10th Apr. 2018

# IoT, Big Data, Cloud Computing, Artificial Intelligence/Machine Learning, BIM and Digital Twins in Building Automation and Management Applications

## EXECUTIVE SUMMARY

We shall admit that the emerging information and communication technologies (ICT), represented by internet technologies, lead the fourth industrial revolution. Many industries have been totally transformed and upgraded by embracing these emerging ICT technologies, including the building automation and management industry.

In this article, we try to do a general review of the applications of some representative emerging ICT technologies, which are the Internet of Things (IoT), Bigdata, Clouding Computing, Artificial Intelligence/Machine Learning' in building automation and management practices. Additionally, we envision the future applications of Building Information Modeling (BIM) and Digital Twin Technologies. Some Singapore case studies are also introduced followed by the discussion on the challenges in adoption of these emerging technologies. In the latter part of this article, we summarize some phenomena we observed how ICT transforms and upgrades building automation and management industry and discuss the future technology trends, which may inspire further discussion.

**IOT, BIG DATA, CLOUD COMPUTING, ARTIFICIAL INTELLIGENCE/MACHINE LEARNING, BIM AND DIGITAL TWINS IN BUILDING AUTOMATION AND MANAGEMENT APPLICATIONS**

## Introduction

In July 2017, Gartner published the Hype Cycle for emerging information and communication technologies (ICT), as shown in Figure 1.

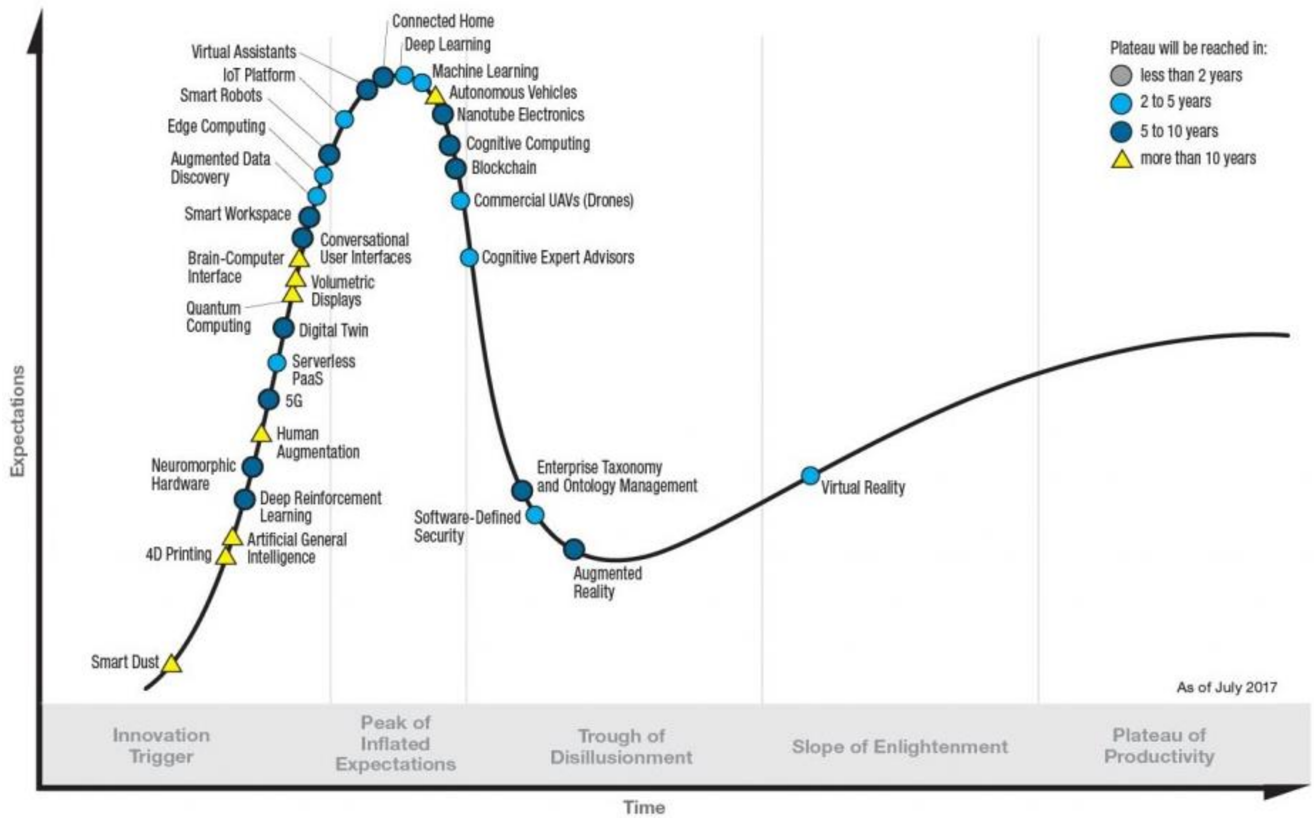


**FIGURE 1 GARTNER HYPE CYCLE FOR EMERGING TECHNOLOGIES, 2017**

To certain extent, most of these emerging ICT technologies could find their applications in the building automation and management practices. More specifically, Royal Institute of Chartered Surveyors (RICS), just published a chart, shown in Figure 2, plotting what emerging ICT technologies building operators should most concern with and when.

