BIM as the Digital Enabler For Smart Cities

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Abstract

Connected, convenient, and digital—this is the city of the future. The design and construction industry must adopt a data-driven approach that allows success in this rapidly changing environment. Building information modeling (BIM) is the digital enabler of smart buildings and cities. Through BIM, the physical assets of buildings and infrastructure are transformed from analog to digital, which opens a myriad of possibilities. Today, facilities connecting BIM data to other sources of data, such as sensor or IoT data, historical facilities management data, and building usage data, are beginning to become more common. This data is helping enhance building operations and predictive maintenance. In the near future, buildings will become more than passive spaces for their tenants; they will transform into an active service that improves the tenant experience, through support such as facilitating teamwork, helping employees decompress after a long day at work, and improving commutes.

Keywords: BIM, Data, Integrated Design, IoT, Prefabrication, Virtual Reality

Introduction

Today, there is a proliferation of technology that is fundamentally changing not only the way our cities look, but also the way we interact with our cities. Similar to how the most magnificent skyscrapers and built structures have strong, unseen foundations that allow creative environments to be built above them, the data to support the digital applications for our built environment also require a strong foundation. The data-driven foundation can be found in building information modeling (BIM). Today, we are starting to see facilities connecting BIM data to other sources of data, such as sensor or Internet of Things (IoT) data, historical facilities management data, and building usage data. This data is helping connect the physical space to the digital. In the near future, we are planning buildings that will become more than passive spaces for their tenants, transforming into active spaces that not only have a digital “thread” connecting inhabitants to the buildings, but also to the surrounding infrastructure. If we are going to achieve our future vision of a truly connected digital space, we must start treating the digital representation of the analog environment,
through BIM, as a co-equal in importance to the analog, physical environment.

**Crossing the Chasm—From Analog to Digital**

The built environment, by its very nature, is analog—with building blocks of concrete and steel, as opposed to data. The analog nature of our buildings and infrastructure was matched by an equally analog design and construction processes. Peer into nearly any construction project today, and it looks relatively similar to construction projects 50 years ago.

But this is starting to change. Building information models (BIMs) represent the industry’s best bridge from analog to digital (see Figure 1). BIM is a data-rich 3D model-based process used to design, construct, and operate building and infrastructure assets. The fundamental power of BIM is driven by the fact that it digitally represents geometry, information, and location. Because BIM is geospatial data, it is the ideal platform for smart cities. It is the platform by which all other sources of data are hosted—including the physical location and geometry of the asset (see Figure 2).

The concept of BIM is by no means new. While the initial origins of BIM are often debated, Stanford University’s Center for Integrated Facility Engineering (CIFE) BIM prototype in 1988 formed the foundation for data-driven 3D model-based BIM processes (see Figure 3). Over the last 30 years since the introduction of BIM, advancements in processing power and storage capacity mean that the tools themselves are no longer barriers. Moreover, the industry has realized a return on investment from BIM, from design to construction to operations. But most importantly, it has highlighted a need, which will be the focus of this paper.

The analog nature of the built environment can no longer be a barrier to this connected, convenient, and digital city—a smart city. The design and construction industry must respond with a data-driven approach that allows us to succeed in this rapidly-changing environment.

**Smart Cities**

The term “smart cities” is used often, though with many different meanings. For purposes of this discussion, it is important that we come to a consensus on the definition. The author’s firm believes that a smart city at its core must use a data-driven approach to enhance the present and future quality of life for its stakeholders. These city-stakeholders include the people who live there, the government that promotes the general welfare and order, and the businesses that transact in the city. Quality of life is multi-faceted, but can be distilled down to economic growth, sustainability, safety, and convenience. Traditionally, our cities face many problems—crime, homelessness, congestion, resource allocation.
Buildings where space is allocated efficiently. But if flexibility, energy consumption and usage patterns of buildings.

report on various data. Through IoT, we understand occupancy, (Lueth 2018), which allow the physical assets to sense and adaptability are built into the environment, these IoT devices can inform needed changes, creating buildings that learn and improve over time.

