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Developing Smart Cities in a BIM environment

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Abstract: *The increasingly modern urbanized world together with its modernization, technological and industrialization trends have led to an explosive growth of city population with gradually increasing need of smart cities. In the context of Smart City worldwide, built environments play a much important role and are used to convey useful information that can be used to realize Smart City goals. Conventionally, information models are used only during the planning and construction phases. In the Smart City phase however, the situation is gradually changing. During the operation phase, projects are now producing more data than before. This paper majorly covers futuristic and sustainable smart cities and the technologies used. It looks especially at BIM and its role as a catalyst in the development and management of smart cities. It presents how the technology develops the creation of extremely functional communities and spaces for living and working that enhance the idea of coexistence, while the structures are like responsible citizens, contributing towards sustainable development. This paper aims to address the data integration challenges of BIM in respect to Smart City by using the current research work in the Linked Data sector in order to facilitate the interoperability among and beyond BIM resources. In the era of IoT and Big Data, taking BIM to smart city planning and management definitely seems to be the logical next step.*

Keywords –*Building Information Modelling, Smart City*

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I. Introduction

The idea of a smart city is like a modern day urban development which brings together information and communication technology (ICT) and Internet of things (IoT) to manage a city efficiently. It manages all the sectors included in a city viz. schools, hospitals, parks, waste management and other services. The technologies used enable a better link between the community and officials and understand the performance of the city, further bettering the interaction and involvement of citizens in the city. An innovative way of collecting data from the residents through their devices is implemented by the application of sensors incorporated within real time monitoring systems, and this collected data is further analysed and used to better understand the performance of the city as a whole and overcome the obstacles posed in the form of inefficiency

Information and communication technology (ICT) acts as a catalyst to enhance quality, and performance of urban services, to eliminate excess costs and resource consumption and to better theinteraction between citizens and officials of the city. Smart city technology is utilized to manage the urban environment efficiently and fulfil the requirement for better real-time responses from the citizens which allow to produce better results in terms of efficiency. A smart city is designed such that it may be more acquainted to respond to difficulties in a productive manner than a conventional city which follows a traditional relationship with its citizens. Yet the term 'smart city'is still not defined in a conventional fashion and is open for various interpretations.

BIM (Building Information Modeling) is slowly and gradually carving its path and being widely accepted in the Architecture, Engineering and Construction (AEC) industries, it leads us to think of a possible next scale solution: the city.Similar to the information models used in BIM help us in designing and understanding our projects more while optimizing its efficiency, virtual city models with the help of BIM processes will find usage in actual city planning and aid us in making the transition from flat GIS to a three dimensional design that includes environment, terrain and other city spaces as its other dimensions. There still does not exist a defined terminology yet to relate to the idea of application of BIM to smart cities, in context to few research papers we will name it as "city information modeling" or CIM. The city information models develop graphical and non-graphical data which can be shared in a common data environment which will assist in planning of the smart cities and their management throughout the life cycle of the project.

II. BIM with "Smart Cities"

The basic idea of applying BIM to smart cities is to have an interactive, smart city model, similar to the method of developing information models for building and other related projects which contain graphical and no graphical data in a common data environment. These information models are utilized to design, operate and manage buildings and infrastructure projects productively with minimum wastage and adverse effects towards the environment, whilst aiming for sustainability. Using the same modus operandi, we can devise city information models for a better impact on their operation and managing. These models can ease the process of planning and construction and have long term positive effects while having minimum impact on the environment. The BIM model of a city formulates the required information and also enables to perform energy analysis and simulate various natural factors and consider various aspects related to traffic, pollution, sun path analysis, disaster management, etc. All in all ultimately designing a better planned city which utilizes its resources best and causes least effects on the environment.

There exist various perspectives on how to make a city smarter but overall everyone has the same aim which is to make the city much better planned, sustainable, well connected and high liveability index. Currently, nations all over the world are increasingly striving for better smart cities to improve their country's economy, tourism and other aspects. Some of the best examples are that of Singapore, Stockholm, Manchester and many more. India has itself launched a Smart Cities Mission to further develop about hundred smart cities with best of infrastructure and sustainability. Involving BIM helps tackle smart city issues to great extent. It develops information models for better design, concept, planning and operation. It does not give much input in smart city policies and governance but primarily focuses on technology as a process to ease the whole concept of making smart cities happen and maintain them. With BIM involved in the building of smart cities we will have to collaborate with technological concepts like Big Data and Internet of Things (IoT).