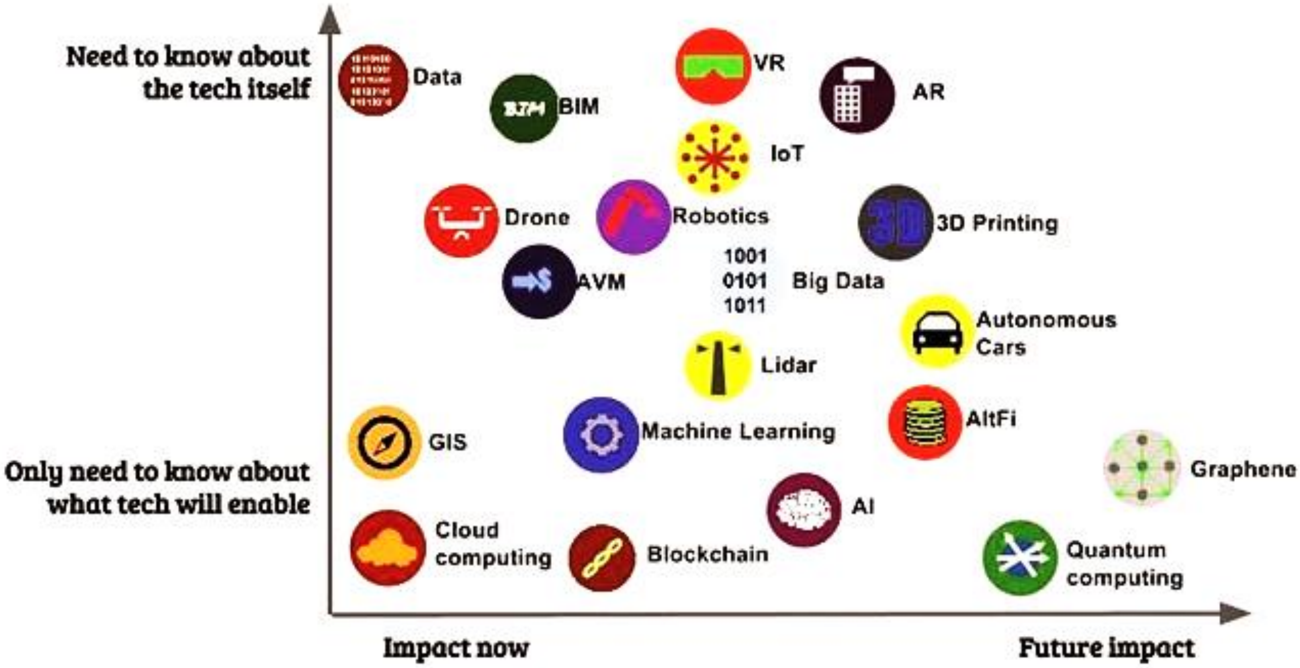


**FIGURE 2 BUILDING TECHNOLOGIES – WHAT YOU NEED TO KNOW AND WHEN**

Among those technologies, Internet of Things (IoT), big data, cloud computing, artificial intelligence (AI) are most relevant to building automation and management. **Figure 3** illustrates how they cohesively work together to bring valuable opportunities to building automation and management. All the building devices/things will be connected to the Internet, which will generate extremely large data sets, i.e. big data. With powerful storage and computing power of cloud computing, big data analysis models and algorithms are running to organize, analyze, and mine these raw data sets, to obtain valuable knowledge and insights. Meanwhile, through iterative self-training, self-organizing and self-adaption processes, Artificial Intelligence (AI) with machine learning (ML) ability become more and more intelligent to autonomously perform the designated building automation and management tasks, e.g. building air conditioning system's optimization, and fault detection and diagnosis (FDD) and so on.

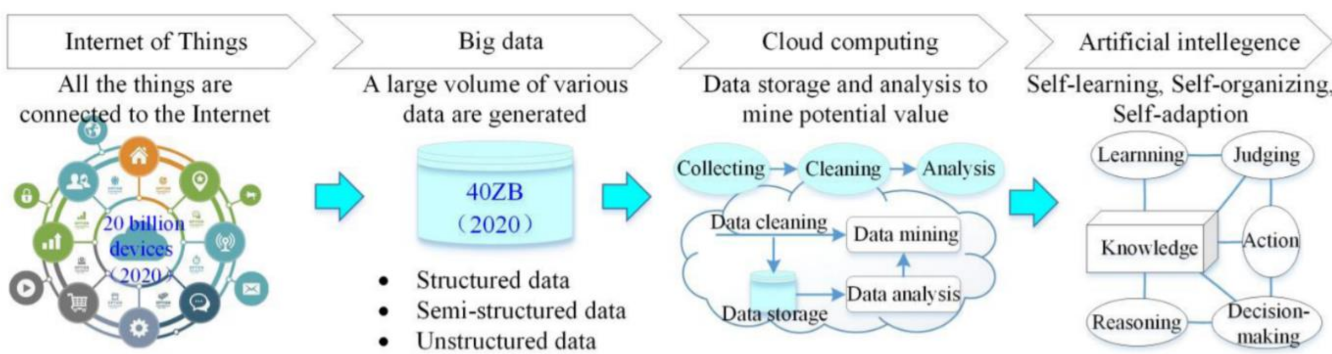


**FIGURE 3 EMERGING ICT AND THEIR APPLICATIONS**

In doing so, these technologies are creating a foundation for the next generation of business models and ecosystems for building automation and management industry.

### IoT becomes the enabler

Internet of Things(IoT) refers to the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data. The sensors are used to generate information from objects, i.e., things. The price of sensors has consistently fallen over the last 25 years as shown in **Figure 4**, and these price declines are expected to continue into the future. Thus, the IoT, with its low-powered networks and inexpensive sensors, is helping to keep smart building costs down. Nowadays, adding IoT-based controls and monitoring to a building can cost from just $5,000 to $50,000. Intel said an IoT-based approach using wireless sensors can reduce deployment cost by around 30% when compared to a traditional Building Management System (BMS). In the context of building automation and management, the IoT is the enabler technology impacting the industry with smart buildings as one of the fastest growing cross-industry IoT use cases.

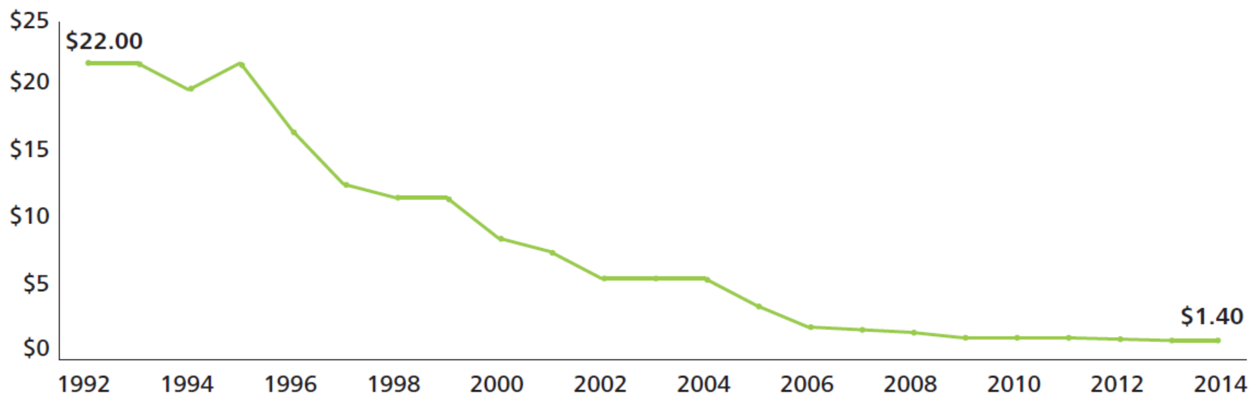


**FIGURE 4 SENSORS PRICES ON THE DECLINE OVER THE LAST 25 YEARS**

On the other hand, the new capabilities enabled by the IoT are increasing building efficiency, tenant comfort, and equipment reliability, among other things. This transformation is taking place. property owners of either new or existing buildings can gain deeper operational insight by taking advantage of open BMS solutions based on IoT technologies, later we will further discuss it.

### Bigdata becomes the capability

In general, big data is to describe the massive data that could not be collected, stored, managed, shared, analyzed, and computed by regular data tools within a short time. Without advanced data tools, people earlier pay more attention to the value of data rather than the enormous quantity. Thus, big data capability is interpreted as the ability to quickly acquire the hidden value and information from the various and large amount of data. It goes beyond the general processing capabilities of users. Besides, big data can also be defined by the following characteristics, which are Volume, Variety, Velocity, and Value, i.e., 4Vs. With regards to Volume, it refers to that the data scale is very large. As for Variety, it means that the size, content, format, and applications of the data are diversified. For instance, the data include structured (e.g., digit, symbols, and tables), and semi-structured data (e.g., trees, graphs, and XML documents), and unstructured data (e.g., logs, audios, videos, documents, and images). Velocity means that the data generation is rapid, and the data processing requires high timeliness. For value, the significance of big data is not the great volume, but rather the huge value. How to extract the value from massive data through powerful algorithms, is the key.