Imagine buildings where the data sources such as BIM and IoT are connected to an algorithmic intelligence tool. These buildings, run by AI, help streamline and move people, goods and services in ways we cannot yet conceive. Spaces are constructed where meeting rooms communicate with transportation systems, refrigerators communicate with groceries, life-safety systems communicate with first responders, windows communicate with energy systems, and lobbies communicate with tenants. This communication, only possible through connected data, drives an exponential enhancement to quality of life, efficiency, and allocation of resources.

AVs, IoT, and AI are all man-made innovations, but perhaps one of the most powerful changes facing humankind is climate change. Designers and constructors to date have responded primarily with an approach of resilience and reduction, focusing on how our structures can withstand the effects of climate change, and how we can reduce our carbon impact. But when the built world is digitized and connected with other data sources, we will be able to use data to gain insights to have a more active approach to climate change and a stronger negative impact on emissions. We can use our urban habitats to help us drive down consumption and waste. We can drive societal programs that will reduce our carbon footprint.

But the most visible changes may be the smallest, the least physical—what we might call “the connected life.” People now can control the internal temperature of their homes through smartphones that directly link to home thermostats. In turn, these applications learn individuals’ habits and preferences. Our music tastes carry with us from our homes, to our cars, to our offices. When consumers buy a ticket to an event, the confirmation in a user’s email is connected to that person’s calendar, which in turn connects to a map application, powered by traffic data, thereby suggesting a good time for that person to leave for the event. These are a few of the countless examples of how connected data is enhancing the day-to-day human experience.

Figure 4. A hierarchy of smart cities. © VATechnik
While seemingly more subtle, this second category of advancements will demand greater change. It is indicative that people are demanding more from the built environment. It’s not just that we can make our buildings and cities smarter, it is that we must make our buildings and cities smarter. Society is already quite comfortable with the idea of an expanding Internet of Things, the connected life, and the start of smart buildings and cities. Yet, to date, the approach of this digital expansion is happening “backwards.” People have focused on creating ways to digitally interface with largely passive objects, such as buildings. Moving forward, people should start not only by digitizing the building, but by the extension, the city itself.

BIM Today

Today we already see facilities connecting BIM to other sources of data, such as construction productivity data, sensor or IoT data, historical facilities management data, building occupant usage data, and more. As a result, BIM is enabling the industry to design better, build better, and operate better—key steps in realizing the vision of the smart city. This is achieved through visualization, integration, and ultimately, automation.

The following discussion highlights how BIM is providing value across the life cycle of the building and infrastructure assets, which has been paramount in driving the industry’s adoption of BIM.

Design Better

The author’s firm has focused on expanding the value proposition of BIM during design, from visualization and integrated systems coordination, to design optimization and automation. One such example is a recent collaboration with a leading off-site construction manufacturer (see Figure 5). They identified various parameters across which to optimize modular components (such as bathroom pods), including material quantities and costs, dimensions, supply chain availability, factory fabrication schedule, etc. (see Figure 6). Through this data-driven design workflow, hundreds to thousands of variations are analyzed so that an optimal design is selected.
Build Better

As defined previously, a "smart city" is a city that actively improves the quality of life for its stakeholders. We must therefore consider the impact that the construction process itself has on the city. Construction's poor productivity and wasteful processes have had overly negative effects on cities.

Construction productivity lags that of the manufacturing industry by a factor of 1.7, and over the last several decades has shown only around one percent productivity growth (McKinsey Global Institute 2017). The impact of improving construction productivity will include US$1.6 trillion in value-added output in the construction sector per year, a two percent boost to global GDP, and an ability to meet 50 percent more of the global infrastructure needs (see Figure 7).

According to a 2012 report by the World Bank, construction building materials account for half of the solid waste generated every year worldwide. This equates to nearly 700 million metric tons of waste, which is expected to increase to 1.1 billion metric tons by 2025 (Hoornweg and Bhada-Tata 2012).

