regenerating urban corridors can be economic, connection with nature and resilience, healthier population and culture and lifestyle. These drivers are global and have different facets and relevance in different urban areas and contexts.

Currently, relevant redevelopments of river/canal sites include the Bradford-Shipley canal road corridor in the U.K. (Bradford, 2017), the Hafen City, Hamburg in Germany (Hamburg, 2014) and Cheonggyecheon stream as part of Seoul's urban regeneration plans (Cho, 2010: Lah, 2011: Lee & Anderson, 2013: Temperton et al, 2014). All projects are to be completed by 2030 with Hamburg and Seoul being on the forefront of urban regeneration awareness.

The fast pace of cities' growth with the societal and ecological challenges requires a step change. Implications on health and wellbeing, housing, future jobs and connectedness need to be addressed in a different way that includes a bottom up community engagement approach. Green and blue corridors present major challenges due to their historic and environmental role but also present opportunities to explore smart urban futures that embrace societal and environmental challenges through the application of technological solutions that promote healthier living for communities.

The integration of BIM and GIS provides for Big Data that can be analysed, visualised and modelled to support the aforementioned challenges.

4 Big Data Analytics

Big data is a considerably used expression that defines the enormous volume of data currently being collected within smart cities context to be analyzed computationally. The relevance is not on the data itself but on the correlation of significant data sets to reveal patterns, trends, and associations, especially relating to human behavior and interactions.

The defining characteristics of big data can be volume, variety and velocity (McAfee et al., 2012), in which volume signifies the quantity of records, contacts, tables or files; velocity refers to the speed of incoming data streams determines (near time, real time) and variety specifies to terms of sensory and non-sensory data sources and/or to the structured and unstructured data formats that increase variety in big data systems (ur Rehman and Batool, 2015) to uncover maximum knowledge patterns.

Gani et al (2015) added three further V's to Big data characteristics: veracity, variability, and value. Veracity refers to the reliability of big data which is represented by authenticity property of big data, data sources and correctness of data. Veracity improves the overall effectiveness of the system. Variability relates to the handling of inconsistencies in big data; and value, represented by the interest of uncovered knowledge patterns of big data. Big data value is directly affected by all V's therefore a proper balance between them signifies more value to in the big data system.

Big data is actively explored in various disciplines and sectors from biology to ecological science and business to agriculture, healthcare, cyberphysical, system, smart cities and social media analytics.The focus of this paper is on the impact off all of these on the urban planning and governance (Hao et al., 2015: Misuraca et al., 2014) of smart ecological blue and green corridors enabling innovation, competition and productivity. Its ability to couple information in innovative ways to create insights and services makes big data a crucial source of innovation; this is a key advantage over small data. Big data analytics has the ability to provide for a holistic vision of the subject matter given the sample size and correlation patterns allowed, which can be integrated in future decision-making.

Recent research indicates that Big Data Analytics has the potential to originate applications based on modeling and simulation (Tolk, 2015) with added value in numerous sectors and disciplines through data-driven decision making. This is of utmost relevance within smart cities context, which relates not only the physical structure but also and more importantly with the human and social dimension of cities. Through the application of several technologies aims to expand the performance of health, connectedness (i.e. traffic, transportations and active mobility), energy, education, and services (i.e. water) leading to higher levels of comfort for their citizens. This can only be achieved by turning information into knowledge using a combination of existing and new approaches.

Big data analytics enables the extraction of information, knowledge and expertise from big data yet this is only useful if translated into actions that are carefully defined and assessed enabling model-driven decision making (Tavana 2014: Saggi and Jain, 2018).
Tavana (2014) proposes six types of data analytic models: Data Mining, Predictive Modeling, Simulation Modeling, Optimization Modeling, Prescriptive Methods and Business Intelligence. Smart ecological green and blue corridors require different layers of data and solid and reliable identification of patterns and correlations to support effective decision making at urban planning and governance level. The different types of data analytic models can support analysis and decision making through big data visualization.