The big data revolution is offering new opportunities and challenges for improving the operation of buildings and achieving energy savings using data analytics. For example, the utility billing data, sub-metered data, and trend data from building automation systems are some of the sources of data that can be analyzed using innovative methods to identify energy saving opportunities. The right methodologies and strategies for data collection, storage, processing, visualization, ownership, and security are the prerequisite for using big data analytics to realize energy savings and equipment diagnostic.

### Cloud Computing becomes the services

Cloud computing is the central data processing unit in the Internet. It is equivalent to the central nervous system of the brain. Internet users will interact with terminals in the cloud and provide inputs to cloud computing and accept cloud computing services. While the edge computing describes a computing topology collects, processes and deliveries the content closer to the to the user/things or "edge" of the networking. Using edge computing design patterns are particularly used for those with significant IoT sensors or devices. Nowadays, some advanced IoT gateways have edge computing capability to process the data coming from the connected IoT sensors.

Edge and the cloud are complementary components of a system. When implemented together, the cloud is used to create the service-oriented model and edge computing offers a delivery style that allows for executions of disconnected aspects of cloud service. It very much like the company organization, the cloud could be the senior management board which takes care key matters about the company operation, while the department head is the gateway to manage the specific functions of a smaller business entity.

### Artificial Intelligence/Machine Learning becomes the tools

Artificial Intelligence (AI)'s development just likes the movement of tides, has moved up and down for 3 times since 1956, when the first AI research was founded at a workshop held on the campus of Dartmouth College. In **Figure 5**, you may notice that AI was a hot topic in 2004 but gradually cool down since that, and became a hot topic again in 2015, cohesively with the IoT and Machine Learning (ML). You may ask why AI tide suddenly becomes the "tsunami" in 2017 and seems to take the world with innovative use cases being applied across all industry segments. The reason is that computer hardware is no longer be the limitation because of the advancement of microprocessors (microprocessor's computing speed increased 1000 times from1992 to 2014, as illustrated in **Figure 6**), as well as with powerful data storage and computing power of cloud computing.

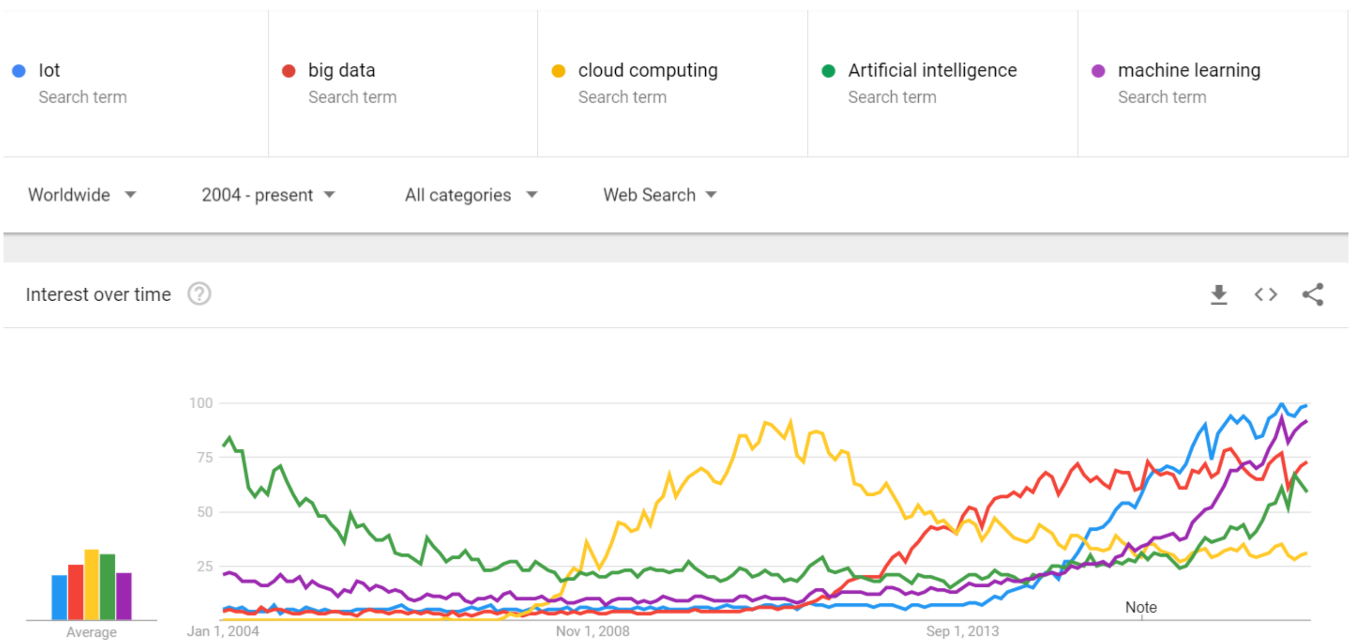


**FIGURE 5 GOOGLE TRENDS FOR IOT, BIG DATA, CLOUD COMPUTING, AI AND ML AS SEARCH TERMS.**

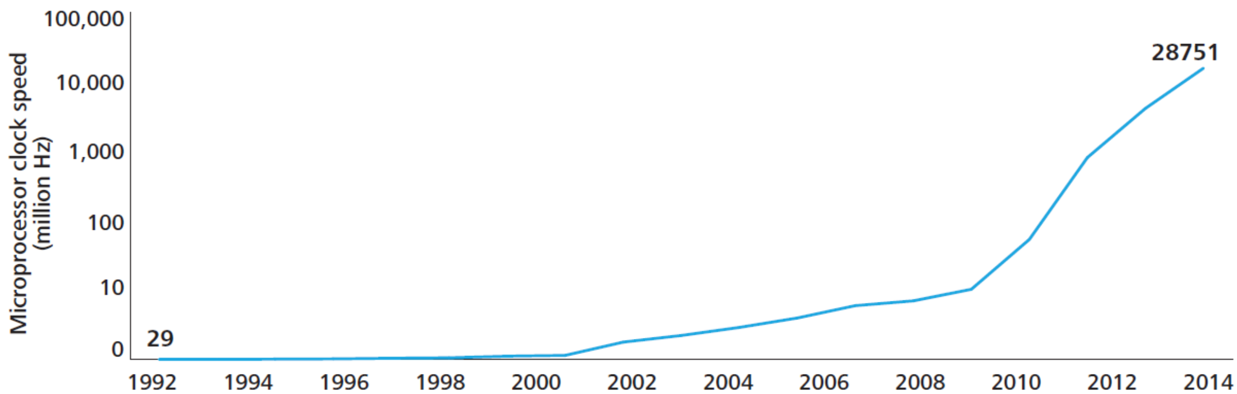

**FIGURE 6 MICROPROCESSOR'S COMPUTING SPEED CONTINOUSLY INCREASING (PLOTTED ON A LOGARITHMIC SCALE)**

Generally, there are two types of AI, Strong AI and Weak AI.

**Strong AI**, also referred to "general AI", is the intelligence of a machine that could successfully perform any intellectual task that a human being can. It is a primary goal of some artificial intelligence research and a common topic in science fiction and future studies. Academic sources reserve "strong AI" to refer to machines capable of experiencing consciousness. Nowadays, the strong AI is still not as "strong" as a 3-year-old kid.