Today, BIM can be implemented throughout the construction process to tackle the productivity and construction waste problem. For example, BIM-based clash detection solves multi-trade coordination issues prior to construction, reducing delays and rework. Fabrication detail BIM is used for material ordering to reduce waste from inaccurate material quantities arriving on the site.

The author’s firm partnered with a co-working real estate firm on a recent project, with the goal of reducing the total construction time (see Figure 8). The Critical Path Method (CPM) schedule was integrated with the 3D BIM to create a visualization of the original planned sequencing. During several collaborative meetings, opportunities for schedule optimization were discussed. All durations and assumed productivity rates were kept constant, and the only optimization techniques implemented were resequencing activities, shortening the lag between activities, and adjusting crews on-site. Because the schedule logic was no longer locked in Gannt chart format, the quantity and quality of ideas to shorten the critical path increased significantly, and as a result the total construction time was reduced by 20 percent.

Operate Better

The value of BIM continues after construction into building operations. BIM for Facilities Management, often referred to as 6D BIM, combines manufacturer data, operations and maintenance data, warranty data with the BIM, thereby creating a “digital twin” of the building (see Figure 9). Owners and operators of the facilities are utilizing this connected data to train and prepare for maintenance procedures and ultimately to enable predictive maintenance. By determining the optimal time for maintenance to be performed, owners are realizing cost savings as well as more predictable quality and comfort within the building.
BIM Tomorrow

In the near future, we are planning for buildings to become more than passive spaces for their tenants, instead transforming into an active "service" that improves the tenant experience. Can my building help facilitate working together as a team? Can my building help me decompress after a long day at work? Can my building improve my journey from point A to point B? Can my building notify me when maintenance should be performed? Can my building utilize flexible and adaptive spaces so that occupants' needs are continually satisfied? The answer to all these questions is a resounding "yes".

Virtual reality can now be used to gather feedback from potential users before their spaces are built. Designers can collect "likes" or "impressions" on various building features and discover which areas of the building are popular. Journeys can be tracked in virtual reality to understand whether people can execute their travel more efficiently (see Figure 10). Typically, this sort of occupancy data is only available after a building is in use. By simulating the occupancy in a virtual reality environment, synthetic data can be used in the early design process, maximizing the ability to design for the ideal user experience.

This simulation is now being extended to the city scale. Instead of only analyzing occupancy data and behavior within the building, the effect on the external environment can be studied. For example, simulating traffic impact and increased demand for housing, schools, neighborhood retail can inform the planning for a new corporate campus.

Opening the Platform to the Masses

All the above only tells part of the story—what about the next next step? The exciting part is that we don't know. Once the platform is opened and the data is available, entirely unforeseen opportunities will result from the digitization of our cities' assets through BIM. We can't pretend to know what will be done with the data once it is accessible to the future disruptors and entrepreneurs. There is a clear analogy to the innovation the world saw from the advent of the smartphone. When Apple launched the iPhone, it birthed a proliferation of apps—clever programs we didn't know we needed until we had them, but that led to a connected, convenient, digital life experience. So too when BIM becomes the "smart city operating platform," we will see another advent of innovation.

Conclusion

If we are going to achieve our future vision of creating super structures that enhance our living experiences, we must start treating the digital representation of the analog environment, BIM, as equal to the analog, physical environment. To date, the physical environment and its digital representation have been disjointed. In Translations from Drawing to Building, Evans (1997) notes, "I was soon struck by what seemed to be a peculiar disadvantage under which architects labor, never working directly with the object of their thought, always working at it through some intervening medium, almost always the drawing, while painters and sculptors, who might spend some time on preliminary sketches and maquettes, all ended up working
on the thing itself, which, naturally, absorbed most of their attention and effort.” This distinction is blurring as we marry the digital and physical on our path towards the city of the future.

The question we are left with is, when will this future become a reality? If history tells us anything, it is likely to be slower than we hope. While only time will tell, it is clear that the rate of change is accelerating. Bit by bit, BIMs are forming the foundation of future smart cities, digital threads are being made from intelligent machines into digital twins of our buildings, and likewise “under construction” are the foundations of the smart cities that will massively transform the way our civilization connects with the built environment.
References:


