Smart Buildings: A Foundation for Safe, Healthy & Resilient Cities

Produced by the GCTC Smart Buildings Super Cluster

ABSTRACT

The SBSC Blueprint aims to inform smart city stakeholders which include municipalities, developers, integrators, property owners, and managers about the design of smart buildings within the broader framework of the smart municipality from township to urban metropolis.

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The Smart Buildings Super Cluster Blueprint was produced by numerous industry specialist volunteers who contributed their expertise and time to share with readers thought leadership and best practices in this developing ecosystem to this point in time.

Smart buildings are a fast-evolving platform, involving myriad technologies and systems. We invite you to continue to visit the Smart Buildings Super Cluster (SBSC) website, to access the latest resources produced by this group.

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I. Introduction

By

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Objectives

The Smart Buildings Supercluster (SBSC) convenes public, private, and academic organizations to collaborate in the development and interrelationship of smart buildings within the smart city context. All SBSC group members and contributors to this Blueprint are volunteers, sharing their expertise in smart buildings, Internet of Things technologies and use cases, architecture, engineering, communications, building management systems, municipal systems management, mobility, data management and security, sustainability, optimal productivity and wellness approaches and technologies. We thank them for their contribution.

The SBSC Blueprint aims to inform smart city stakeholders (municipalities, developers, integrators, property owners, and managers) about the design of smart buildings within the broader framework of the smart city. This Blueprint is meant for municipalities of all sizes from small township to metropolis, each making use of the document in a way that best suits them. As such, the terms of "city" and "municipality" will be used interchangeably to support this intention. Further, the Blueprint describes the smart building ecosystem and explores how smart buildings can be deployed in support of smart city objectives to:

- Provide a sustainable, resilient, safe, robust and thriving community for its citizens, and public and private constituents;
- Accelerate the deployment of smart city, Internet of Things enabled, connected infrastructure;
- Infuse robust and adaptive features into the smart city infrastructure through integrated smart building designs;
- Provide a roadmap to sustainable advantage and ROI for communities that adopt this approach;
- Enable the development and deployment of broader municipal smart applications; and
- Support municipal and regional economic development and growth.

The Blueprint further explores smart buildings as the building blocks of smart cities, attracting corporations, vertical markets, job seekers and entrepreneurs, who will bring their business and their homes to a municipality, and contribute to a region's success while enjoying happiness, health, wellness and local prosperity. (See *Chapter 1 – Value Benefit and ROI Considerations*.)

Because this is a living document, the SBSC invites readers to return to this section to find updates. SBSC members are also available for discussion, brainstorming, collaboration on topics readers would like to see further explored.

Introduction

The built environment is where billions of people around the world live, work and play. On average people in the developed world spend eighty to ninety percent of their lives inside buildings.[1] The built environment also frames our lives. When we step outside — whether in a metropolis, an urban core, a suburb or a rural town — our spaces, including commercial areas and parks, are defined by the built environment.

[1] Regional Conference on Science, Technology and Social Sciences (RCSTSS 2016): Theoretical and Applied Sciences (Springer, Asniza Hamimi, Abdul Tharim, Muna Hanim, Abdul Samad, and Mazran Ismail, 2016, p.6); EPA Report on the Environment: Indoor Air Quality (EPA)

Smart Buildings: A Foundation - Introduction

As with many aspects of our lives, the built environment is becoming digitized — interpreted and managed using a language 0s and 1s through sensors that capture and analyze this data. Smart sensors capture both interior and exterior data on building energy performance, air quality, lighting and temperature, mobility, asset locations, and space usage, to name a few.

Along with increased digitization, building architectures are expanding their sphere of impact and scope through rethinking the construction model and moving toward reconfigurable components with deep embedding of Internet of Things capabilities. This impacts buildings both internally and externally by creating adaptive spaces that meet dynamic needs for all aspects of life - work, leisure and local and national emergencies. This new concept is called *Space as a Service*.[2]

Defining the Smart Building

The data of digitization flows like lifeblood into systems, thereby enabling these systems, platforms and applications to interact and adapt with one another. In a smart building, this data flow can: support the optimized operations of a building; connect the desires of an occupant with building capabilities to provide a personalized, reconfigurable environment; optimize energy usage or enable energy to flow from one building to another through a microgrid system; provide visibility into occupant location, tracking; and other functions.

In addition, digitized data brings to life building information models (BIM) used in construction and "digital twins" (digitized reflections of real-world objects). Digital twins can now be applied to buildings. These high-fidelity building digital twin models present data collected from complex disparate systems which support a building. Two and three-dimensional interfaces and dashboards present the data to show system activity, enabling in-depth review of current status and predictive analysis. Digital twins allow for simulations and "what if" analyses to see optimal approaches for future operations and/or upgrades and augmentations. They are also increasingly being used during architectural design and development, construction, day-to-day operations and maintenance both for individual buildings and across property portfolios. Digital twins are also being used to design, develop and operationalize new city developments for buildings, parks and transportation and related infrastructure (E.g., India, Singapore).

[2] PropTech 101: What is a space-as-a-Service (SPaaS) business model? (InbuildingTech.com, Urvashi Verma, December, 3, 2018)

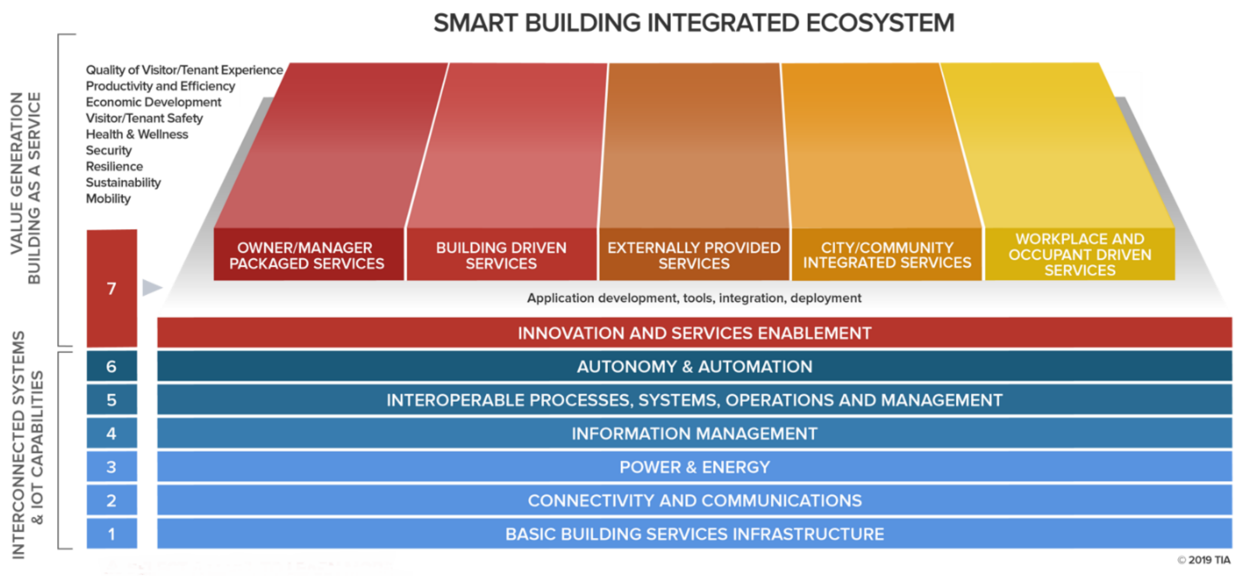

Figure I-1. Building as a Service/Space as a Service [Source: TIA]

To maximize the opportunity smart building's offer, it is important to set a foundation of understanding by defining what is a smart building. To that end, the smart building definition and model adopted by the SBSC as a guideline was developed by the Telecommunications Industry Associations (TIA's) Smart Buildings Program. It defines a smart building as one which "interoperates and integrates systems, technologies and infrastructure to optimize building performance and occupant experience." This creates the building which integrates and interoperates across fundamental building systems, communications infrastructure, power and energy infrastructure, through the use of data and autonomous, intelligent processing to provide any number of valued services to building owners, operators, occupants and visitors. Further, this smart, integrated system-of-systems built environment serves the needs of these stakeholders in real-time, providing the experience (contextualized data) when, where and how they want it. Now occupants and property owners can make informed decisions of what they want to do in and with that property. Through smart buildings systems and technologies, the property asset now becomes a platform that offers services – it enters the domain of *Building as a Service*, and *Space as a Service*. [Figure I-1]

Smart Buildings Integrating into a Smart City

Smart buildings are integral to the creation of smart cities. They are a fundamental building block of the municipal fabric. They are the connective tissue, linking a municipality and its citizenry by fostering human interaction and by supporting IoT rich environments.

The same conceptual model of *the Building as a Service* and *Space as a Service* fits the broader municipal environment of the city or town. Just as today's architectural and interior design objectives are increasingly forging environments that support and care for the well-being and productivity of their occupants and operators within a building, so too are designers of municipalities and open spaces shifting to see city space as fitting the *Space as a Service*, or shall we say, the *Municipality as a Space* model. This shift in intellectual and architectural frameworks, opens new ways to care for a municipality's citizens and businesses, and invites new economic development opportunities increasing the quality of life for all connected to that given space.

When a town or city begins to see an increase in the number of smart buildings, it has the opportunity to start integrating them into the larger municipal infrastructure of systems and services. This scalable, bottom-up approach results in a mesh network of resources not available before and the emergence of a holistic smart city.

The Smart City as a Mesh Network

A way to visualize a smart city is as a distributed, open *mesh network* of connected smart buildings. A biophilic analogy is the mycorrhizal network (Figure I-2) created by roots and fungi that connect individual trees and plants and support the transfer of water, carbon, nitrogen, and other nutrients and minerals among them in a mutually supportive way.

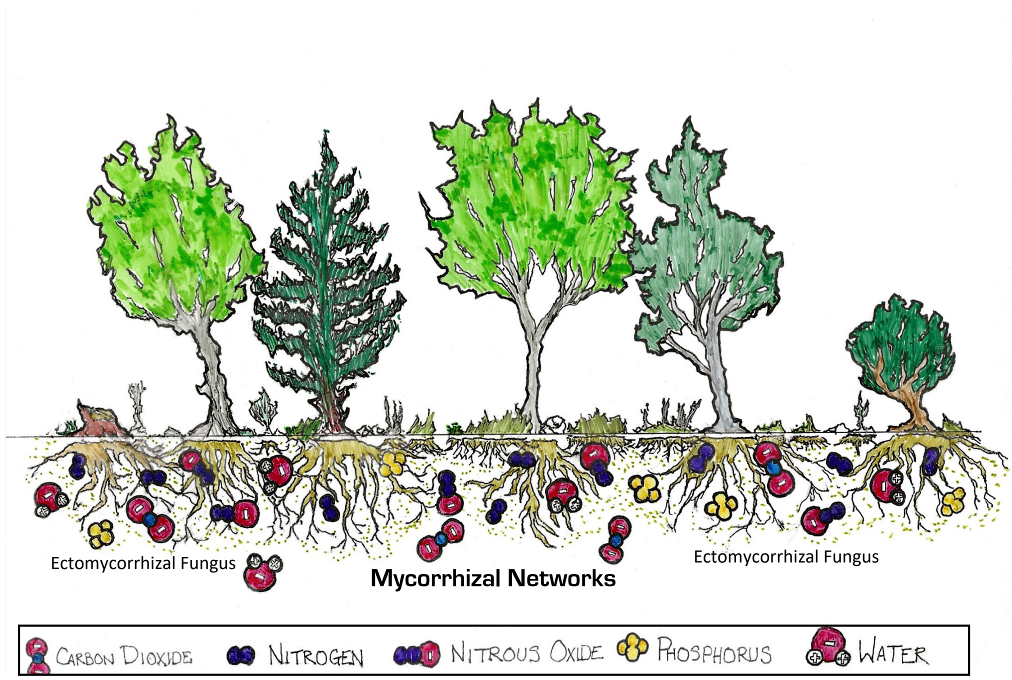

Figure I-2. Mycorrhizal Network [Source: Yuri O. Gawdiak]

Similarly, applying biomimicry and leveraging nature's millions of years of design evolution, an integrated mesh network across buildings allows them individually and, on the city/community level, to generate and take advantage of combined infrastructure and meta behaviors. [Figure I-3]