**Weak AI**, also called "applied AI", in contrast to strong AI, does not attempt to perform the full range of human cognitive abilities. It uses a set of machine-learning algorithms to tackle with a specific, highly scoped task (such as understanding language, play go or driving a vehicle in a controlled environment). An example of the triumph of weak AI, AlphaGo AI Go player defeated human world champion in 2017.

According to the application basis classification of AI technologies in **Figure 7**, ML is a subfield of AI. It is a current application of AI that gives machines access to data and let them learn for themselves to carry out the specific tasks.

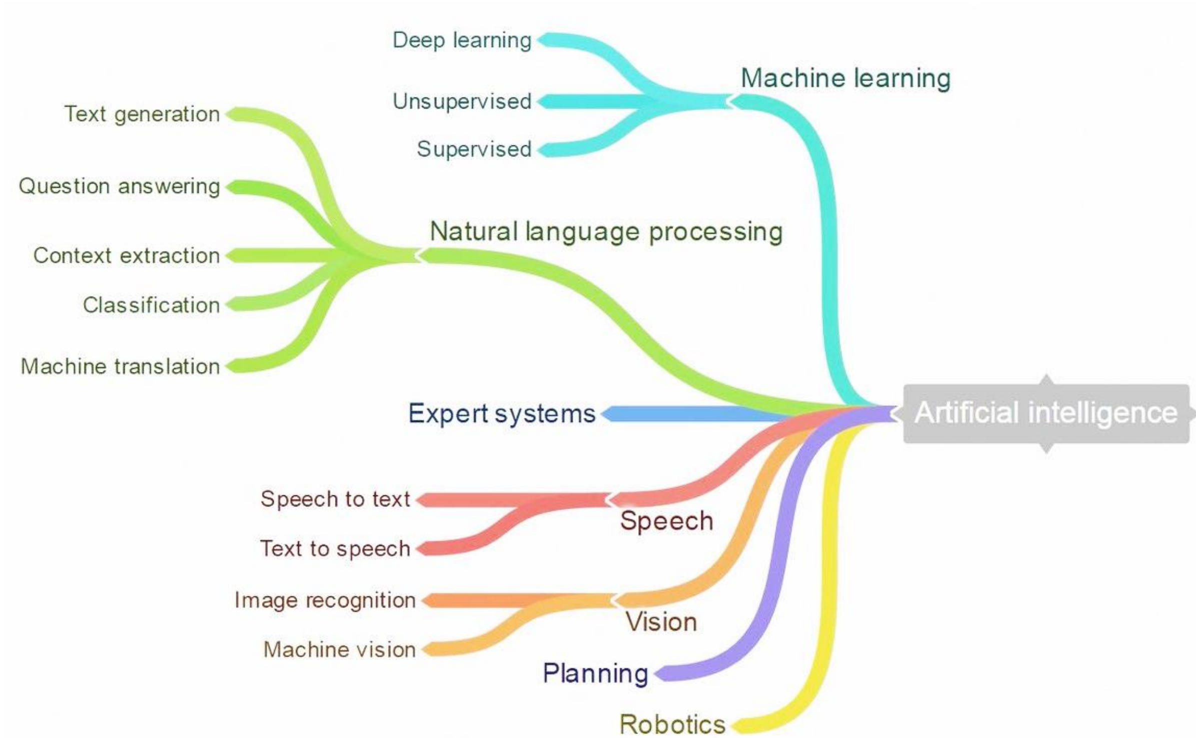

**FIGURE 7 CLASSIFICATION OF AI TECHNOLOGIES**

Facebook, Microsoft, Amazon, Google, and BAT (Baidu, Alibaba, Tencent) are in the midst of reinventing themselves as ML companies. In fact, they are in heated battle to be ML's #1 contender. They've recognized that ML is the edge that they need to be the best in advertising, cars, consumer marketplaces, buildings or whatever other business they'd like to enter in the future.

In the context of building automation and management, ML is an innovative tool for buildings systems to collect, process and use the data collected from all building operations and maintenance activities to provide actionable insights in real-time for building managers to make quick decisions about maintenance and overall operations.

## Today's BMS towards fully integrated, IoT based BMS

Implementing a Building Management System (BMS) today is a lot of work, especially with so many new technologies and options to learn about and consider. It's stressful knowing that after operating the building, building operators may find they're stuck with what they bought with almost no chance to adding new features or data points to the existing BMS. That's because today's BMS are mostly proprietary solutions that can only be upgraded by the system manufacturer – a time-consuming and expensive pursuit. And the average cost to deploy a basic BMS is at least $25 per square meter and can be as high as $70 per square meter, equivalent to at least $250,000 for a 10,000-square-meter building. The very high cost of traditional BMS means Return on Investment (ROI) is a challenge for all but the largest buildings; often it takes at least four years to recover the cost of a BMS installation. Low ROI limits the willingness of owners to invest in BMS deployments in small size buildings. Where BMS is deployed, it is usually only to control the Air Conditioning and Mechanical Ventilation(ACMV) system in the large buildings, those well over 10,000-square-meter.

### The foundation - Individual BMS

Before we talk about IoT based BMS, let us revisit the foundation of BMS. BMS is a parallel industry of Supervisory Control and Data Acquisition (SCADA). The main manufacturers are represented by Siemens, Johnson Controls, Schneider Electric, Honeywell and some Heating, Ventilation, and Air Conditioning (HVAC) companies like Carrier. BMS is using communication protocols such as BACnet, EIB, and LonWorks.

According to ISO standard 3-level model shown in **Figure 6**, a characteristic setup of BMS consists of:

• Management level is the top Level usually employing Ethernet complied BACnet. A workstation or PC running GUI function to assist the building operator to conduct system control.

• Automation level works as the bridge between the lower and upper level. The function as a timer, scheduling and a Supervisory controller running script function.

• Field Level usually on some RS485 type of network with either open or proprietary protocol.

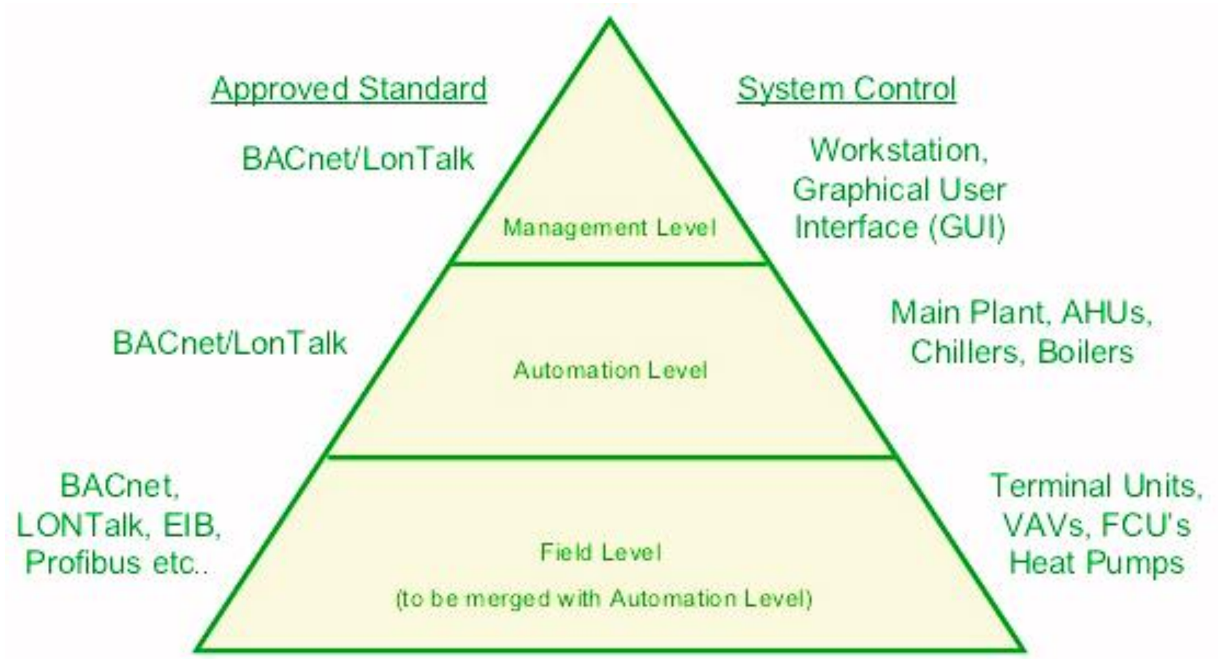


**FIGURE 8 ISO STANDARD LEVELS MODEL**

Today, more and more standards have been developed or extended for building automation and management applications. **Figure 9** shows some commonly seen protocols for the three-level model.

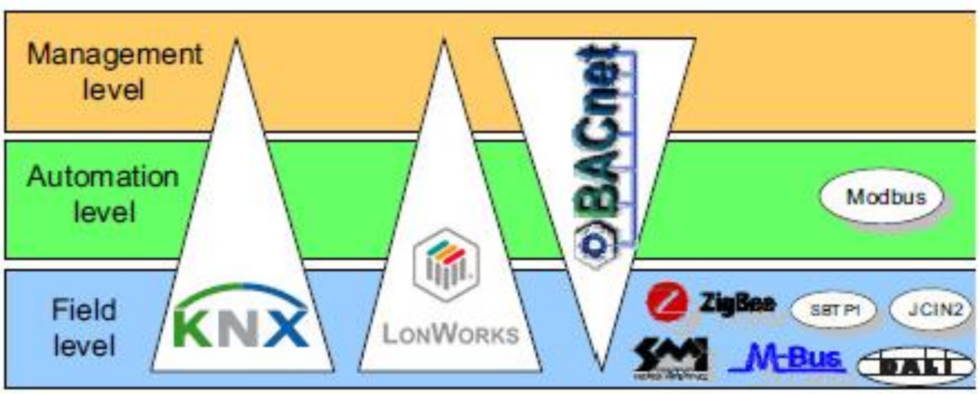


**FIGURE 9 COMMON STANDARDS FOR BUILDING AUTOMATION AND MANAGEMENT APPLICATIONS**

Most control systems used in BMS and ACMV systems employ Direct Digital Control (DDC). DDC system is a computer doing the job of a programmable logic controller (PLC). The DDC controller is processing control code and sending data to a BMS server. As shown in **Figure 10,** BMS server is sitting at the end of the building local area network (LAN) and running a SCADA software to tackle with higher level system automation and management. Similar to DDC, the gateways perform as terminals for BMS server to control and manage the underlying subsystems or equipment, e.g., Uninterruptible Power Supply (UPS) and so on.

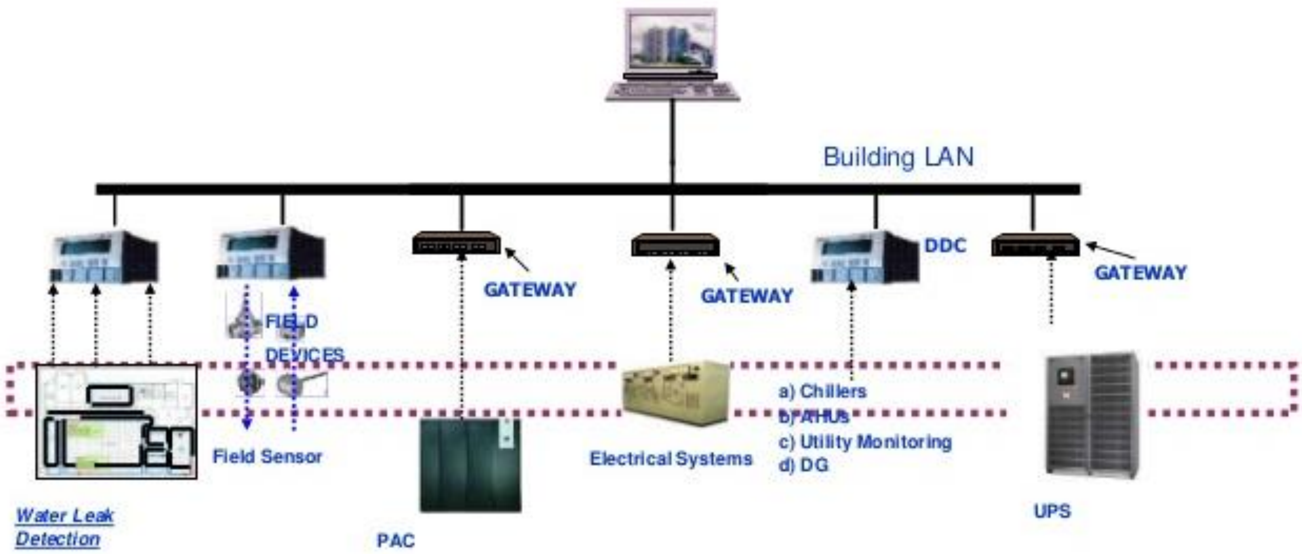


FIGURE 10 STRUCTURE OF A TYPICAL BUILDING MANAGEMENT SYSTEM

**Partly integrated BMS - Integrated BMS and EMS**

We often see building systems such as BMS, lighting, security and more that operate as standalone systems, with each as "automated silos" of information. These automated silos result in a lack of insight into how buildings can be utilized at peak efficiency. For example, if a building is unoccupied, and the security system does not share this "building is unoccupied" information with BMS and the lighting controls, the air conditioning system and lighting will be left on, and the result is wasted energy.

One solution is integrating Energy Management System (EMS), BMS, lighting, security into the one platform to break down barriers between previously siloed systems. Sharing data removes the blindfold and creates visibility and context, enabling a continuous feedback loop for building operation. **Figure 11**illustrates the underlying tasks of BMS and EMS, and how they can work together to make economic sense.