5 Impact of BIM and GID Integration in Derive Big Data

The increased interest in GIS and BIM integration is sustained by the need for effective decision-making supported by an understanding of the environmental, geographical and infrastructure information. The numerous data generated, collected and stored in BIM and GIS can be utilized to facilitate the decision-making process through big data analytics (Schönberger and Cukier, 2013). Increase computer science and data technologies can make the fusion possible but its exploration is still at early stages and innovative applications are and will continue to be explored (Lu et al, 2017) and have the potential for co-creation and collaboration between different authorities and stakeholders which have thus far been working in silos to provide for a better built and natural environment.
GIS has been explored by urban planners at a macroscale while BIM has been advocated by architects, engineers and contractors and facility managers at a microscale (Lu et al, 2017). With the rapid urbanisation, the impact of climate change and the problematic of governance, the implementation of an effective City Information Modelling (CIM) can provide for a significant shift in the way cities are planned and developed. Big data stored in BIM at the micro level can further be integrated to CIM through GIS at an urban scale.
Some explorative studies have been conducted to integrate GIS and BIM through automatically transform the geometric and semantic information of a BIM model to a geo-referenced model for spatial planning (Rafiee et al. 2014) or use semantic web technology to ensure semantic interoperability between existing BIM and GIS tools (Karan et al. 2015). Approaches include ontology construction, semantic incorporation through interoperable data formats and standards, and querying of heterogeneous information sources (Levi at al. 1996).
Efforts have also been conducted for integrating BIM technology into GIS for developing a 3D digital city model (Xu et al. 2014) which can be used for city planning and management. The studies focus on the use of BIM and GIS static information hitherto the integration of dynamic and real-time BIM and GIS for Big data analytics for visualisation in a digital environment presents the real challenge. Both are not static but continuously enhanced with real-time incoming information incoming as the systems function. The volume, variety and velocity of the data make the systems highly dynamic. The implications of a large volume of traffic data within an urban area could bear an impact if captured in the GIS for different applications including road, traffic management but also accidents and public health. The integration of sensor networks and computing provide for real-time collection of big volumes of data that need to further be included in big data analytic systems for smart cities.
Integrating the two models and enabling technologies will have a significant impact on solving problems in the building and infrastructure sectors but also in the effective management of the natural and built environment overall. The main challenge presented is that the systems were created for different purposes therefore the ontologies and taxonomies applied in each are significantly different and not easy to integrate.
In broad terms it could be said that BIM deals with micro data flow of complex 3D through specific standards and GIS focuses on macro data flow and is based on raster and vector geometries also through specific standards. Both systems are file-based storage with specific standards. The main argument for their integration is based on establishing connectivity through web semantics and open spatial database combined with open BIM data base (Karan et al. 2015: Rafiee et al. 2014).
This integration would bear benefits in smart urban futures through sharing experiences and knowledge with individuals and other entities and continuing to obtain effective results and make appropriate decisions but more effectively on: reducing costs through higher efficiency in map creation and customer information collection, by supporting the decision to select the best location for different types of creations (i.e. institutions, enterprises, business, infrastructures etc.) thus avoiding interventions, such as constructions, in environmentally inappropriate locations and choosing the most suitable path for different infrastructures. It also has the potential to increase revenue as simulation allows the development of digital maps and provide technical consultancy in the field of natural resources and the built environment (i.e. real estates) and potentiates the development of new products such as satellite images with projected 3D data and the development of evacuation plans for environmental disasters in the smart city.
The non-tangible benefits include providing better services to city residents through geographic information system to support decision making, as well as using the information available in the system to manage institutions and services more efficiently.

The data generated through the dynamic integration of GIS and BIM can be used in big data analytics to support planning, management and decision making in smart urban futures, yet this is not a clear-cut process. The fact remains that cities operations involve different stakeholders, disciplines and authorities whose expertise differ, and big data analytics will not on their own provide for a solution.