III. BIM modules for Smart Cities

Building module:

Each building in big city has its own defined characteristic, buildings having varied architectural style or structural data are stored in different building information models. There exist various methods to collect the required da afro these building information models. In recent BIM environments used for the construction of huge projects information models have been developed in CAD or Revit formats. Similarly, this method is used to develop information for various buildings in a smart city which is to be developed. Rapid scanning technologies are used to get both exterior and interior information of the buildings. It contains all information pertaining to exteriors, interiors, materials, and structures. This module particularly lays stress on the information models developed of a building which will further assist in the development of a smart city.

Transportation module:

This particular module is used to develop pavement/ road information including length, materials and cost. It locates the previous buildings in that area and simulates traffic in that area of the city. The traffic information model optimizes in managing real time road monitoring, accurate vehicle positioning and showing efficient routes for every user according to their needs, thus eliminating any possibility of huge traffic. It also maps a path for emergency vehicles to reach the destination in shortest time possible

City furniture module:

This module incorporates the ancillary facilities of a smart city like public garden, parks, and other services. These utility service are an important provision for the citizens and are necessary for their entertainment and leisure. They are a source of recreation for the citizens. Information related to these services can prove beneficial for the government as they can analyse and provide better services to the citizens

MEP module:

In the last couple of decades BIM has been able to enter the AEC industry, and has simplified the construction process by introducing information models which integrates graphical data and no graphical data in a common data environment. It has also found use in MEP services. Especially, Revit MEP is doing great work in developing MEP information models including the HVAC system, underground piping and other systems. Revit MEP provides an information model of MEP services required in the project which can easily be clubbed with other information models. The piles and drainage information models are developed in four stages described below:

1) Piles and drainages information standardization. It is used for industries of piles and drainage model which involve heavy industry work, so that it forms a complex information model system. While incorporating information models form various data collection environments, Industry Foundation Classes should be the accurate information exchanging centre to assure genuine information.

2) Building an information model which enhances exchanging and write-in access. Under the guideline issued by IFC, we are required to develop an information model interchanging and providing write-in access for information model updating and miscellaneous information that we weren't able to get from the existing methodologies.
3) Piles and drainages information aggregation.
Some of the piles and drainages projects are finished lately, so it is possible to get the information from project completion data. While some mega projects are too old and which resulted in data loss, we could find a solution using RFID or GIS to collect and form information models under this situation.
4) Setting up a dynamic update daily mechanism.
A dynamic mechanism can be set up to realize MEP management and timely updating.

Water body module:

This part contains the water bodies, such as river, etc. Water plays an essential role in our lives, but the water pollution is a major problem, and the water used by us is becoming less and on the other hand, the water bodies are also important for the ecosystem. Collection of this data makes it possible for us to make better use of water. There are certain elements have not been taken into our consideration, such as the city waste disposal system. On one hand some of these prevalent systems cannot be built in information models using the existing methods, as the city information model has an access for information and city model has an IFC standard and when the required information could be collected, it can be easily wrote in. On the other hand, some of these information models can be obtained from existed methods, so the information models required can be easily imported into the city information model. This imported model is used to optimize the productivity while identifying the obstacles or possible threats during a projects life cycle so as to deliver efficient projects to its citizens and maintaining its effects towards the environment.

IV. BIM Solutions

With the increasing need of smart cities all over the world its much expected for top organizations of BIM applications pertaining to AEC industry to input resources to research and develop software to enable BIM application in smart cities by producing city models

Autodesk is already working at great pace to develop tools for producing city information models namely, InfraWorks.

Figure 1. Shown here is a proof-of-concept InfraWorks 360 3D model of Los Angeles. (Courtesy: Autodesk)

Digital City by Autodesk was developed with the ideology to create a single software that would allow a common environment to visualize, analyze and simulate future developments within the smart cities and help in producing efficient results in the terms of better planned smart cities. It combines various applications and platforms.

Figure 2. Autodesk Digtial City platform

A close competitor to Autodesk, Bentley has also strived to develop a potential smart cities solution to provide an incorporated model of both above and below surface terrain characteristics of the city information model which includes the built environment. A number of software include BIM applications like AECOsim Building Designer, other GIS applications such as Bentley Map, InRoads, some of its project management software like ProjectWise and Navigator, few point cloud solutions as in Descartes and Pointools. Also special mention to their latest project portfolio additions, ContextCapture and LumenRT. Bentley's BIM solutions have found application in huge smart city projects to produce their information models like London's Crossrail project. A more recent innovative example is the application of Bentley tools to produce 3D map data and information models for Singapore city.

Figure 3. 3D model of Singapore created using Bentley's CIM products. (Courtesy: Bentley)

Additionally, other BIM solutions for smart cities specifically are developed which are advantageous as they are developed keeping smart cities in mind and not an extension of previously created information model software. It simplifies BIM solutions for smart cities. These solutions work together with BIM and GIS technology such as CityGML, an exclusive open data model and XML type format to facilitate storage and exchange of city information models, which enables a free geodatabase to virtually store and manage city information models.

Figure 4. Nagoya city - 3D CityGMLmodeling example

There exist varied systems with such characteristics, a few would be products developed by virtualcitySYSTEMS which produce a range of products for developing, designing, managing and working with city information models, a product from Cityzenith which produced a web based SaaS platform named as 5D Smart City, which will incorporate data from any city, state or government and club it with data received from social media, maps and models so as to keep better track of various resources and utilities and ultimately help the officials understand the sentiments of the citizens and aid in providing better optimized facilities by reducing pollution, traffic, and delivering best required resources to the citizens.

Furthermore, there exist organizations which primarily focus on developing such solutions that visualise city models, like SmarterBetterCities, which produces an online platform named CloudCities for visualizing and sharing city information models. A US based vendor, CyberCity3D has recently launched a mapping application for officials to visualise their smart cities while considering various developments and scheme.

Figure 5. 3D model of San Francisco crated using CityZenith

Figure 6. The CloudCities platform for visualizing city models, even on mobile devices.
Courtesy: SmarterBetterCities

V. Discussions and Conclusion

The idea of conceptualizing and creating information models for smart cities which will ease the process of design, planning and operation during and post its construction phase is filled with potential. Once we have succeeded in producing excellent results in applying BIM to smart cities and increasing efficiency in every aspect

can we further work towards utilizing BIM applications in creating information models of areas of greater geographical area and concentrate on conceiving the idea of smart countries, continents and even a smarter planet. BIM has the power to give structure to our thoughts and define a process for building which will utilize resources efficiently and deliver projects with optimised and best services.

There still lies great scope of exploration of BIM in consideration to its application in smart cities. Further articles related to smart cities built in a BIM environment will consider technologies like maps and CityGML and their requirement to collaborate to build even smarter, interactive information models to improve on the shortcomings of the current approach and evaluate continuously to enhance the living, health, safety, services and happiness index of the people who live in those cities.

From an architect's perspective, the complexities involved in designing urban landscapes are affected by various factors and their analysis is necessary to determine a better way to approach to solutions and identify the most accurate path for integrating information and evaluating decisions to make better plans and designs for the urban environments. The decision whether a single 5D information model, with time and cost as the other two dimensions may be one of the future standards allowing better visualization of all the related complex issues will be a central topic for the author's work in near future. The main aim of creating a city information model is to create such information models that can be interactive and will be stored in a common data environment that is accessible to everyone involved in the project to facilitate decision making and improve the efficiency of the project. Such an interactive database will aid in minimizing the administrative work of managing metro cities and simulate decision making, thus also providing timely corrective measures to rectify malfunctions.

The next step in application of BIM in smart cities will be to define a particular criterion for forming a thorough mechanism to collaborate various types of information models and their evaluation depending on requirements of various users. Their still lies great scope for research and development to utilize technology to plan and develop better smart cities and aim for sustainable development while also striving to increase the nation's economy as a whole.

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