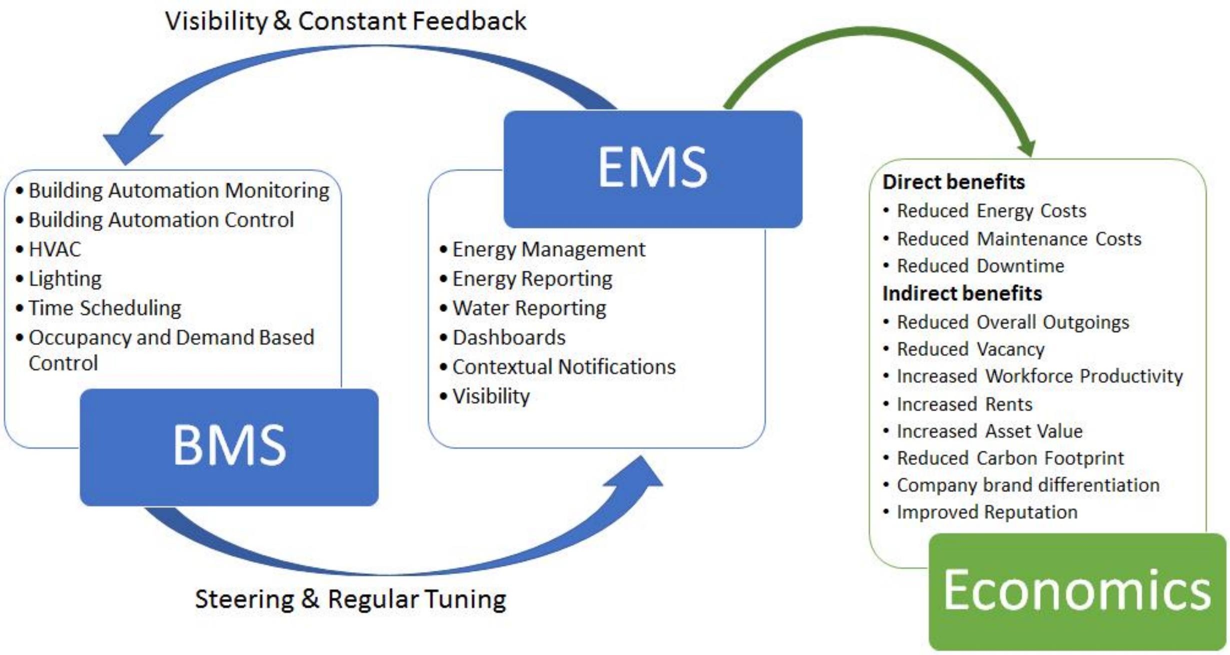


**FIGURE 11 INTEGRATED BMS AND EMS**

### Fully integrated BMS - IoT enabled BMS

And another alternative and more futuristic solution is to implement a BMS solution based on IoT technologies and an open platform. This makes it easier to integrate innovative and cost-effective options from a broad ecosystem of suppliers. A typical solution is illustrated in **Figure 12**, showing how buildings can be monitored and controlled by sensors, routers, gateways, cloud-based software, and personal devices, all the "things" coming from different vendors. What's more, new features can easily be added to such an open architecture.

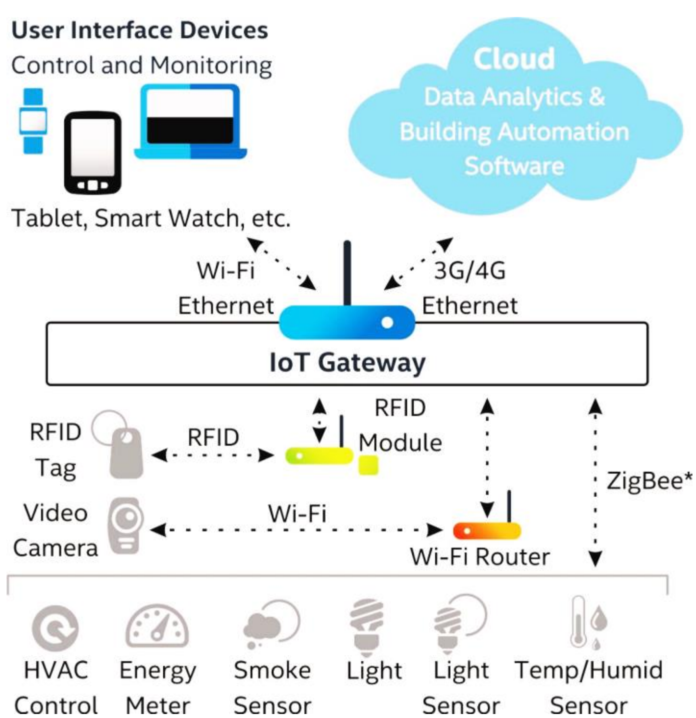


**FIGURE 12 TYPICAL IOT BASED BMS SOLUTION**

Memoori [2] generally benchmarks the features of individual BMS, partly integrated BMS and fully integrated, IoT enabled BMS, shown in **Figure 13**.


**FIGURE 13 BENCHMARKING OF INDIVIDUAL BMS, PARTIALLY INTEGRATED BMS AND IOT-ENABLED BMS**

With the cloud-based computing and data analytical ability, IoT based BMS will increase building efficiency, tenant comfort, and equipment reliability, among other things. Furthermore, as the technology develops, AI/ML will increasingly appear in a variety of objects ranging from smart equipment to autonomous system operation, optimization and fault detection and diagnosis (FDD). Later we will share some case studies happening in Singapore.

## What is the next, infinity BIM towards Digital Twin

Also, thanks to the fast advancement of emerging ICT, Building Information Modelling (BIM) technologies are developing very fast in the recent years. The 'Infinity BIM' concept came about as a reaction to the overuse of BIM 'dimensions'. The emergence of the so-called fourth, fifth, sixth and seventh dimensions of BIM has been decidedly less revolutionary. They comprise, in roughly historical order, the addition to BIM models of scheduling (4D), costing (5D), sustainability (6D) and facility management (7D) dimensions. Each new use brings new human and non-human actors and thus new needs for data exchange. To fully embrace emerging ICT, as-built BIM models shall be linked to the numerous building system objects, i.e. building IoTs: for building operation managers, security systems, maintenance crews, and tenants. Thus, it no longer makes sense to add individual new BIM "dimensions" because of adding new factors: 8D BIM, 9D BIM and so on. What's needed is "infinity BIM" – technology able to effectively manage building information for any conceivable use.

Quite simply, a Digital Twin is a virtual model of a process, product or service. This pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations.

Fraunhofer Institute claims that BIM with a consistent and structured data management is the key to generate such a Digital Twin building whose dynamic performance can be studied by building simulation tools for a variety of different boundary conditions. An infinity BIM, which integrates data from all project stakeholders, could be seen as one example for the application of Digital Twin technology in the building automation and management practices. However, BIM is neither "the key to generate" a Digital Twin nor the best way to exploit Digital Twin Technology, it is still a data framework and information carrier.

A Digital Twin building is the exact representation of, for example, a building as digital data. Imagine a database which knows everything that happened during building operation, like:

1. Every status change reports and real-time operating data for all building assets, devices and equipment, facilities,
2. Maintenance, cleaning and security teams' real-time actions and movements,
3. Building users' real-time feedback,
4. Issues and incidents that needed to be tackled with, and when those have been resolved and by whom,
5. All real-time data points are accurately mapped on the very precise 3D building and objects models,
6. All simulative performances of every virtual building systems.

Such a database should be considered a Digital Twin, since it really is the exact representation of the building operations. And Digital Twin technology would not be limited to representing something real in the digital world. Building's Digital Twin data should be used to generate valuable insights by embedding big data and AI/ML technologies. Based on the simulative and predictive outputs of Digital Twin models, these automated evaluations could help operators to quickly understand the state of their building, facilities, and assets. And if it is necessary, let the machine to operate all building systems in an autonomous manner, without human's supervision.

Same as BIM applications, the success of Digital Twin application depends on being maintained properly: Once the real-world changes, the digital representation needs to be updated accordingly. Thus, the future applications of Digital Twin technology in building automation and management will rely on the IoT technologies to linked to real-world building objects and put the required real-time information into the system.

Over time, Digital Twins of the building objects will be connected dynamically with their real-world counterparts and infused with big data and AI/ML capabilities to enable advanced simulation, operation and analysis. Building users, building operators, security and maintenance teams will all benefit from this long-term shift to the integrated digital twin database.

With the advances in IoT, Bigdata, Clouding Computing, AI/ML, BIM and Digital Twin, smart building operation is becoming the focus of building automation and management transformation and upgrading. Besides, the digital twin paves a way for the cyber-physical integration of building operation, which is an important bottleneck to achieve smart building. Since the BIM and digital twin can be complementary, how they can be integrated to promote smart building operation are waiting for us to explore.

## Case studies

### A Better School Environment Thanks to IOT - SMU

Although the flexibility offered by open BMS solutions is highly desirable, property owners have too much invested in existing systems to simply abandon them. And some survey said only 10% of BMS functions are used by building operator. When "rip and replace" is not an option, it's possible to use IoT technologies to instrument buildings with utility meters, people counters, and other sensors.

This was the approach taken by Singapore Management University (SMU), augmented its existing building automation systems (BASs) with utility meters and an IoT gateways. Their goals were to reduce energy consumption and improve student performance by:

1. Creating a safer, more comfortable, and highly productive learning environment for students
2. Metering water and electricity
3. Benchmarking kilowatt-hour (kWh) per student
4. Tracking building occupancy in real-time

### Autonomous optimization for chiller plant operation through Machine Learning - Kaer

Kaer, a local company, funded by BCA Green Buildings Innovation Cluster (GBIC) programme, has developed a system using ML algorithms to autonomously optimize the chiller plant operation for maximum energy savings. In their system, ML algorithms are running behind to crunch the chiller plant's real-time operation data and building's environment data and give out the optimum chiller plant operating set points, for example, chilled water/condenser water supply temperatures set points, to achieve the minimum energy use of the entire chiller plant. Besides, the system offers real-time and adaptive controls to chiller plant for autonomous operation and optimization. Traditional chiller plant operation and optimization require engineers to monitor and configure the plant operation parameters through BMS, which highly depends on-site engineer's skill and won't ensure compelling outcomes. Instead, "Machine" runs the chiller plant autonomously and deliver a continuous, optimized operation without the supervision of the human. As a result, Kaer can create new business model, called "air conditioning as a service" to provide their customers of the air conditioning service at lower operation cost without owning the chiller plant and facility team. And through remote control, Kaer can proactively manage the performance of the chiller plants in various building and address air conditioning system issues before they happen, thus avoiding expensive repairs and unpleasant temperature excursions.

In their piloting project of running their ML algorithm to real-timely optimize the operating set points of the chiller plant in a building, they saved seven percent in energy cost. This is just the beginning, as Kaer is putting more sensors in buildings to collect more data in order to increase operational efficiency, better forecast energy, and perform predictive analysis.

### Using Big data and ML for Faulty Diagnosis and Detection and Energy Savings - JTC

Jurong Town Corporation (JTC), a Singaporean state-owned real estate company, understands the value of having an elevated level of command and fine control over building operations. They called an open tender in 2017, which worth 40 million Singapore, to develop an Integrated Smart Estate and Building Operation System (JOp) to connect 39 buildings and 180,000 data points to their operation center's central platform for real-time monitoring, data analytics, and workflow automation. A consortium consists of Microsoft, ICONICS and NCS won the project.

The JOp system is expected to offer online diagnostics provide year-round, 24-hour predicative maintenance and operation through early detection of equipment deterioration and abnormalities. Besides, this system is also expected to increase operational efficiency, better forecast energy consumption, and perform predictive analysis for equipment maintenance.

Here we would like to heighten this system's Fault Detection and Diagnosis (FDD) solution. The traditional methods of detecting faults or "performance creep", which are labor-intensive. Typically, building operators or engineers use intuition and various rules of thumb to identify the problem. In practice, the labor-intensiveness of these tasks is such that they are not routinely performed and in fact may never be performed. In this innovative system, first, rule-based diagnostic routines are incorporated for FDD. In this approach, a priori knowledge is formulated through a set of if-then rules coupled with an inference mechanism searching through the rules to draw a diagnostic conclusion. Rule-based frameworks can be designed based on expert knowledge or first principles. Their advantage is simplicity and ease of deployment; however, as problem complexity grows or when new/additional rules are added, the simplicity of the approach is lost quickly. Furthermore, sometimes the activation of the rules depends on the thresholds, which may depend greatly on model uncertainties, measurement errors, or other issues.

To complement the rule-based methodologies, ML algorithms are combined into the system. The fault diagnostics is interpreted as the process of analyzing a system behavioral pattern (observed performance) and comparing it with a set of hypothetical patterns to find the closest match. Each hypothetical pattern is developed based on the assumption of the existence of none, one or more faults in the system. A problem can be formulated as a classification or regression problem which ML algorithms can resolve.

The JOp system is expected to help JTC to meet the 10–15% energy savings in daily building operation with the capability of detecting when a failure has occurred or even before the failure occurring (predictive maintenance), when performance is creeping and to identify the likely offending equipment or operating condition. Automated systems for predictive fault detection are essential for low-energy goals to be met.

## Challenges in adoption

### Too many solutions, too little resource

With the booming of emerging ICT technologies, building operators are exposed to too many similar "smart" solutions. However, most of the solution providers will try to lock their clients to their proprietary platform, which in turn make themselves be silo systems, difficult to interface and integrate with external systems. Below are the rules of thumb for building operators to choose the solution:

1. If the solution has the flexibilities for data storage and deployment, adding additional features at reasonable cost, interfacing and integrating with external systems.
2. If the solution could meet the expected ROI.
3. If the solution will be well maintained and updated.

### Too many data, too costly to process and analyze

The Bigdata generated from the building which would need too much time and money to be stored and analyzed to obtain huge value. Besides, ML algorithms require a continuous and ample supply of structured data to deliver any meaningful results. But that is no reason for building operator not to get started readying the buildings for big data and ML right away. Smartness comes from data. Integrated analysis for the building operational big data will be beneficial to all aspects of building automation and management. Building operators may start by conduct a right data policy and strategy that support unobstructed data flow and simple feedback loops. And building operators may consider leveraging free business intelligence(BI) tools like Power BI to slice and dice building data, giving them deeper insight into building performance.

## Phenomena of Industry transformation

This is a time that building automation and management industry and market are dramatically changing. Below are some phenomena we observed and would like to share with readers to inspire further discussion.

### BMS -Tech companies vs. Tech-BMS companies

The BMS-Tech companies are represented by Siemens, Schneider Electric, Honeywell, and Johnson Controls, they provide their proprietary solutions and add-on features to their clients. Now they are also slowly moving to develop fully integrated BMS solution with data analytics capability and provide open interfaces to allow additional sensors. While, the Tech-BMS companies are represented by Microsoft, Google, and Intel, they intent to building an "eco-system" or an operating system (OS) for building operation based on IoT infrastructure and cloud services, just like iOS and Android to the smartphones.

Microsoft's 88 Acres project, applying an "Internet of Things meets Big Data" approach, their team invented a data-driven software solution that is slashing the cost of operating the campus' 125 buildings. The software, which is saving Microsoft millions of dollars, has been so successful that the company and its partners are now helping building managers across the world deploy the same solution. Google has closed the books on its $3.2 billion purchase of Nest Labs, which introduced Nest Thermostat, making it easy to connect home Heating, Ventilation, and Air Conditioning (HVAC) systems to the Internet. Intel launched their open IoT platform reference architecture for building automation and management. And now Chinese IT companies are also entering this industry. For example, Alibaba has launched their second City Brian as their smart city solution for the city of Kuala Lumpur, after the first deployment in the city of Hangzhou, China. And another Chinese IT giant, Huawei, recently launched their smart estate project to operate and manage their company HQ campus in the city of Dongguan. These Tech-BMS companies may gradually eat into the markets of BMS-Tech companies, like what Tech-Fin companies did to the Fin-Tech companies. However, these two kinds of companies may complement each other if they would like to collaborate.

### Lesson learned from Nokia's fall

The smart mobile phone's history may mirror the road of BMS. The competition among BMS players very much likes the battle of the smartphone, which happened 10 years ago. Nokia was the most valuable mobile phone brand in 2008 and used to dominate the market. However, as everyone knows, they eventually lose the phone war against the Apple, originally a computer company. If we look back, probably they made three critical mistakes along the way: 1) operated a failed smartphone ecosystem, Symbian, and few partners would like to join them; 2) too slow in transforming herself from phone manufacturer to technology innovator, as what Samsung did; 3) embraced the wrong smartphone ecosystem – Windows 8. However, we shall have no doubt that Nokia senior management had made every right decision along the way, from their stands. Nokia's lesson may give BMS players some inspiration.

### Matthew effect – big becomes bigger

IT giants like Microsoft, Google, Amazon, and Alibaba are always attempting to hire the smartest people in job market and buy the most promising unicorn companies. There will be little chance for start-ups to enter their business. Leveraging on their accumulated, disruptive technologies, data, knowledge and talents they assembled, they can freely enter other industrial domains and take away the businesses from the earlier players. They will just become bigger and bigger.

### Tug of War between IT giants

As IT giants like Microsoft, Google, Amazon, and Alibaba are almost equally big and have been building their respective ecosystems and have their loyal partners and markets, they may not be able to knock out others as the boxer knock down his opponent in a boxing game. Instead, the competition among them just likes a game of Tug-of-War. They want more partners and followers, e.g. the BMS-tech companies, to join their ecosystems. They will reach out to those devices and equipment suppliers as well as silo IoT application providers to pull them into their respective ecosystems.

So those companies doing well in producing devices and equipment (e.g. lighting, air conditioning system, sensors, controllers etc.), as well as IoT applications development may harness the substantial benefit by joining those ecosystems. Just like how those smartphone manufacturers and mobile apps developers' have succeeded by embracing iOS and Android ecosystems.

## Trends of Industry transformation

Building owners and operators are finally beginning to understand the potential the right smart building automation and management solution can bring. From controlling operational costs to mitigating risk, they're leveraging tools like automatic FDD, real-time control and operation, sustainability reporting, occupancy sensors and tenant feedback to form their strategies. Intel recently released a list of smart building trends that are primed to make large growths to be developed and adopted by building operators.

1. Energy efficiency — Ambitious sustainability goals will continue to drive adoption of smart building technologies. Reducing the carbon footprint of a given property requires both close monitoring and actionable data insights on energy and water use in the building. Advanced sensors and analytics will empower building managers to better control their assets and reduce energy waste that can be harmful to the environment.

2. Asset optimization — Increasing operational efficiency will also be a major focus. Instead of taking a costly "rip and replace" approach to upgrading legacy building systems and assets, building managers can improve operations with technology solutions that enable them to retrofit existing systems with sensors, securely delivering asset data to the cloud. Other key operational benefits for smart buildings include improving uptime of building equipment and avoidance of loss of assets.

3. Meeting occupant expectations, delivering new experiences — As consumers increasingly embrace a connected lifestyle, there will be a demand for more seamless building environments that offer customized experiences based on occupant preferences. Examples include allowing office building tenants to easily adjust temperature settings in a specific area via supporting app, quickly locate an available conference room or know how long the cafe queue is before they arrive. These personalized experiences will provide additional value to smart building operators looking to attract and retain tenants.

4. Achieving autonomy with emerging ICT technologies — Artificial Intelligence/Machine Learning and 5G connectivity will work together to make building management a more autonomous task. 5G connectivity is for more advanced data exchange between smart buildings that will be a major part of the groundwork for smart cities of the future.

Buildings will become more connected and professionals at all organizational levels will acknowledge the need to become more IT savvy. Frustration with outdated systems and processes will drive internal advocacy for more efficient, technological solutions. With the wave of building IoT devices collecting vast amounts of data, enterprises are beginning to invest in smart building technology teams to take advantage of increased building connectivity and emerging software tools to manage portfolios.

Visionary executives are formatting smart building automation and management change from the top down. Big players will feel pressure to operate large portfolios more efficiently as early adopter competitors embrace new solutions and garner dramatic results. Leaders will fuel organizational transformation by pushing traditional management teams to explore new technological solutions to old ROI challenges. The focus is shifting from "How much did we spend?" to "How much did we save?". Key executives are empowering sustainability and facilities teams with the emerging ICT technologies to manage risk, cut operational costs and save energy. Full-service property management firms are opting to acquire or partner with smaller tech companies rather than build tools in-house.

Commercial building operators will begin to leverage the systems they use to strengthen their brand reputation, provide an exceptional occupant experience and attract top talent. Tenant-centric business models are springing up around the globe. Brands are gaining recognition and appeal for their tech-enabled spaces, sustainable practices, and comfortable environments, particularly from the up and coming millennial workforce. Founded in 2011, WeWork has redefined the way occupants experience buildings by implementing a tenant-centric business model. To date, they've raised nearly $10 billion, creating a significant disruption for competitors like Regus, Impact Hub, and Galvanize.

Labor costs are rising and it's no longer cost-effective to have an on-site facilities management team in each building. The industry will begin to centralize building management and control, requiring fewer people onsite. Like what JTC did, many REITs and property management firms will establish central offices where energy managers, sustainability professionals, and facilities teams can leverage technology to remotely manage their entire portfolios.

Companies that invest early in the effective smart building solutions will have a significant advantage over the competition. Early smart building technology adopters will be ahead of the curve, and their savings over time will compound like interest.

Over the next few years every app, application, and service will incorporate AI at some levels. AI will run unobtrusively in the background of the much familiar application while giving rise to entirely new ones. AI has become the next major battleground in a wide range of software and service markets, including aspects of building operation.

As smart building automation and management proliferate, we shall expect a shift from silo smart things and systems to a swarm of collaborative intelligent things and systems. The leading companies shall absorb emerging ICT technologies into its DNA to be empowered.

## References

[1] F. Tao and Q. Qi, "New IT driven service-oriented smart manufacturing: Framework and characteristics," IEEE Trans. Syst., Man, Cybern., Syst.

[2] Building automation prepares for building internet of things (BIoT), Memoori, May 1, 2014; Deloitte Center for Financial Services analysis.

[3] Insider the Internet of Things (IoT), Jonathan Holdowsky, Deloitte University Press

---

Prepared by

Jin Guang Yu