The design of a graphical representation through tables, images, diagrams is required to make sense of the patterns from the data analytics. According to Becker (2016) visual perception, design, data quality, missing data, end-user visual analytics are future trends of visualization which can be developed in form of charts, graphs, histogram, excel spread-sheets, heat maps and geographical maps to name a few. These aim to support interpretation of inferences drawn in a comprehensible manner.

Two main instruments are frequently used to interpret big data: visualization and modelling. These mechanisms are perceived as the most effectively to support smart ecological urban corridors as they provide for an effective way to assess big data analytics from different sources and layers allowing for overlapping of data sets which provide for a holistic view as well as more in-depth analysis if needed.

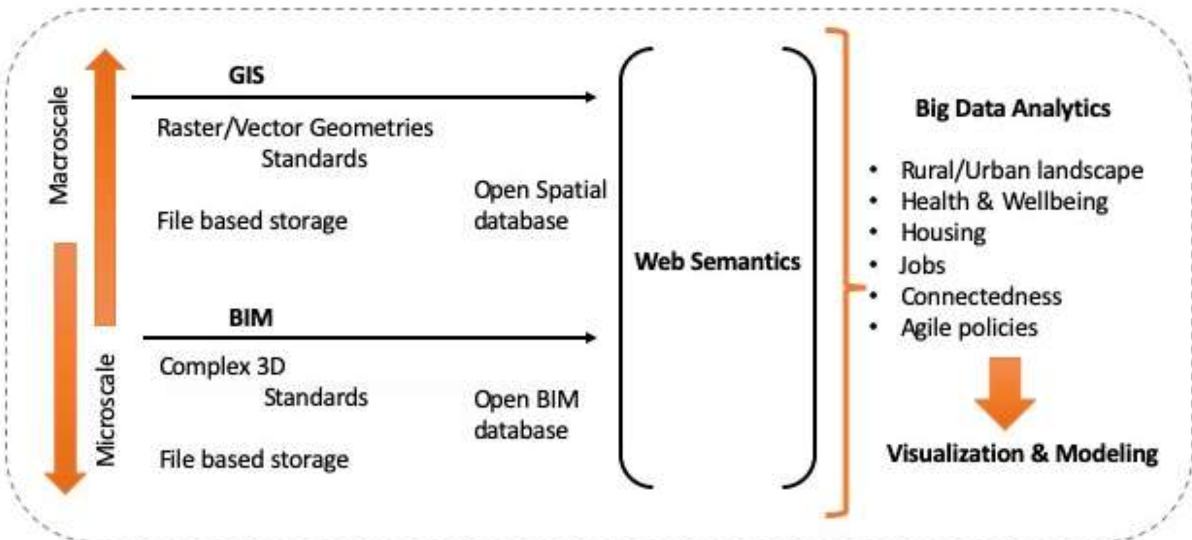

Fig. 1: BIM and GIS Integration Impact in derive Big Data.

6 Conclusions

Through the literature review it is possible to conclude that Big data from GIS and BIM can provide for the identification of the ecological smart urban green and blue corridors by being able identify patterns between the different data sets that can be correlated into layers, such as life expectancy, communities access to green areas and existing health infrastructures to assess the needs of existing communities for example. The potential goes beyond the mere correlation of data sets but also through the visualisation and modelling of the data.

Landscape and biodiversity data sets can be crossed with existing infrastructures data objects to provide for a thorough analysis of a potential developing area through the identification of the existing natural and build infrastructures. The data sets can be developed into visualisations and modelling to assess existing scenarios of both environments and explore the potential of new proposed ones.

The correlations and patches to be established can be infinite once the fusion works effectively. Smart urban Green and Blue corridors can be proposed based on big data analytics from the integration of both systems to support rural and urban landscape development by promoting healthier living and well-being projects, improve housing quality, identify new potential jobs in localised areas and of utmost relevance: maintain connectivity of people and goods in fast growing cities and the challenges of climate change without further harming the environment.

Visualisation and modelling are the tools to be further explored to support community, stakeholders and authority's engagement in developing cities as living laboratories promoting sustainability through smart urban corridors development.

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