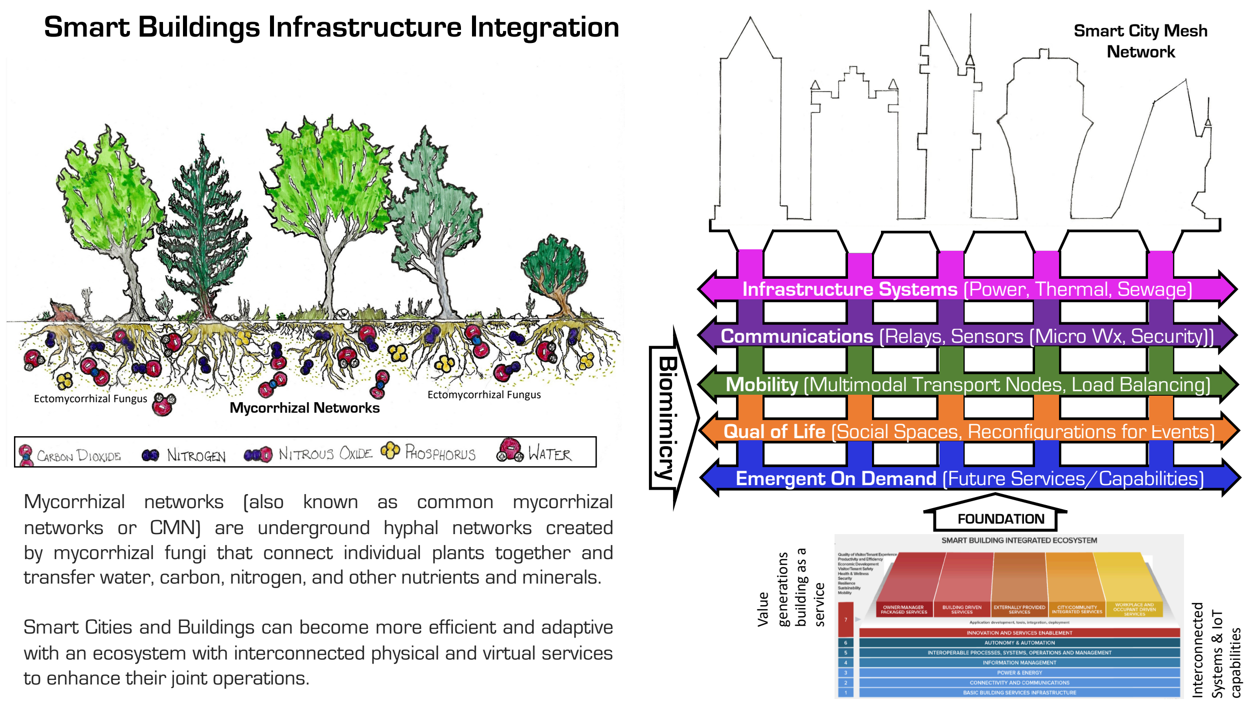

Figure I-3. Biomimicry and Combined Underlying Infrastructure [Source: Yuri O. Gawdiak]

These new capabilities enable synergistic efficiencies and enhanced resiliency of the city. Some of these capabilities include, but are not limited to:

- Communications Infrastructure: Expanded communications across the municipality, supporting equal access to all citizens and businesses
- Infrastructure Systems
    - Power Management: Optimizing local power generating & demand loading; microgrids
    - Public Safety: Advanced warning of various disruptions and events such as flooding, cyber-attacks, civil unrest and enabling autonomous preventative action
    - Water Management: Monitoring clean water delivery; protecting against bad actors
- Quality of Life and Civic Engagement: Reconfiguration of building facades and mobile structures to form customized local social spaces for a range of events from entertainment and leisure
- Mobility and Traffic Management: Optimizing 'last-mile traffic' flow, anticipating bottlenecks and supporting rerouting and time sequencing of arrivals and deliveries; supporting autonomous vehicles

Resilience and Municipality as a Service

At the time of this writing, the Covid19 Pandemic is in our midst on a global level. Other events taking place around the globe, including other natural and human-made situations, are challenging processes, resources, systems and infrastructure. Resilience is the watchword for humanity, for businesses and for the localities in which they reside.

Municipalities are faced with challenges of how to support businesses and people within their environs, ensure that they stay safe, secure, and have the resources to continue forward, rebuild and redefine their lives in a possibly new context. Given the digitized built environment and evolving adaptive design approaches described above, municipalities are challenged to evolve as well. Their challenge is to develop principals, policies, regulations and processes that give room for adjustable support and recovery to sustain municipal operations and those of local business under a myriad of conditions.

Citizens and businesses expect municipalities to offer not only a means to survive, but to support a continued thriving, economically and in wellness, even through ever-dynamic situations that affect the city-scape. The experience that people want in the built environment (which includes green space) is quickly evolving to include health, wellness, happiness, affordability, equity, access, caring, opportunity, productivity and more. To meet these expectations of services coupled with flexibility in a connected environment, municipalities are challenged to adopt the new model of *Municipality as a Service*.

Adopting the *Municipality as a Service* construct is best accomplished through a multi-phased approach which supports the general objectives of the municipality, and which is affordable. To begin the process priorities are recommended. The SBSC proposes the following:

- First: Stabilize and jumpstart economic processes in a quick, efficient manner (avoid adding financial burden which would dampen desired social and economic recoveries);
- Second: Provide safety, and security of all citizenry and property in an equitable process; and
- Third: Design and develop the smart built environment in a manner that supports flexible space, reconfiguration and adjustment to changing needs and resources.[3]

Learning from Wuhan, China: Adaptive Architecture:

Faced by a spreading pandemic in Wuhan, China, the government realized additional hospital services were needed. If existing buildings had been structured for agility and flexibility, China could have reconfigured dozens of existing co-located smart buildings into a distributed hospital. Instead, the government was forced to build from ground zero with resulting infrastructure and time costs. The question is: How best can buildings be designed for adaptability and then designated for use in large scale emergencies. This model would allow hospital care to be available in a fraction of the time and at lower cost. It also allows for continued ability to scale to meet demand. [*Example of Modular Construction].

[3] Other examples include: Reconfiguring smart buildings and transportation systems to support airlifts or supply drops depending on the nature of the emergency; or designing large sports and entertainment complexes infrastructure in such a way that they are easily configurable to play a role in supporting large scale emergencies. The latter would seem particularly appropriate since they are often financed with public funds.

This is supported by certain principles. The SBSC proposes the following:

- Flexible and Adaptable – Space, function, system – Each needs to be designed to be as fluid and reconfigurable as possible to meet changing requirements and available resources (I.e., the anticipated increased shift to distributed workforce);
- Accessible – Supporting equal, unbiased access to all citizens;
- Safe and Secure – That all aspects of engagement with the municipality and in the built environment is safe and cyber-physically secure;
- Healthy, Well and Happy – Increasingly design of the built environment includes support of health and wellness of works and citizens. To this the Blueprint adds "happiness," however that is interpreted;*
- Sustainability Concepts of Net zero/carbon neutral/etc. – Municipal systems be integrated with the built environment through meshed systems to enable achievement of municipal goals;
- Built for Green - Materials used, resource management, in support of the circular economy; and
- Healthful Construction – That all aspects of the construction process from worker health through construction processes and materials used, maximize health, sustainability and operational efficiency.*

It is important to note that policies and regulations may need to change or new ones implemented to both support and incentivize adoption of proprieties and principles a municipality ultimately adopts.

[*Concepts developed by the Greater Washington Board of Trade Connected DMV Building & Urban Design Group.]

Structure of the Smart Buildings Blueprint

This Blueprint is designed to introduce municipalities and all who are involved in the design, development, build, transformation, and maintenance of a built environment to the issues and concepts surrounding smart cities at this time. The intention is for this material to assist in municipal and citizen leadership to make informed decisions to implement and realize *their* vision for *their* city.

It is the further intention to share information about "smart" technologies, systems and processes and how to make use of them to create the most favorable living environment for a municipality's citizens.

This Blueprint takes the mesh structure shown above as a framework to expand on the particular aspects through a series of chapters:

Chapter 1: When contemplating the *Municipality as a Service* concept, there is the overarching value query of whether and what are the **Benefit, Value and Return on Investment (ROI) Considerations** for creating this intermeshed ecosystem of the built environment. The Blueprint begins by addressing what purpose smart cities and smart buildings serve toward a municipality achieving its target city and civic outcomes, and why a smart city should consider the smart building as part of its infrastructure.

Chapter 2: Quality of Life in the built environment is comprised of **Organizational and Individual Productivity and Wellness**. Smart, Internet of Things (IoT) technologies can both support efficacies in productivity and the capturing of metric data to measure the impact of changes in environment, behavior and physical well-being. This section offers an in-depth review of current approaches to implementing organizational and wellness optimization.

Chapter 3: The means to realize the ROI on an individual building level and across a municipal mesh is through **Next Generation Building Operations**. This section defines what smart building operations means and how it is implemented in today's digitized environment.

Chapter 4: Increased connectivity through IoT and sophisticated communications infrastructure broadens the cyber threat landscape. **Cybersecurity** is important on every level of the smart municipality and across all infrastructure in the built environment. This section offers concepts and approaches to maximizing protection and building resiliency into systems should a breach occur. In addition, a **Cybersecurity and Privacy Risk Management Preparation Questionnaire and Handbook** based on the NIST Cybersecurity Risk Management Framework is added as an Appendix to the Blueprint to assist and guide a review of cybersecurity and privacy policies and actions taken by property owners and managers.

Chapter 5: Communications (under development)

Chapter 6: This chapter on **Interfacing with City Services and Utilities** expands on communications infrastructure as the Fourth Utility. It reflects on how smart buildings, as an integrated part of the fabric of the smart city, play a role in a number of specific situations which municipalities face. The specific areas of focus include smart city services, and energy management and services.

Chapter 7: The past several years has shown an explosion in new types of **Mobility** and choices will only continue to grow as automation, new flight technologies, and edge compute capabilities become established. This section reviews how the built environment will be required to change in design to adapt and take best advantage of upcoming new mobility paradigms.

Appendix: Cybersecurity and Privacy Risk Management Preparation Questionnaire and Handbook as described above.

Next Steps

This first publication of the Smart Buildings Blueprint, discusses each of these topics as introductions to philosophies, approaches, and developments in the smart, built environment. As this newly burgeoning segment of the real estate industry grows, and technology and its uses increase in sophistication, the Smart Buildings Blueprint will continue to evolve.

The SBSC invites readers to stay abreast of latest Blueprint updates and other information by visiting the group Supercluster page.

II. Chapter 1: Value, Benefit and ROI Considerations

By

Benson Chan and Renil Paramel

Introduction

The emergence of next generation technologies, such as the Internet of Things (IoT), artificial intelligence (AI), telecommunications (public and private LTE networks, 5G, Wi-Fi improvements, LPWAN, etc.), and data science, are poised to transform today's cities into advanced smart cities. These cities are more resilient, safe and secure physically and digitally, healthier, economically vibrant, have a higher quality of life, and are more attractive to their residents, businesses and visitors. As an example, the city-nation of Singapore, is leveraging its considerable digital infrastructure to build an advanced smart city to support the current and future needs of its 5.5 million citizens in a very dense urban setting. Despite these benefits, building a smart city is a complicated and expensive multi-decade undertaking.

Many cities take a top down approach to building a smart city. However, this approach brings several challenges. It takes a lot of time and vision, require coordination and agreement with a large number of city stakeholders who often work in silos, and significant political support and funding. Committed resources and funding are often pulled to support new priorities of incoming political and city leaders. Top down approaches are multi-year journeys often lasting well beyond the term of political tenures.

Against these realities, an organic bottom-up approach is necessary to complement the top-down efforts. A smart city is not built all at once, but one block, one park, one building, one neighborhood, one community at a time. Bottom up approaches enable manageable smart city development that are aligned to current needs, priorities and available funding sources. They involve a smaller group of stakeholders, a narrow set of priorities and outcomes, and move much faster than a top down approach.

Smart buildings are one "bottom up" component of a smart city. They incorporate advanced and integrated digital technologies, algorithms and analytics, to bring new and significant value to tenants, building owners and operators. These benefits range from increased tenant productivity, comfort, a safe and healthy environment, lower operating costs, and higher satisfaction. While the benefits and Return on Investment (ROI) of smart buildings are well documented for tenants, occupants, and building owners and operators, similar information for cities is limited at best.

This is because the role and value of smart buildings in a city has not yet been defined or understood from a municipal perspective. Understanding this perspective requires answering the following questions:

- What role do smart buildings play in smart cities?
- What value do cities get from smart buildings?
- Why should city officials and residents want smart buildings in their cities?
- Why should cities encourage the development and retrofitting of smart buildings?
- How do the value that smart buildings bring to its owners, operators, tenants and occupants translate to value for cities and communities?

This chapter provides an approach for defining the value offered by smart buildings from a smart city perspective. It starts with a discussion of the eight outcomes that cities care about, and the four civic dimensions these outcomes are evaluated against. A framework (Figure II-6), describing the activities enabled by a smart building, is then introduced that aligns these activities to the outcomes. A second framework, correlating the eight outcomes with the four civic dimensions, provides the necessary structure to identify and capture the smart building benefits and value that the cities care about. The chapter concludes with a sample set of these benefits mapped into the second framework (Figure II-8).

What Do Cities Care About?

Cities are dynamic entities with diverse constituents and complex geographical, economic and political needs. In order to understand how cities benefit from smart buildings, we begin with some background and understanding of the drivers of civic value. We will start with the things that cities care about (civic outcomes), who creates these outcomes (outcome providers), and how the value for these outcomes is quantified and evaluated by city stakeholders.

Ultimately, these interconnected outcomes must lead to the ultimate overall ROI for a city - a place that is healthy, productive, safe, self-sustaining and attractive over time, and where citizens and businesses choose to live and operate in.

City Outcomes

A city, large, medium or small, is in the "business" of creating and maintaining civic outcomes[4] for its residents, businesses and visitors (Figure II-1). Civic outcomes reflect social, economic, health or political needs. A civic outcome is streets that are safe for pedestrians and bicyclists. Another example could be access to affordable housing for low income families and fixed budget senior citizens. A third example outcome could be access to affordable digital connectivity and services, supermarkets, and healthcare services in underserved neighborhoods.

While all cities care about these outcomes to a certain extent, some outcomes are more relevant to them than others. Each city is unique, and its focus on specific civic outcomes reflect its unique economic, geographic, political and temporal priorities, and the needs of its many constituents. For example, economic development is a priority for some cities, while public safety and quality of life are more important for others. These outcomes are documented in a city's strategic vision and plans, codified in its policies and regulations, and implemented in the form of funded initiatives and programs.

The COVID-19 pandemic of 2020 has disrupted and devastated cities and communities worldwide. From the loss of lives, overwhelmed health care facilities, interruption of essential day-to-day services, to disruption of the global economy, no one is spared. For example, in many cities, emergency declarations are made and a "shelter in place" is ordered for the general population to stay home. Schools are closed and in-class instruction has shifted to distance and remote learning. Non-essential businesses are closed or operating remotely, and enabling new modes of working that were not considered before. Mass public gatherings and events are banned. Face to face interactions and transactions are conducted at "social distances".

In light of the disruption to cities and communities caused by the COVID-19 pandemic, public health outcomes are now top of mind. More importantly, the pandemic has caused a dramatic rethinking priorities and outcomes for the years ahead. Cities who have not prioritized resilience, health and public

[4] Planning sustainable smart cities with the Smart City Ecosystem Framework, January 24, 2018, https://strategyofthings.io/smart-city-ecosystem

safety outcomes are now focused not only on these outcomes, but on driving economic rebuilding and recovery.

Figure II-1 - Eight types of civic outcomes [Source: Strategy of Things]

City outcomes are created by an ecosystem of "outcome providers"

City government is not alone in creating civic outcomes. Civic outcomes are created, delivered and maintained by an ecosystem[5] of five groups of "outcome providers" – cities, utilities, corporations, communities and citizens (Figure II-2).

Each "outcome provider" is responsible for delivering outcomes within its scope and domain. For example, the city is responsible for such things as maintaining streets, traffic signals and parks, while utility companies are responsible for gas, water and electricity. In other areas such as mobility, the city and private companies collaborate together to provide bus service, taxis and ridesharing, scooters, bicycles, and on-demand specialized transport services. This provider ecosystem works collaboratively to deliver certain synchronized outcomes in some cases, while working independently with limited to no collaboration in others.

Supporting these city "outcome providers" is an infrastructure composed of people, organizations and businesses, policies, laws, processes and technology integrated together to create the desired outcomes. The responsive civic ecosystem is adaptive, agile and always relevant to all those who live, work in and visit the city. When advanced digital technologies, such as IoT, AI and analytics, are incorporated and integrated into this underlying infrastructure, new disruptive and transformational civic outcomes are created.

[5] ibid

In this civic ecosystem model, the smart building is an outcome provider to the city. In order to be relevant to the city, smart buildings must create those outcomes that cities care about, and to do it in ways not possible before, or with less cost, greater efficiency, and fewer resources.

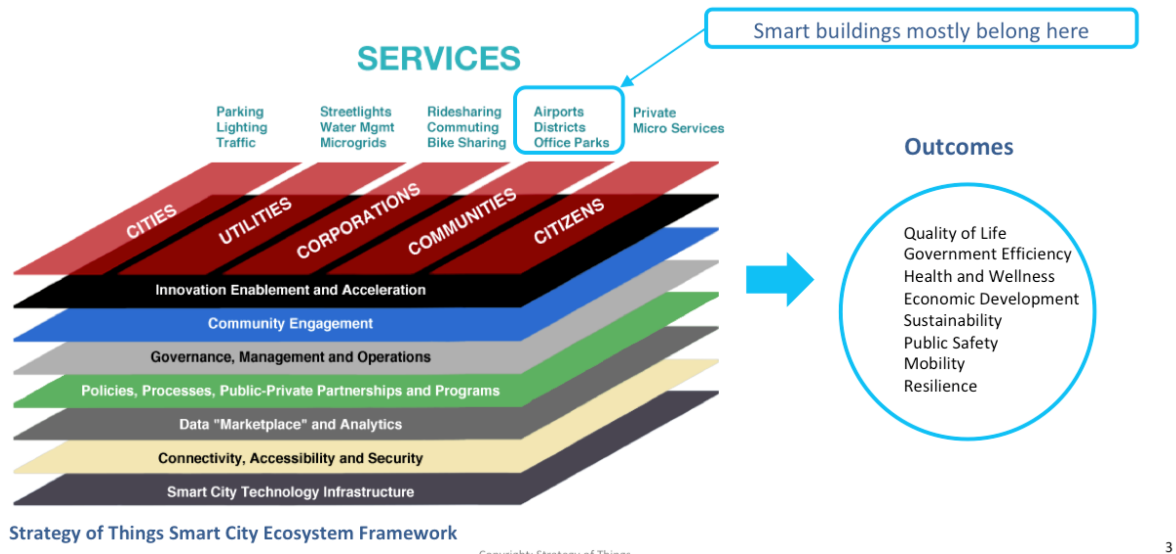

Figure II-2 - The Smart Civic Ecosystem Framework [Source: Strategy of Things]

City outcomes are measured differently

In business, ROI is a common metric used to determine whether a new initiative should be undertaken, how existing ones are performing, whether those should be continued, and what new resources should be applied. As a business has many competing initiatives and priorities, management allocates its limited resources to those that generate the highest returns, financial or otherwise. Except in strategic instances, business initiatives typically meet a minimum ROI threshold to be considered or to continue.

In contrast, cities are not businesses. Cities have different goals and "business models". They do not create revenues to make a profit, but to produce, maintain and enhance city services. Cities create services and often solve problems that have negative ROIs but serve a "common good", such as to promote community vibrancy rand economic growth. They serve "customers" and stakeholders, as well as sectors and communities that businesses do not find profitable to service. Their main source of "revenues" is from taxes, as well service fees (parking, citations, administrative fees, etc.), designed to offset the cost of providing the various services. As a result, the concept of ROI for cities need to be redefined and viewed through a different perspective. This is done by examining the set of activities that a smart building conducts or enables and mapped against the eight city outcomes (Figure II-6). The mapped value of these activities is further evaluated and categorized against the four civic dimensions (Figure II-4) and placed into the smart building value framework (Figure II-8). These models are explained in the sections below.

Cities focus on creating city outcomes (Figure II-1). In addition to a ROI based solely on financials, cities also evaluate a ROI based on effectiveness of the delivered city outcomes. For example, some considerations and metrics cities care about include:

- How many new jobs were created?
- How much crime was reduced?

- How many lives were saved due to a faster response time, and/or more accurate location information?
- How many homeless has the city taken off the streets?
- How effective was the city in getting communication participation on key issues?
- How effective was the city in responding to and limiting loss of live and property from natural or man-made hazards, such as earthquakes, hurricanes, or civil unrest?
- How effective was the city in responding to and mitigating an unplanned health emergency, such as the COVID-19 outbreak?

The ultimate overall ROI for a city is that its initiatives and programs lead to a place that is healthy, productive, safe, self-sustaining and attractive over time, and where citizens and businesses choose to live and operate in.

City outcome ROIs fall into three categories

The benefits, or value provided, by city outcomes cannot always be easily quantified. The ROI for creating outcomes fall into three categories[6] - direct benefits, indirect or second order benefits, and innovation benefits (Figure II-3).

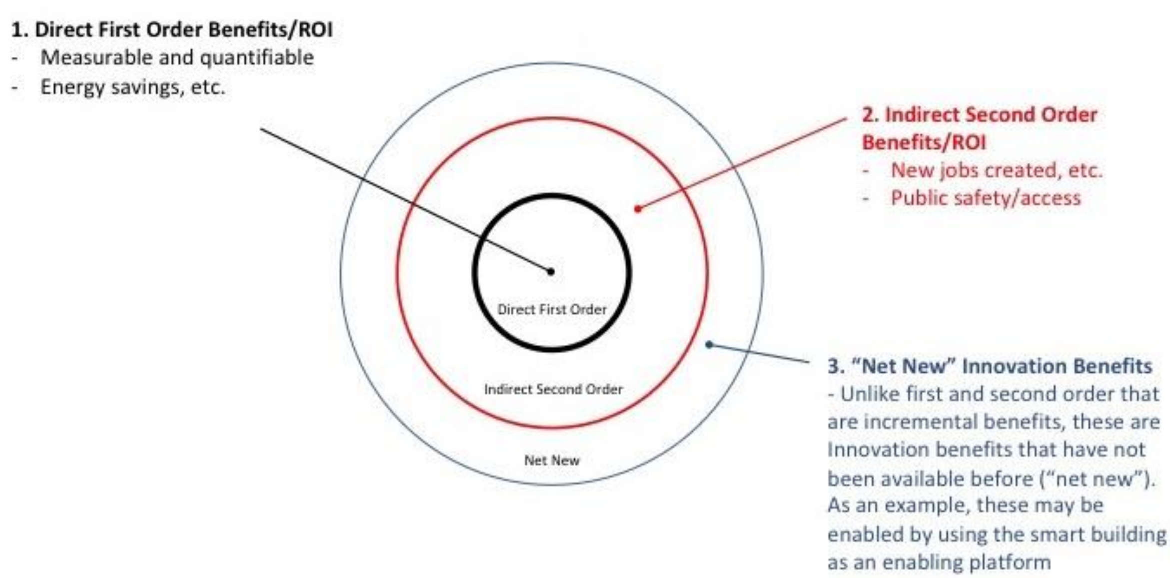

Figure II-3 - Benefits for civic outcomes fall into three categories. [Source: Strategy of Things]

Direct benefits are those benefits that arise as a direct consequence of implementing a program or delivering a service in creating a civic outcome. For example, when a city deploys a smart and connected streetlight system, the immediate benefit is awareness of the state of every streetlight. This leads to the elimination of personnel needed to drive around the city at night manually looking for broken lights and results in lower streetlight maintenance costs. Direct benefits are directly correlated to the initiative, and are typically easily quantifiable.

[6] Smart buildings – what's in it for cities (Part One), March 22, 2020, https://strategyofthings.io/smart-buildings-part-one

Indirect benefits are those that arise from a secondary consequence of implementing a program or delivering a service. For example, because the smart and connected streetlight system eliminated the need for personnel to drive around looking for broken lights, the same personnel can be redeployed to work on other city projects. The result is that the city can now do more with the same amount of people and budget. Depending on the specific benefit, indirect benefits are generally quantifiable (although not always as easily).

Innovation benefits are created from additional services that "piggyback" onto the newly implemented smart building infrastructure and capabilities to create new offerings. For example, the infrastructure of the connected and smart streetlight system can support other smart city systems. Sensors, including cameras, can be mounted on top of the system controller at the top of the streetlight. Wi-Fi access points, can also tap into the power source and connectivity, on the existing streetlight system controller to provide local Internet service. These innovation benefits (and the services that create it) are not always known at the time the smart building is planned or constructed. These benefits fall into the "unknown unknowns" and are not easily quantifiable, nor do we always know when they will be "activated". However, innovation benefits are real and must be specified (when known) and taken into consideration, even if they cannot be quantified.

Civic outcome ROIs and benefits align to one of four civic dimensions

Smart buildings, one of the building blocks of a smart city, create similar tangible direct, indirect and innovation benefits and ROI for a city. What those benefits are, and how they are activated and valued varies from building to building, building type to building type (public, commercial, residential, industrial, etc.), and city to city. Each city is unique, and its focus on specific civic outcomes reflect its unique economic, geographic and political priorities, and the needs of its many constituents. Cities have a diverse set of stakeholders with differing perspectives and priorities. These stakeholders hold differing perspectives based on their roles, responsibilities, goals, and constituents.

Figure II-4 shows the four dimensions[7] that outcomes and benefits are reviewed against. There is no one single view of an outcome - different stakeholders within the municipal ecosystem will be looking at the outcomes from one of these perspectives.

[7] ibid

Figure II-4 - Outcomes are viewed against four civic dimensions. [Source: Strategy of Things]

The strategic dimension considers how the outcomes and benefits are aligned with a city's long-term vision and strategic needs. Many of these priorities are documented in a city's general plan or vision document. These priorities are translated to specific initiatives which are implemented over the plan's lifetime (typically 10 to 25 years).

The operational dimension considers how the outcomes and benefits are aligned with the day-to-day "run the city" activities and how well the city is able to provide services effectively and efficiently. These operational priorities vary from city to city, and are focused on resources, capabilities, costs, productivity and responsiveness. These priorities and needs are captured in each city department's charter document and its operating plan.

The political dimension considers how the outcomes and benefits are aligned with the long term and day-to-day electoral, governance and legislative needs of the city. It reflects the priorities of the political leaders and the citizens who elected them. These priorities may not always align with the city's strategic and operational priorities. At other times, they may be consistent with the city's strategic priorities, but not aligned on when they should be implemented. These priorities are typically documented in the campaign platform or promises that political leaders got elected on, and addresses the specific needs of their constituents.

The emergency or unplanned dimension considers how the outcomes and benefits (also known as resilience dividends) are aligned with the resilience capabilities and resource needs of the city when something unexpected occurs. For example, a natural or man-made disaster, a massive event, or some other crisis event. These needs may be captured in the city's and department's resilience planning documents. With the COVID-19 pandemic of 2020, this dimension is now top of mind. Key considerations consider how the outcomes can prevent future outbreaks, protect and mitigate against current infections, limit adverse financial and economic impacts to the community, and respond to and recover from the pandemic.

When selling the value and ROI of smart buildings to municipalities, one must understand not only what direct, indirect, and innovation benefits are offered to the city, but also how these benefits are aligned to the four civic dimensions.

Where Do Smart Buildings Offer Value to Cities?

In the last section, an understanding of the types of outcomes cities care about, the role of ROI and types of benefits, and how those benefits are viewed against the four civic dimensions were provided. In this section, potential sources of smart building value creation for cities are discussed.

Smart buildings and cities come together at interaction points

Figure II-5 identifies the major interaction points between the smart building and the city over a typical building life cycle[8]. At each stage of the building life cycle, a different set of activities, and interactions, are involved between the smart building, the city, and others in the civic ecosystem. Some of these interactions are identical to those that exist between the city and traditional buildings. However, smart buildings provide additional interactions (highlighted in green), enabled by their advanced energy and digital infrastructures and capabilities. These interactions create new opportunities for value to the city.

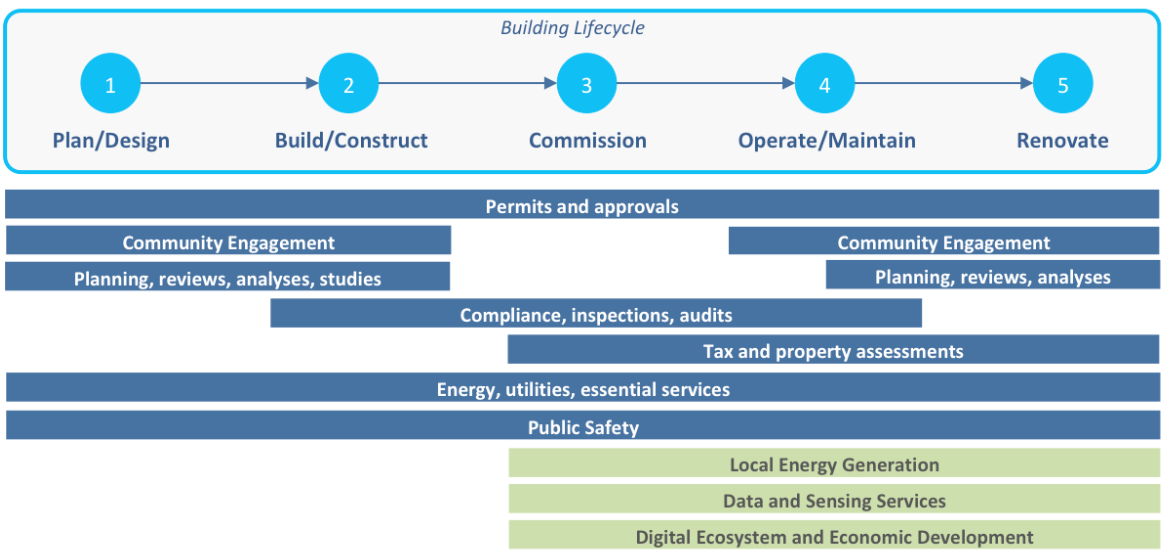

Figure II-5 - Lifecycle view of the smart building and city interactions. [Source: Strategy of Things]

These smart building-city interaction points provide the path or channels for the delivery of benefits to the city. But what exactly does a smart building do to create the value that is transferred to the city through these interaction points?

[8] Smart buildings – what's in it for cities? (Part Two), March 22, 2020, https://strategyofthings.io/smart-buildings-part-two

Smart buildings create value through direct and indirect activities

Civic value creation in a smart building comes from three distinct sets of activities[9] (Figure II-6). Tenant business operations and support activities create tangible value for the city indirectly as it carries out its non-city task. On the other hand, smart building value operations are those services directed at the city as the customer.

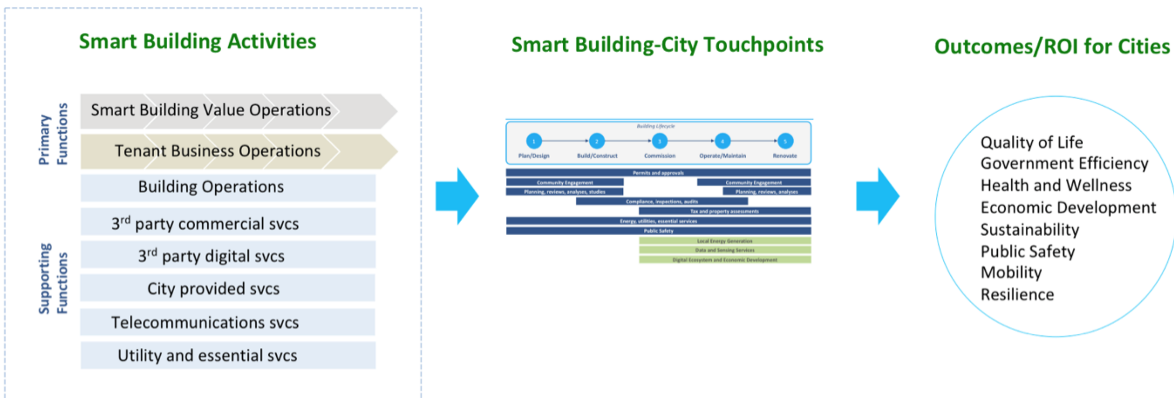

Figure II-6 - Activities that lead to the direct and indirect creation of civic outcomes. [Source: Strategy of Things]

A smart building creates value by enabling its occupants to work more effectively, productively and safely on a day-to-day basis than in a non-smart building. For example, a smart building may incorporate controls that adjust the lighting levels to match the daily circadian rhythm helps to reduce occupant drowsiness, improve mood and concentration during working hours. This building may incorporate occupant personalization technologies, such that when they schedule a conference room, the climate control systems adjust to account for the number of people, the teleconference and audio/video systems are already configured for the meeting, and digital resources for the meeting are routed to this room.

In light of the COVID-19 outbreak, smart buildings have taken on a new and vital role – to keep its occupants healthy by avoiding and minimizing exposure to the virus. Sensors can detect people with a high body temperature and prevent them from entering the building. Security camera feeds, combined with AI algorithms, monitor social distancing and face mask compliance. Contact tracing applications, based on bluetooth radios located on employee badges and personal mobile devices, facilitate notification of people who may have been inadvertently exposed. Sanitizing robots autonomously clean heavily trafficked areas on regular intervals. The extensive use of these technologies in response to the pandemic raises issues of effectiveness versus personal privacy and consent.

In increasing productivity, health and safety, these occupant tenant activities directly or indirectly contribute new (or more) value for the city that it couldn't have offered otherwise. Tenants are more likely to seek out smart buildings, stay in them longer, be more willing to enter into premium leases, and more likely to locate, expand and hire more employees. This in turn leads to higher assessed building assessed values (and surrounding buildings) and higher property tax revenues for the city. At the same time, a more productive tenant contributes to the development of the local businesses, which leads to increased tax revenues generated from the business ecosystem.

[9] ibid

A smart building has a more robust and advanced digital and communications infrastructure than a non-smart building. Its excess capacity can be used by the building owners to create direct outcomes for the benefit of a city. Unlike occupant activities which indirectly benefit the city, the smart building value operations are activities that are specifically designed to leverage the building's capabilities and infrastructure to provide direct value and outcomes to the city. For example, the smart building may leverage any excess capacity on this infrastructure to provide data and sensing services to the city. It may do this by hosting an Internet of Things (IoT) sensor network to monitor outside pedestrian and motor vehicle traffic around the building. It may integrate with other nearby smart buildings to extend a citywide communications network infrastructure. It may utilize its analytics and data processing capabilities to review the sensor information, create actionable insights, and provide the data directly to the city or the community. A smart building may use the excess energy produced by its solar panels and provide it back into a local microgrid to meet the demand of its neighbors.

Smart buildings facilitate tenant operations and smart building value operations through a series of support activities. These range from building maintenance operations to telecommunications services. In a smart building, these supporting activities will also contribute to the attainment of city outcomes. For example, the operation of the smart HVAC system, designed to keep building occupants comfortable, results in decreased energy usage and reduced greenhouse gas emissions. The smart HVAC system, heavily dependent on a new generation of digitally savvy engineers, integrators and service technicians, results in new "smart" jobs and a supporting digital vendor ecosystem, and creates economic development outcomes. The operational aspects and considerations of smart buildings is described in more detail in a later section.

Sample Smart Building Value and Benefits for Cities

To discuss the benefits of smart buildings to a city, consider a community level metric. A community with a "positive tipping point" of smart buildings leads more easily to being considered a "city of the future." A few smart buildings can attract new talent, workforce and positive tax-flow, but by themselves are not enough to create a connected, Smart City. A more unified approach is needed. The city of Henderson, Nevada[10] is a good example of a city where the build-out is thoughtful along all 8 outcome dimensions, and as a result is the 3rd fastest growing destination for businesses and relocating individuals in the country at this time.

Using the above model and considerations, review the smart building activities against the city-building touchpoints to identify potential ROI and benefits (Figure II-7). This is not a comprehensive list and there will be additional benefits beyond the initial set listed. It is left to the reader to identify those that may be unique to their city and smart building(s). The benefits in Figure II-7 are further classified into the three categories defined earlier in Figure II-3.

[10] City of Henderson Smart City Strategy, February 18 2018, https://cityofhenderson.com/docs/default-source/information-technology-docs/henderson_smart_city_strategy.pdf?sfvrsn=2

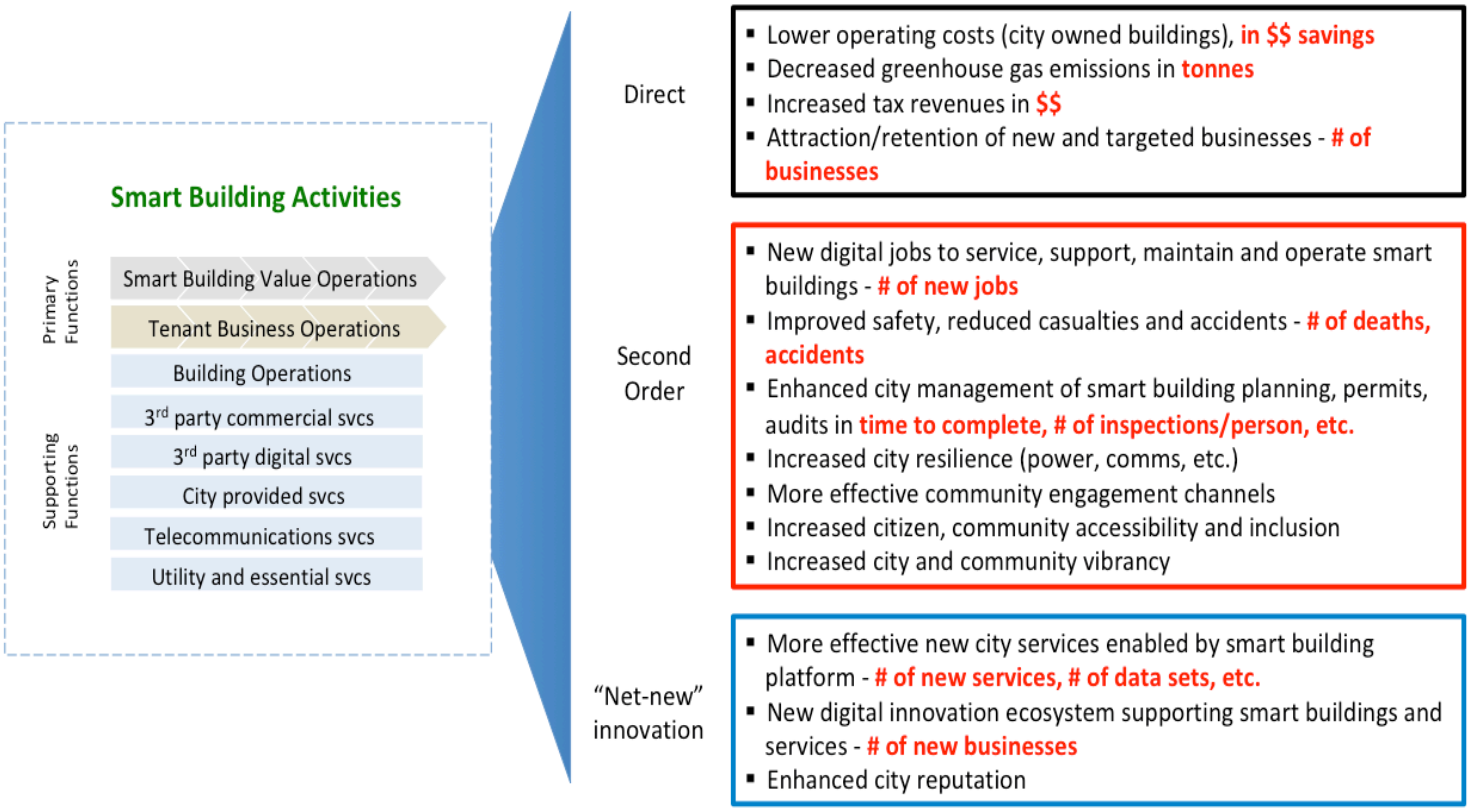

Figure II-7 Smart building benefits for cities (sample set). [Source: Strategy of Things]

Direct Benefits

- **Lower operating costs for city owned buildings** that have been converted to smart buildings (in $$ savings). Depending on the type of smart building and the number of modifications and extent of "smart", the city may realize varying levels of operational cost savings. These cost savings may come from lower energy costs, reduced number of security, maintenance personnel required to service the building, and lower insurance costs due to a lower risk profile.

- **Decreased greenhouse gas emissions** (in tonnes). Smart buildings use less energy, and as a result, the amount of heating, cooling required is a lot less in a smart building. Buildings operations generate a lot of greenhouse gas within the city. By reducing and more importantly, optimizing energy usage, a lot less greenhouse gases are generated and released. It is estimated that a smart building uses 30 to 40% less energy than. In addition, smart buildings facilitate "green" transportation options, from infrastructure that natively supports electric vehicles, integration with public transportation and ridesharing, or with future air mobility options.

- **Increased tax revenues** (in $$). A smart building is a desirable real estate asset for building owners. The smart building allows tenants to work in a more productive, comfortable and safer environment. As a result, the smart building attracts premium tenants, who are more likely to sign longer leases, pay higher rents, and are less likely to leave. For a city, this increases the building's assessed value, and the corresponding property tax revenues.

- **Attraction/retention of new and targeted businesses** (in # of businesses). A smart building attracts premium tenants. These types of tenants may be consistent with the mix of businesses the city wants to attract as part of its strategic plans. For example, a city wishes to attract high paying jobs typical in technology, financial services, research and healthcare businesses. In turn, these premium businesses attract an ecosystem of secondary businesses to directly and indirectly support and service them.

- **Healthy workspaces enable employees to work in the office and ensure on-site business continuity** (in # of vacancies). A smart building enables its occupants to work in a safe and healthy environment. For example, these buildings may implement a variety of technologies to limit exposure and transmission of airborne contagions, such as COVID-19. This facilitates in trust and confidence in building tenants and occupants, and allows businesses to physically open and operate. As a result, the smart building will be more desirable as it attracts new tenants and retains old tenants. Tenants are likely to choose smart buildings and pay a premium rate for these spaces.

Indirect or Second Order Benefits

- **New digital jobs** to engineer, design, service, support, maintain and operate smart buildings (in # of new jobs). Smart buildings operations require additional new skills and capabilities not needed with traditional buildings. These skills include networking, advanced telecommunications, cybersecurity, application development, multi-systems integration, information technology/operations technology (IT/OT) integration, and analytics. As more smart buildings are built (or retrofitted), the demand for these new jobs will continue to increase. New jobs (and training programs) will be created to fill these high demand digital positions.

- **Improved safety**, reduced casualties and accidents (in # of deaths, injuries, accidents reduced). Smart buildings employ a variety of innovative solutions to protect its occupants and those who work and maintain the buildings. From high performance access control systems, advanced fire management systems to sensors and predictive algorithms, to remote monitoring of critical systems and integration with public safety access points (PSAP), and informed sharing of real time data and conditions before arrival on scene, smart buildings facilitate safer working conditions and more effective first responder responses. In addition, smart buildings can interact with nearby smart buildings to proactively notify its occupants of nearby public safety incidents and take necessary precautions.

- **Enhanced city management** of smart building planning, permits, audits in time to complete (in # of inspections/person, time, and accuracy). From initial reviews to annual safety inspections, smart building sensors, systems, and algorithms can facilitate and automate (to the extent possible) inspections, compliance reviews and audits. These capabilities facilitate "smart processes" which enable the city planners and inspectors to perform more inspections, do it more accurately, and with less resources in less time, thereby increasing city department efficiency and productivity.

- **Increased city resilience** (power, communications, information, health). Smart buildings are equipped with a robust power, digital and telecommunications infrastructure. From in-building small cell private and public, land mobile radio (LMR) networks to satellite to wi-fi and IoT connectivity technologies, smart buildings bring a resilient communications infrastructure. Similarly, smart buildings may be equipped with a variety of power generation capabilities (solar, batteries, generators), reducing dependence on external sources, and may act as a microgrid. Smart buildings leverage data, algorithms and its array of sensors to inform, augment and support human responses in critical situations (e.g. location of an incident, wayfinding, etc.). Smart buildings enable its occupants and tenants to continue on-site business operations, and thus ensure physical operational continuity. From a resilient city perspective, smart buildings provide the city with limited communications and operational functionality during unplanned emergencies and incidents.

- **More effective community engagement channels.** There is no one size fits all channel to reach and engage community members living, working or visiting a city. A smart building, with its advanced digital and communications infrastructure, provides additional mechanisms for engaging the community. Its digital signage systems can be used to provide news, events information, safety alerts, mass notifications, public transportation information, wayfinding, and other critical messaging to tenants, employees and visitors in real time. In addition, the smart building's digital infrastructure may also deliver personalized content directly to the user through their smart mobile device. The ability of the smart building to engage more directly, as well as provide timely and vital information to the community is a critical city outcome.

- **Increased citizen and community accessibility and inclusion.** Inclusion and accessibility is an important, top of mind issue with most cities. The ability to digitally connect their citizens of all ages, genders, sociodemographics and cultures is an important outcome for city leaders. Smart buildings can contribute indirectly to inclusion in a number of ways. They may leverage their robust communications capabilities to provide public Wi-Fi in open public spaces. They may indirectly bring in a fiber infrastructure into a nearby neighborhood or community when planning a fiber infrastructure to support the building needs. They may leverage their building and digital infrastructure to host a variety of telecommunications systems for a city that the municipality may not otherwise have.

- **Increased city and community vibrancy.** Smart buildings attract new businesses, digital workforce talent, and create demand for new opportunities, skills, and jobs. This new and growing economic vitality creates optimism, drives new growth in the surrounding communities, and brings in new supporting businesses, as well as a continuous influx of new residents and businesses to the civic ecosystem.

- **Increased capabilities to support new working and learning options.** The advanced digital and telecommunications infrastructure in smart buildings support office to office, office to remote (home, field, etc.), and home to home telecommunications. These capabilities enable new working, learning and care arrangements to support a new and existing workforce, student audience, and patient base. It facilitates access to a new workforce resource pool, delivery of services to a wider base of workers, students, patients and customers. In the current COVID-19 pandemic where face to face interactions and travel outside the home is discouraged, these capabilities support a hybrid (local, remote, and work from home) workforce and maintain essential healthcare and education services.

Innovation Benefits

- **More effective new city services** enabled by smart building platforms (in number of new services, number of data sets, etc.). Smart buildings will leverage its digital and communications infrastructure, as well as the data collected, to create new insights and services that will be invaluable to the city. As one example, the smart building can be host to a variety of sensors. These sensors may monitor weather conditions, vehicle and pedestrian traffic patterns, building conditions, and contribute to the creation of a digital twin of the city. This digital twin can be used by city planners to model and simulate various city initiatives (for example, to see how changing traffic signals may impact accident rates, air quality levels, pedestrian foot traffic and its impact on surrounding businesses). Information from the digital twin can then be used to design a program, where it can be tested and evaluated. There are a myriad of innovative services, too many to list here, that can be developed by using the data collected from inside and outside the smart building.

- **New digital innovation ecosystem supporting future innovation** and services enabled smart buildings (in # of new businesses). Smart buildings over the next few years require a new supporting ecosystem of services and skills to design, build, support and operate it. Equally important, the smart building is a platform for future innovation, with many of these future services not yet discovered or enabled yet. These future innovations and services, built on top of the existing smart building infrastructure, capabilities and skills, will be even more transformational. These innovations will attract new talent and skills, new businesses and accelerate the expansion of the ecosystem of businesses needed to support smart buildings (and the smart city).

- **Smart Buildings as connected intelligent nodes** in a city forms a smart mesh network allowing for meta behaviors and communications to form. These capabilities drive synergistic efficiencies and enhanced resiliency of the city. New capabilities include: local coordinating last mile traffic flow management: anticipating bottlenecks and supporting rerouting and time sequencing of arrivals and deliveries; local power generating and demand loading; advanced warning of various disruptions and events - flooding, cyber attacks, civil unrest; and reconfiguration of building facade and structures to form local social spaces for a range of events. Smart building benefits grow exponentially when multiple buildings are connected to the same power grid and backhaul infrastructure to share resources between buildings.

- **Enhanced city reputation.** Smart buildings enhance the reputation of a city as innovative and forward thinking as it enables the transition of a city into a smart city, one smart building at a time. Smart buildings support lasting economic value by attracting a new ecosystem of tenants and businesses, supporting businesses, as well as new higher paying jobs aligned to the 21st century needs.

As a final step, the initial set of smart building benefits for cities (Figure II-8) is summarized. These benefits are further categorized into the outcome areas that cities care about, and aligned to one or more of the four civic dimensions. The purpose of Figure II-8 is to organize the benefits into a format that is directly relevant and consumable by city leaders and others in the ecosystem. Each city may have its idea of strategic, operational, political and emergency/unplanned dimensions. They will reorganize the benefits into these dimensions as needed. This is a necessary step in order to understand, communicate and gain support of city officials for the development (and retrofitting) of smart building.

	Strategic Priorities	Operational Priorities	Political Priorities	Resilience Priorities
Quality of Life	• Accessibility & inclusion • City reputation • Increased city vibrancy	• Effective community engagement • Accessibility and inclusion	• Effective community engagement • Accessibility & inclusion • City reputation • Increased city vibrancy	• Effective community engagement
Government Efficiency	• Increased tax revenues	• Lower operating costs • Increased tax revenues • Enhanced permits, audits, inspections mgmt • Effective community engagement • New city services • Enable on-site operations continuity	• Effective community engagement • New city services • Enable on-site operations continuity	• Enhanced mgmt of permits, audits, inspections, etc. • Enable on-site operations continuity
Health and Wellness	• City worker wellness • Citizen health/wellness	• City worker wellness • Citizen health & wellness	• City worker wellness • Citizen health & wellness	• City worker wellness • Citizen health & wellness
Economic Development	• Attraction and retention of businesses • New smart bldg jobs • Innovation ecosystem • Increased city vibrancy	• Innovation ecosystem	• Attraction and retention of businesses • New smart building jobs • Innovation ecosystem • Increased city vibrancy	• Enable on-site business operations continuity
Sustainability	• Lower greenhouse gas emissions		• Lower greenhouse gas emissions	
Public Safety		• Improved safety • Effective community engagement	• Effective community engagement	• Improved safety • Effective community engagement • Effective emergency preparedness
Mobility				
Resilience	• Increased city resilience	• Increased city resilience		• Increased city resilience • Effective emergency response/preparedness

Black = Direct benefits Red = Indirect benefits Blue = "Net New" innovation benefits

Figure II-8 Smart building - city value framework (with sample benefits) [Source: Strategy of Things]

First Steps to Consider

- Review and understand the framework. The framework is a structure for aligning the key smart building value and benefits to the issues that cities and communities care about. Adapt the framework, as appropriate, to the needs of your specific situation.

- Understand and document some of the specific outcome categories and priorities of relevance to a city and community. These will differ from city to city, and community to community. Some of this information is available in reviewing the community's general plan or vision documents (and its corresponding departmental plans). Others may be found in city council meeting minutes, and from conversations with various city operations and political leaders.

- Identify smart building services, capabilities and value that aligns to the specific needs of the community or city. The more of these relevant services or capabilities can be identified and/or created, the more support the smart building will receive from the community. These services and capabilities should be incorporated into the smart building development or retrofit as early in the cycle as possible.

- COVID-19 is currently top of mind with cities, communities, building owners, commercial real estate companies and tenants. Identify smart building services and capabilities, such as those that lead to the creation of "COVID-19 safe spaces", into the building design and retrofit.

- Think beyond COVID-19 and identify resilience needs that a smart building can address. These may include a variety of natural hazards (earthquakes, hurricanes, etc.), as well as man-made events (acts of terrorism, industrial accidents, civil unrest, etc.). Integrate smart building capabilities and update community resilience and emergency response plans.

Key Walkaway Points

- **Cities create civic outcomes for its residents, businesses and visitors.** These outcomes fall into eight areas – government efficiency, economic development, health and wellness, mobility, quality of life, resilience, public safety and sustainability.

- **Focus on a different set of ROI metrics when evaluating the value of smart buildings to cities.** The ROI of smart buildings is different for cities than for building owners, commercial real estate companies and tenants. Cities look beyond financial metrics, and focus on smart buildings contribute to the creation and delivery of civic outcomes.

- **The value created for cities by smart building fall into three categories – direct, indirect and innovation. Direct benefits** are those benefits that arise as a direct consequence of implementing a program or delivering a service in creating a civic outcome. **Indirect benefits** are those that arise from a secondary consequence of implementing a program or delivering a service. **Indirect benefits** are those that arise from a secondary consequence of implementing a program or delivering a service.

- **The value and ROI of smart buildings are reviewed against four dimensions that cites care about.** There is no one single view of an outcome - different stakeholders within the municipal ecosystem will be looking at the outcomes from one of these perspectives. These dimensions are strategic, operational, political and emergency/unplanned (resilience). The **strategic dimension** considers how the outcomes and benefits are aligned with a city's long term vision and strategic needs. The **operational dimension** considers how the outcomes and benefits are aligned with the day-to-day "run the city" activities and how well the city is able to provide services effectively and efficiently. The **political dimension** considers how the outcomes and benefits are aligned with the long term and day-to-day electoral, governance and legislative needs of the city. **The emergency or unplanned dimension** considers how the outcomes and benefits (also known as resilience dividends) are aligned with the resilience capabilities and resource needs of the city when something unexpected occurs.

- **A new framework is provided here for cities to evaluate the value of smart buildings.** This framework organizes the value provided into the outcome areas that cities care about, and aligned to one or more of the four civic dimensions. The information is presented into a format that is directly relevant and consumable by city leaders and others in the ecosystem.

Closing Thoughts

A smart city is built one street, one neighborhood, one school, one community, one business district, one building, one business park, and one university campus at a time. Smart buildings are important building blocks of a smart city.

Whether you are a municipal official developing policies for smart buildings, or an urban planner developing strategies for smart buildings, or a building developer or investor planning smart buildings, the value and ROI of smart buildings to a city goes beyond the traditional financial metrics used by business enterprises.

The concept of ROI for cities differs from that for businesses. Cities are not in the business of maximizing profit, nor do cost savings get returned to taxpayers. Cities are in the business of delivering outcomes to its constituents in a cost effective, responsive and effective way. Cities are continuously developing and building on these services to deliver services. City services are typically cost centers, and not profit centers. Cities rely on tax revenue, bonds, grants and other financing mechanisms to develop, operate and deliver services. Unlike a business, a city is not in the position of generating profits from its services, but to partially offset costs of maintaining and delivering those in part or in whole. Any profits earned from city services is used to fund existing operations or new initiatives that create desired outcomes.

Because of this, the value and ROI that smart buildings have on cities are different than the ROI that smart buildings have for building owners, tenants and others. In this case, it is necessary to expand our thinking beyond and look at the social, community benefits, or the Return on Community. These are a very different set of lenses.

A framework for thinking about smart building ROI for a city, and provide a structure for identifying, classifying, and ultimately communicating those benefits to stakeholders in a relevant and consumable format is shared here. In the future, as smart buildings emerge in greater numbers and grow in maturity, it is possible to better quantify the social and community benefits of smart buildings.

III. Chapter 2: Organizational and Individual Productivity and Wellness

By

Jiri Skopek

Objective

This section explores the application of smart technologies in buildings to increase the **ORGANIZATIONAL PRODUCTIVITY** of the various private/public sector stakeholders: the owners & investor organizations, property and facility management organizations, government and corporate tenants (i.e. organizations who occupy or rent space) and individual occupants. The objective of this section is:

> *To identify smart building technologies that will improve organizational productivity*

Definitions & KPIs — Problem Statement — The Role of Smart Buildings

Definitions & KPIs of organizational and workplace productivity

Organizational Productivity: The National Library of Medicine defines "organizational productivity" as:

> *The capacity of an organization, institution, or business to produce desired results with a minimum expenditure of energy, time, money, personnel, materiel*[11].

Simply put, it is a measure of how effectively an organization uses its resources to achieve its goals.

Organizational productivity is generally measured using a **basket of metrics**, sometimes measured in different units. These will vary depending on the type of organization.

For a *building owner's organization*, the basket of metrics could include revenue from rent; operational and energy costs per square foot; vacancy rates; resale value and insurance costs. For a *tenant organization*, the basket might include: the cost of space per employee; salaries vs. revenues generated per employee; cost of turnover, recruiting and retaining talent, facility management costs per square foot and so forth. It is by factoring all these metrics, that organizations determine their overall balance of costs and revenues.[12]

Workplace productivity is just one element of organizational productivity. It is defined as:

The amount and quality of work accomplished in a work environment (for example, an office, a hospital or a restaurant) and how efficiently workers complete tasks at their workplaces

Workplace productivity, like *organizational productivity*, is generally also measured using a *basket* of metrics, for example: the speed at which workers generate contracts and revenue; handle technical support calls for a tech firm; serve customers at a restaurant; produce a product at a factory; or come up

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[11] Harvard Catalyst, *Efficiency, Organizational* https://connects.catalyst.harvard.edu/Profiles/display/Concept/Efficiency,%20Organizational

[12] *Defining and measuring productivity in the public sector: Managerial perceptions*, July 2010, International Journal of Public Sector Management 23(5):479-499 https://www.researchgate.net/publication/235317696_Defining_and_measuring_productivity_in_the_public_sector_Managerial_perceptions

with profitable innovations in addition to speed, the value of creative new ideas, problem resolution, and product designs.

Keeping workplace productivity high helps an organization to reduce its costs, satisfy its stakeholders, expand its operations, and stand out in a competitive marketplace. By understanding common causes of low worker efficiency, it becomes possible to modify the workplace to streamline business processes and foster higher morale in the individuals that make up the workforce.

Workplace Productivity contributes to Organizational Productivity

A plethora of studies have demonstrated that the physical environment - that is to say, the form and function of the workplace – is a key determinant of workplace productivity, which, in turn leads to overall organizational productivity.

Like all organisms that thrive in their optimal environment, humans function better and our brains operate at their best in **clean oxygenated air** and certain **thermal conditions** of temperature, humidity and air movement. Just like every other species, humans need certain **light conditions** to trigger alertness and sleep and **acoustic conditions** that enable us to process information. We need **hydration** and **nutrition** and **space to move**. And we need to **relax the body** and periodically **rest the mind**[13]. For each of these physical factors, there are prescribed ranges under which the human body works better, and the brain operates at its best.[14]

These physical environmental factors are observable and <u>measurable</u>, and their effect on brainpower output (productivity) has been well documented.[15]

Bad indoor air quality, thermal discomfort, noise and distractions, lack of daylight and poor visual ergonomics have a measurable negative effect on the productivity of individuals. For example, if we flush out carbon dioxide, and remove VOC pollutants from a workplace and in pump fresh air, – all else being equal, human brainpower improves measurably in terms of **problem-solving, speed, and accuracy.**[16]

That said, a common misunderstanding is that the physical workplace environment is *the* primary driver of employee engagement. Employee engagement results from the interaction of an employee's response to both the culture and physical space, and the engagement level that results, though it can be predicted, is unique to the individual based on his/her ideal workplace characteristics. *Engagement* is an *emotional* response that is produced when people find their jobs meaningful and fulfilling, as well as when they feel they can do their best work. The emotional factors that are necessary for sustained employee engagement relate both to the work environment and to management style and the extent to which employees find,

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[13] GCA, Sustainable Facilities Tool: Building and Health at https://sftool.gov/learn/about/576/buildings-health#building-design

[14] Skopek S., 2017, *SMART Green + Productive Workplace – A desk companion for corporate real estate professionals,* JLL

[15] Skopek S., 2019, *Workplace wellness and the bottom line - How workplace wellness measurably increases the Human Capital of an organization*, JLL

[16] Allen, J., *Building evidence for health: Ventilation*, Harvard School of Public Health. Available at: http://forhealth.org/Harvard.Building_Evidence_for_Health.the_9_Foundations.pdf

in their work: **M**eaning, **A**utonomy, personal **G**rowth, recognition/**I**mpact and human **C**onnection — 'MAGIC' [17] Some of the most successful businesses of our time such as Apple, Microsoft or Amazon began as start-ups in cramped, uncomfortable workplaces.

Comparing the effect of various workplace strategies on worker productivity

Strategies to improve productivity / Productivity KPIs	"Better Building" technologies that are advanced by BAS e.g. lighting/HVAC	Private office (vs Open office)	Workplace Health Program	Bonuses	Flexible Work
Does it reduce absenteeism? *Industry statistics* scale 2 days /year 15	Reduces absenteeism by 0.4 up to 1.5 days per year	Reduces absenteeism by up to 3.2 days per year	Reduces absenteeism (depending on the wellness program)	Reduces absenteeism by up to 1 day /year	No data
Does it reduce employee turnover? *Industry statistics* scale 30 18	Reduces turnover by an index of 1.3	Reduces turnover by an index of 18	Does not reduce turnover(i.e. Reduces turnover (index 0)	Reduces turnover by an unspecified value	No data
Does it improve performance (self-assessed)? *Targeted research/theory* scale 0 100	Improves self-assessed performance by an index of 2 to 10	Improves self-assessed performance by an index of 8 to 15	Improves performance by an index of 0 to 10 (depending on the wellness program)	Improves performance by an unspecified value	No data
Does it improve job satisfaction? *Industry statistics* scale 60 80	Contributes to job satisfaction by an index of 4 to 9	Contributes to job satisfaction by an index of 5 to 10	Contributes to job satisfaction by an index of 0 to 12	No data	Contributes to job satisfaction index 0 to 10
Does it improve health & well-being (symptoms)? *research/theory* scale 30 60	Contributes to health & wellbeing by an index of 5 to 9	Contributes by unspecified value	No data	No data	No data
Does it improve health & well-being (overall)? *research/theory* scale 55 75	Contributes to health & wellbeing by an index of 6 to 10	Contributes by an index of 11 to 12	Does not contribute to health and wellbeing (i.e. index 0)	No data	Contributes by an index of 6
Does it reduce complaints to FM? *Targeted research/theory*	No data	No data	No data	No data	No data

Figure III-1. Comparison of the impact of workplace strategies on worker productivity

Numerous studies have been done on the sorts of measures that are typically expected to improve productivity. The table (Figure III-1) adapted from "*Improving Organizational Productivity with Building Automation Systems*" study[18] by the National Research Council (NRC) and CABA (Continental Association of Building Automation) summarizes the results. The study consisted of a broad review of national and international statistics and targeted studies on productivity in the workplace. The study attempted to tabulate the findings into a coherent framework that compares the benefits of various workplace strategies on worker productivity. One of the strategies that was compared relates to building features and operations". Using the traffic light nomenclature, the areas in green represent the greatest positive effect; those in pink the least effective. The results show that there are indeed other factors than the physical workplace that affect productivity, such as privacy, wellness programs, flexible work and financial incentives.

[17] Rogel C., *MAGIC: The five keys of employee engagement*, Decisionwise, https://www.decision-wise.com/5-keys-of-employee-engagement-magic/

[18] CABA, National Research Council of Canada, *"Improving Organizational Productivity with Building Automation Systems"*, 2017

Problem Statement

According to the US Labor Department, organizational productivity, nation-wide, has stalled or declined in recent years despite the internet revolution, artificial intelligence and advanced robotics[19]. The problem is particularly acute in the service sector – that is to say, in industries whose productivity is not measured by the amount of physical goods produced but rather in terms of the value a customer receives.

The **Problem Statement** is the following:

In recent decades, organizational productivity in advanced economies has stalled.

There are several theories to explain the nation-wide stagnation in productivity including a reduction in research and investment and declining education standards among the larger population. Economists at the Bank of America have theorized that the decline may be partly due to the large cohort of retiring baby boomers who have decades of skills and experience, along with the dramatic influx of young, relatively inexperienced workers, who tend to change jobs often.[20]

As the next generations become the majority groups in the workplace, the values they bring to work are not appearing to change - that is, they identify with work as part of life, vs. the main aspect of success in life. And with this trend will come a need to redefine what productivity looks like in Smart Buildings of the future, especially since almost 30% of American workers either have a side "gig" or work remotely part of the time.

The role of smart building technology to improve organizational productivity

Notwithstanding that there are many diverse aspects to the problem, there is no denying that **smart building technologies** are having a significant influence on the type of measures that organizations are adopting to improve their organizational productivity. For example, smart building technologies are affecting:

- the type of investments by Building Owners
- the way Property and Facility Managers operate buildings
- the strategies being employed by Government and Corporate Tenants to empower and accommodate their employees
- the interaction between Occupants and the workplace

Stakeholders

In office buildings, there are several private and public sector stakeholders whose decisions and behaviors will determine the level of productivity within their respective organizations. They include: i) Owners/Investors, ii) Property/Facility managers, iii) Public Sector or Commercial tenants; and iv)

[19] US Worker Productivity In Serious Decline — The Reasons Why https://www.valuewalk.com/2016/08/worker-productivity-collapse/

[20] Duronio B., 2012, *Retiring boomers are bad news for US productivity*, Business Insider, https://www.businessinsider.com/bofa-expects-less-work-productivity-when-baby-boomers-retire-2012-3

Occupants (i.e. individual occupants). Each stakeholder has a different perspective and expectations as well as different key performance indicators to measure their organization's productivity. For example:

- For **Owner/Investors/ Asset Managers (including Municipalities).** Much of the real estate is owned by financial institutions and they want high value but low risk. They are interested in offering a building environment that attracts and retains tenants, drives high rental revenue and reduces operational costs and retains or increases resale value, but they are reluctant to invest in as-of-yet unproven solutions. However, whether they are in the public or private sector, they want to be leaders and will often invest in buildings that push the envelope, such as the Deloitte Edge in Amsterdam, which is currently the smartest building. There, organizational productivity can be a measure of return on investment.
- For **Public Sector or Corporate organizations that are leasing or occupying buildings**, the objective is to attract and retain the best talent and provide a frictionless, comfortable, healthy and productive working environment that will maximize the human capital (i.e. employee brainpower) by increasing work output. For some tenants, building data is now becoming part of the enterprise data management strategy. So, for example, the data building from sensors can be correlated with absenteeism, space occupancy and other HR data to provide indicators of productivity.
- For **Property or Facility Managers** it is a measure of the ability to operate the building with ease, efficiency and effectiveness to the satisfaction of the owner and the occupants.
- For **individual tenants and occupants,** it is a measure of the health, the potential for "flow" or highest-level work environment, comfort, professional amenities, work efficiency and human connection (professional and social) that the workplace offers.

How Smart Building Technologies Contribute to Organizational Productivity Goals[21]

Improving Organizational Productivity — The Business Case for Smart Building Technology

When it comes to cost savings and performance, smart building technology offers some of the best returns on investment, with as little as a one or two-year payback, through energy savings from heating, cooling and lighting, and through operational efficiencies as well as security and tracking of building space utilization. For example, smart building sensors and controls can optimize the use of elevators, detect water leaks, and alert a waste hauler to pick up waste only when a bin is full. While the evidence of the savings is still largely kept by the leading smart building providers as a 'market advantage", the ACEEE's Buildings program offers 1.5 years project payback evidence in their study "Using Smart Technology to Save Energy in Existing Buildings"[22]

[21] Skopek S.,2 017, *SMART Green + Productive Workplace – A desk companion for corporate real estate professionals, (Chapter 26),* JLL

[22] Jennifer King and Christopher Perry "*Using Smart Technology to Save Energy in Existing Buildings*" ACEEE Report A1701,
February 2017 https://www.aceee.org/sites/default/files/publications/researchreports/a1701.pdf

Smart buildings are part of the IoT revolution and digital transformation

The convergence of building science, big data analytics and IT telecommunications to produce 'smart buildings' is not a new concept. It is part of the same IoT revolution that improves organizational productivity of cities by solving congestion problems, enables global supply chains to deliver 'just-in-time,' and allows airlines to achieve powerful efficiency gains across large fleets of commercial jets. It is also a part of the digital transformation that organizations are undergoing in their approach to conducting business.

In real estate, the 'Internet of Things' (IoT) technology enables asset managers to operate entire portfolios of buildings from remote operations centers. There, they analyze ongoing data streams from sensors in the buildings, optimize each building's use of energy, electricity and water, manage work orders, and dispatch mobile technicians to the buildings when needed. The technology to enable this competitive edge is already at hand, and the business case is compelling.

Increasingly the building data are becoming one of the inputs of the data management.

Smart Capabilities that contribute to organizational productivity for building stakeholders

TABLE A outlines how a SMART building can help to achieve the Organizational Productivity goals for each stakeholder organization and the SMART **CAPABILITIES** these may require.

Stakeholder Organization	Organizational Productivity GOALS	Smart building CAPABILITIES to achieve the Organizational Productivity Goals
Owner/Investors	· **Produce savings and strong ROI** from energy, operations and maintenance	***SMART capabilities (criteria):*** ◘ Smart energy efficiency and water efficiency features and controls ◘ Smart energy management including monitoring, fault detection, analytics and diagnostics and continuous commissioning ◘ Smart operations & maintenance including janitorial services, waste management ◘ Centralized property management
	· **Attract and retain tenants** with services and amenities	◘ Similar to the Government or Corporate Tenant Productivity criteria (see below)
	· **Future-proof** the building by ensuring flexibility and resilience	◘ Flexible telecommunications ◘ Renewable energy, microgrid ◘ Disaster mitigation features against flooding, leaks, fire etc.
Property/Facility Managers	· **Produce savings and ROI** to the satisfaction of the building owner from: energy, operations and maintenance	***SMART capabilities (criteria):*** ◘ Similar to the Owner & Investor SMART criteria for savings and ROI
	Provide a user-friendly interface with smart building technology in order to operate the building with ease, effectiveness, and efficiency	◘ Adequate training ◘ Performance monitoring and diagnostics ◘ Automated work orders

	Offer Health, comfort and wellness, thereby achieving occupant satisfaction and minimizing complaints	◘ IAQ, thermal comfort, and visual comfort features and performance ◘ Sanitation
	· **Provides ease of communication with occupants**	◘ Occupant experience app to provide occupant feedback in real-time
Public Sector or Corporate Tenants	**Maximize human capital**, by attracting and retaining top talent	***SMART capabilities (criteria):*** ◘ Similar to Employee/occupants criteria for health, comfort and wellness, and human connection (see below)
	· **Produce operational savings**	◘ Similar to Owner & Investor and Property Manager ROI criteria
	· **Optimize space efficiency**	◘ Space utilization
	· **Drive productivity**	◘ Similar to Corporate employees (aka occupants) health, comfort and wellness criteria and Work Efficiency
	· **Ensure business continuity**	◘ Similar to Owner & Investor Future-proofing criteria
	· **Produce operational savings**	◘ Similar to Owner & Investor and Property Manager ROI criteria [D3]
Individual employees/occupants	· **Work efficiency** (e.g. timesaving)	***SMART capabilities (criteria):*** ◘ Commuting, parking, wayfinding ◘ Reserving rooms
	· **Safety**	◘ Security features
	· **Health, comfort and wellness**	◘ IAQ, thermal comfort, and visual comfort features and performance ◘ Sanitation
	· **Human connection (professional and social)**	***SMART capabilities (criteria):*** ◘ Communications platform with other occupants

TABLE A – How Smart buildings help to achieve organizational productivity for each stakeholder organization

Smart Technology Requirements to Achieve the Desired Capabilities

A SMART building needs the right technology and functionality to meet the Smart Building goals listed in Table A These can be broadly grouped in two areas:

1. Operational Efficiency & ROI for the building owner and property managers. The technology typically consists of an analytical engine with a building that receives information, analyzes it and automatically adjusts controls through a building automation system (BAS) -i.e. a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. They are summarized in Tables B below.
2. Organizational productivity for the public sector and corporate tenants and occupants, and a positive human experience of the occupants in the workplace. These are increasing the subject of development of Digital Assistants, which are all the “buzz” in Proptech. They are summarized in Tables C below.

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System	Operational Efficiencies	Examples
Smart energy management including monitoring, fault detection, analytics and diagnostics, and continuous commissioning	Smart Energy Analytics and Diagnostics aggregate and analyze building data to generate actionable insights that will save energy and cut costs. The programs address energy consumption and cost in three specific ways: i. Energy management through systematic tracking and optimization of building energy consumption and performance over time, while changing the behavior of building occupants with visual dashboards and benchmarks. ii. Fault detection and diagnosis to enable timely and targeted interventions in cases of faulty or under-performing building equipment. iii. Alarm management to prioritize the many notifications generated by existing building systems and point engineers to the most impactful issues and automated work orders	Sky Foundry. IntelliCommand Coppertree BuildingIQ BlueSurge
Other smart energy features	• Occupancy sensors to switch off HVAC and lights in unoccupied zones • Smart Elevators	
Water efficiency and management features and controls/Smart bathroom	• Artificial intelligence systems identify the source of the water leaks and how to fix the problem • Smart bathrooms can monitor leaks, usage, and environmental factors such as temperature, humidity and odor, and user satisfaction with maintenance	BlueSurge WINT Water Intelligence
Waste	• Sensors that communicate when bins need to be emptied	VS Relay BigBelly
Asset Monitoring and Critical Asset tracking	• Tracking of physical assets – including critical assets – either by scanning barcode labels attached to the assets or by using tags using GPS, BLE or RFID which broadcast their location.	CHEQROOM Emerson BlueSurge

TABLE B – Smart Technologies that produce Operational Efficiencies

System	WORKPLACE PRODUCTIVITY for the government and corporate tenants, and HUMAN EXPERIENCE of the occupants	Examples

Space utilization/people count	• Space utilization monitoring can help to reduce the real estate footprint of an organization by helping it to determine how much space it needs to support its workforce.
	• It is also useful for:
	  ○ Controlling lighting and HVAC
	  ○ Booking meeting rooms
	  ○ Scheduling cleaning
	  ○ Enhancing building security, (e.g. by providing a headcount during emergency)
	It typically uses IR Utilization or Imagining Sensors
		• Utilization IQ
		• BlueSurge
		• Serraview's
		• Asure Smart Office

Wayfinding or presence detection in open-plan	• Wayfinding apps save time when people are looking for someone to collaborate with or a place to work. • They can also show which conference rooms are available at any given time.	• Serraview's Locator Pro and Elite • mappedin

Conference room scheduling/ resource booking	• Online software for booking and scheduling for coworking spaces reduce administration and increase usage • Concierge services	• Skedda • Desktime • Cobot • Nexudus • Yarooms
Temp/lighting/IAQ "smart" environmental control	• Smart environmental controls give occupants a sense that they are in control of their environment, which is emotionally empowering. • Monitoring CO2 levels is one way to measure the need for ventilation within a space. Demand-controlled ventilation reduces HVAC energy consumption by 20% by using actual space utilization data from sensors to adjust ventilation according to real-time demand. • Companies are experimenting with the use of technology to gauge employee mood and adjust the office lighting accordingly	• Comfy • ThoughtWire-@Work app
Digital office management	• Smart buildings use technology to collect data and automate processes so they can better adapt to management and occupants' needs. • By providing data on how employees are using the workspace and their experience and satisfaction with the environmental conditions, smart buildings and IoT make it possible for CRE teams to remove the roadblocks to productivity.	• iOffice • SpaceIQ • CenterStone • ThoughtWire-@Work app • LANE • Managed by Q (WEWork)
Ergonomics	• For Real Estate and Facilities Managers, sensors in the office furniture capture utilization data into the organization's space management system, another tool for improving occupancy planning. • Workplace apps can even 'remember' an individual's ergonomic preferences and prompt them to sit or stand throughout the day based on the selected health settings	• Herman Miller LiveOS
Engagement/Employee Interaction and Collaboration	Centralized mobile solutions with role-based or personalized layers to connect employees and visitors to the information, people and resources they need.	• Modolabs • Slack, Microsoft teams, Google Hangouts, etc
Shared transportation, Smart parking	IoT has generated tremendous flexibility in transportation options from better usability of public transport, to bike sharing, ride sharing and smart parking • Ridesharing Apps offer on-demand hailing of vehicles. Some have the advantage of volume, while others offer better prices and superior technology. • Smart parking Apps provides a range of services to property managers People searching for parking spots can find a parking space, register their car, and pay all through Smart Parking Apps.	• Innovative Urban Transportation Apps for 2019 • The best ridesharing apps for 2019 • Smart Parking

TABLE C – Smart Technologies that produce Workplace Productivity for Public Sector and Corporate tenants and occupants

To deliver the capabilities effectively, the building should meet certain standards, discussed in other sections of this supercluster for:

1. Communications and Connectivity
2. Interface and Interoperability with Municipal Services
3. Safety
4. Transportation

Implementation[23]

Smart systems are a core design element of most new buildings. However, aging buildings are also having to consider upgrades to maintain their value against newer, smarter ones. For an existing building, the best time to do a smart building upgrade maybe during a major renovation. Even if a major renovation is not planned, signs of congestion in the building's communication pathways, additional tenant communication needs or building system failures may indicate a pressing need to upgrade the building's systems.

A survey showed that the leading drivers of smart building installations are energy efficiency and the desire to reduce costs. The technologies that are the most in-demand at this time are closed-circuit television and security (78 percent), HVAC (74 percent), fire systems (69 percent) and building energy management systems (67 percent).[24]

Turning an existing building into a smart building is more challenging than designing a new smart building from scratch. It may require modifying an existing BMS or BAS, as well as constructing an IT eco-system with a common backbone, which will interconnect all the sensors to a master control hub and drive critical information to a common database.

Fortunately, many systems such as lighting, HVAC and building security now feature 'open' communications and data exchange protocols. These make it easier to integrate systems from different vendors and suppliers and leverage existing infrastructure. There is now also integration software that can interface with and gather data from systems that have different communications protocols. 'Middleware,' sometimes described as a 'software glue,' mediates between an application program and a network.

Engage a neutral automation consultant

The plethora of choices in the market with respect to smart building systems and configurations can be confusing. Many firms design smart building systems using their proprietary equipment and programming. However, sometimes these new installations fail to integrate other existing building systems into the smart building network. As a result, the building will miss out on the beneficial synergies of an integrated network. Moreover, the building may be stuck with a system that can only be serviced by the company that installed it.

Before speaking to any vendors, it is wise to engage a neutral automation consultant, who will provide unbiased advice, and take responsibility for the design, sizing, installation, and commissioning of all smart components. This person should be familiar with the principles outlined in ASHRAE's Guideline 13:

[23] Skopek S., 2017, *SMART Green + Productive Workplace – A desk companion for corporate real estate professionals, (Chapter 27),* JLL

[24] Weinschenk, C., 2017, *Smart buildings and the IoT are complex and challenging*, Energy Today Manager, https://www.energymanagertoday.com/smart-buildings-iot-complex-challenging-0166257/

Specifying Building Automation Systems,[25] which describes typical configurations and offers tips on creating a system that will meet specific objectives.

A neutral consultant/coordinator will design an installation based on an open protocol that works with a wide range of systems and does not lock the building into a single service provider. Working with the IT department and the facility management team, the coordinator will help to develop a master plan, and will suggest product options that will be suitable for the type and size of building, the budget, any proposed upcoming projects, specific building requirements and tenant needs.

Things to consider when designing a smart building

When designing a smart building system, **tenant expectations** must be considered. This is especially important in a multi-tenant building, where each tenant may have different needs and require different systems. For example, some tenants may require a high level of security to screen visitors and deliveries, whereas others may feel that excessive screening drives away clients. If tenant expectations aren't well understood and considered, this can lead to tenant dissatisfaction. The best approach is to have face-to-face meetings to work through the floor plans with each tenant, discussing the specific features (such as security) to be implemented in each area, and identifying which specific technologies will work best. Understanding current and future needs is also important to ensure that the infrastructure is 'right-sized,' and that groundwork is provided for future expansion, especially with respect to the communications backbone at the site and enterprise levels.

Another important area of consideration, when upgrading a building is the current **state of the building's existing systems**, such as the age and performance of the current server, warranty issues, serviceability and so forth. These factors will help to determine whether to integrate older controls into a new communications system by simply adding gateways and interfaces, upgrade the old controls, or replace the controls and software entirely.

Finally, the **human component** must be factored in. For example, does the existing facility management team have the time and skill level needed to operate the system? Will ongoing services be self- performed or delivered by a service provider? And finally, how well does the solution predict the emotional and engagement responses of the employees who will need to function in the space? Realizing that different tenants have different kinds of businesses and skills of employees, it's important to realize that solutions cannot be "one size fits all".

An overarching goal of a smart building is to **capture data** about building systems. However, data only has value to the extent that it can be used by those operating the building. Micrometric details about every circuit are useless unless they translate into useful knowledge and action. If building operators have difficulty navigating and understanding the controls and interfaces, interpreting the data, or troubleshooting, then this can erode user confidence. Elements of smart systems may end up being overridden. This undermines a smart building's capabilities and negates promised efficiencies.

[25] ASHRAE Guideline 13-2015, *Specifying Building Automation Systems*, https://www.techstreet.com/ashrae/standards/guideline-13-2015-specifying-building-automation-systems?gateway_code=ashrae&product_id=1894498

To avoid this, the solutions providers must deliver a user-friendly system. That said, smart building operators, for their part, must have a general working knowledge of how all the building systems share information and how to work across the disciplines.

Designing a smart building system should be a collaborative effort

Designing and implementing a smart building system should be a collaborative effort between the site team, consultants, contractors, engineers and vendors. It should include the predicted needs of stakeholders in the short and long run, be guided by a neutral, third-party advisor, and the implementation should be carefully monitored by a technical project manager.

Needs assessment

The process begins with a need assessment. This consists of analyzing tenant requirements, researching energy and building usage trends, and looking ahead, to lay the groundwork for future expansion. Assess all the existing systems. Identify existing components that can be migrated or leveraged on a smart building network, and places where new components will need to be added. Develop a concept of the basic skeleton of the smart building network and a preliminary cost estimate.

Design

Once the project and costs have been scoped, the actual design should specify all existing building systems that need to be migrated, as well as all new systems. All components should be aligned with the physical space to determine appropriate locations for new infrastructure. The output of the design phase should include costs, installation timelines and priorities, keeping in mind that smart building network deployments need not be completed all at once, but can be phased in over a period of months or years.

Implementation

Implementation includes installation, configuration and commissioning. The result should be a fully functional smart building network with documentation, which other building systems can leverage. A skilled technical project manager will ensure that the activities associated with the implementation are completed properly.

Ongoing communications between property management and tenant organizations

Once a system is commissioned and up and running, communications between tenant organizations and owner should be ongoing. This is important for many reasons, including the security of the building and data. For example, if the tenant fails to update the database when employees leave the firm, then there could be many people who continue to have access privileges even though they are no longer authorized.

It's important to keep in mind that even smart buildings need people to run them and act in response to fault detection and diagnostics (FDD) data. The good news is that the user interfaces are becoming ever more user-friendly, enabling facility managers to control and monitor their building, alerting them of malfunctioning equipment, and flagging where maintenance is needed.

The role of the tenant's IT team

In industrial applications, the Internet of Things (IoT) is commonly found deeply embedded in sensor-laden machinery and assembly lines as well as the facility's infrastructure of lighting, HVAC systems, thermostats, and security. These enterprise applications serve production purposes, for example, by improving manufacturing efficiencies, and collecting data to drive artificial intelligence and predictive analytics.

One of the greatest benefits of the industrial IoT is how it can dramatically improve operating efficiencies. If a machine goes down, for example, connected sensors can automatically pinpoint where the issue is occurring and trigger a service request. Perhaps more importantly, the industrial IoT can also help a manufacturer predict when a machine will likely breakdown or enter a dangerous operating condition before it ever happens[26].

But what about offices?

At the building level, the focus of building operators is to manage plant operations, HVAC systems and maintenance teams. There is also a new layer of smart devices such as occupancy detection and other sensors, which link to occupants' devices. In a smart office building, *enterprise management* provides connections between the building systems and the occupants — for example, allowing them to book spaces, or activate lighting and air conditioning in conference rooms only when they will be occupied. With this, occupants can be better served by integrating their enterprise operations with the physical environment. However, to extract maximum value from the data and controls of a smart building's networked devices and the occupants' devices, there needs to be a relationship between the building's and the occupants' IT teams.

Traditionally, the role of an occupants' IT team has been to focus primarily on business software and communications, often with very few links to the building environment. However, with smart buildings, there is now an opportunity to link corporate networks with building networks, as part of a broader IT strategy.

The data that smart buildings generate can be extremely valuable to the *occupant organizations*. For example, intelligent, wireless, sensor-laden LED lighting networks have a software back-end that can generate data about occupancy patterns and usage of meeting rooms. Understanding how the occupants are using the facility offers useful insights for safety, health, environmental and energy management.

When striving to provide occupants with greater control of their workplace environment, the occupants' IT team needs to be involved in decisions regarding access to the data that these smart building systems can generate. For example:

- What kind of data will the system(s) generate?
- Who will control the data and manage the integration of that data across systems?

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[26] *Industrial IoT: How Connected Things Are Changing Manufacturing,* Wired magazine, https://www.wired.com/wiredinsider/2018/07/industrial-iot-how-connected-things-are-changing-manufacturing/

- Who will have access to the data?
- Who can benefit from access to the data? How can this benefit be shared across business units and/or departments?
- What standards will be supported for data and network integration?
- Who will have long-term responsibility for IoT within the enterprise, including the infrastructure, network security, and standards, while ensuring maximum business value?
- What will be the system of record — an enterprise resource planning (ERP) system or a building management system (BMS)?
- What KPIs will be tracked?

To work out these issues, clearly there needs to be a relationship between the occupants' IT team and the building IT team, to integrate the relevant building data into the enterprise resource planning software or corporate social responsibility tracking software.

Smart Buildings for Smart Cities[27]

Organizational Productivity isn't just for owners, property managers and occupants. It also applies to cities. For municipal governments, the smart city approach offers a wide range of other opportunities for savings and efficiencies.

Smart cities offer a wide range of benefits, from cost savings to livability, safety and security, resilience, and sustainability. London and Singapore lead in terms of their budget, vision, leadership, financial incentives, support programs and a people-centric approach. Municipal governments around the world must also come to grips with the fact that cities are major contributors to climate change—and are highly vulnerable to its disastrous effects.

Besides, cities are now competing for talented individuals and employers that grow the local economy based on the designation of "Smart Cities". Cities like Philadelphia, Columbus Ohio, and San Francisco actively use their advanced connectivity as well as "Smart Buildings" to lure talent from smaller, less progressive communities. (Smart Cities Conference, Washington DC, October 2019). Smart buildings are a key contributor to the returns that include jobs, tax revenue, and higher quality of life. While the benefits and Return on Investment (ROI) of smart buildings are well documented for tenants, building owners and operators, similar information for cities is limited at best. *Blueprint Chapter 1 – Value, Benefit and ROI Considerations* provides such understanding.

Smart cities are gaining their momentum, fueled by communication advances and innovations such as G5, autonomous vehicles, drones and blockchain. In an urban ecosystem that integrates digital technology, knowledge, and assets, the goal is to improve services and efficiency, fuel the economy and deliver a better quality of life to citizens.

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[27] Skopek J., *Smart City infill: People, Services, Buildings and Infrastructure Densify Digital Connectivity*, Canadian Property Management, December 2018

The current focus of smart cities is on social aspects – linking people to services

The prevailing theory is that "smart city strategies start with people, not technology"[28]. Applications that strengthen the social fabric are what attract young talent and innovators, and result in increased linkages between the physical, digital, and human spheres (Figure III-2). Establishing digital connections between people and the built environment affects where people live and work. Most smart cities focus on mobility, but those that have the greatest number of applications, such as New York, Los Angeles, London, Singapore, Shenzhen, and Seoul—have branched out into multiple additional domains. Extending the focus beyond mobility gets a city closer to creating a virtuous circle of benefits such as telemedicine, smart street lighting and networks of cameras that monitor streets for suspicious behavior, can prevent crime or terrorist attacks before these take place.

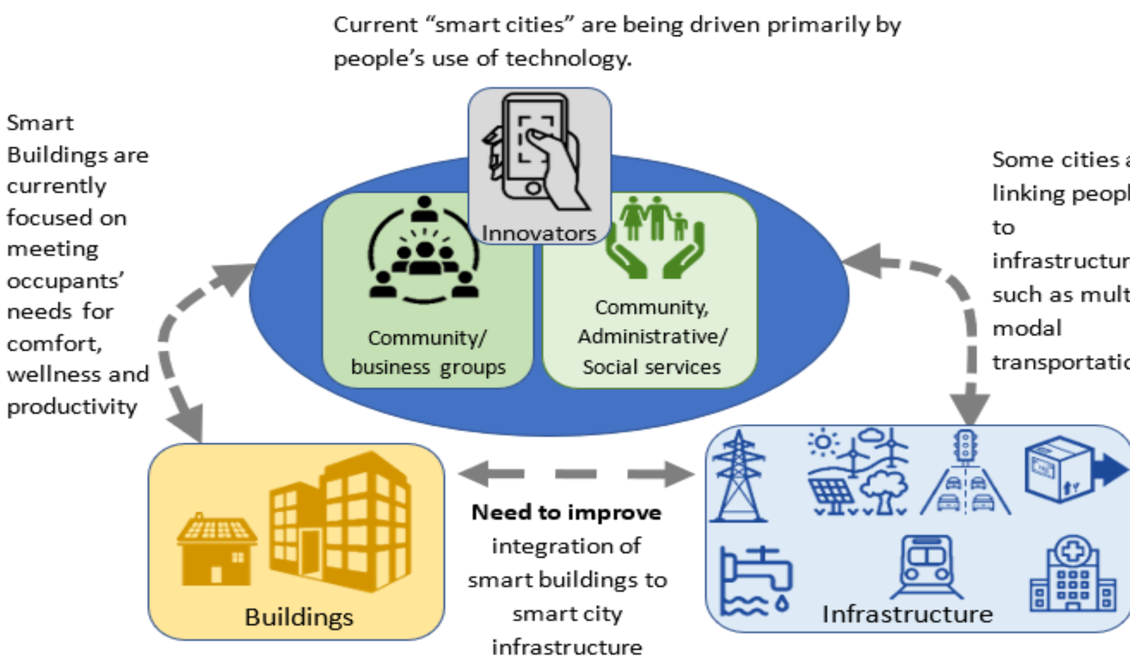

Figure III-2. Establishing links within the city fabric [Source: Author]

As the public and private sectors, academia and civil society race to produce and avail themselves of smart technology, there's more to smart cities than just a plethora of applications linking citizens to services.

To derive the fullest benefits, another category of digital connection is critical: between buildings and the various elements of a city's infrastructure.

Smart metering of energy and water, smart parking, automated garbage pick-up and waste-stream sorting, and emergency response services are just some examples of digital connections between buildings and infrastructure.

[28] McKinsley Global Institute, *Smart Cities: Digital Solutions for a more livable future*, June 2018 https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/smart-cities-digital-solutions-for-a-more-livable-future

The role of smart buildings in a smart city

Smart cities have implications for real estate. For one thing, they attract a high-end demographic of "information innovators" – companies and people who demand smart workplaces and homes. In today's full-employment economy, employers need to focus more than ever on differentiating their real estate, not just their wages.[29] Smart buildings in a smart city will be critical for attracting occupiers seeking to retain this highly educated talent.

There are other advantages of linking buildings to public and/or private smart city services and infrastructure. For example, there are operational savings from being able to detect water leaks or alert a waste hauler to pick up only when a bin is full. Smart meters allow energy usage to be monitored remotely, which leads to cost savings over manual meter reading. Some utilities even give their customers reduced rates if they allow the utility to make momentary, unobtrusive adjustments in electricity loads during peak hours by remotely powering down their customers' less critical systems for short periods of time during periods of heavy demand on the grid.

Utilities may be the biggest winners when it comes to linking smart buildings with smart infrastructure and using the predictive analytics of smart grids to match capacity to demand. As photovoltaics and battery storage becomes commonplace, smart buildings may become the virtual power plants providing both the utility and necessary resilience against power cuts or brownouts.[30]

The McKinley Global Institute analysis indicates that digital tools and applications could help on average to cut greenhouse gas emissions by 10–15 percent and lower water consumption by 20–30 percent. Smart technologies that link with buildings make it possible to streamline services such as waste collection and reduce the amount of solid waste per capita by 15–20 percent.[31]

Linking to smart buildings also benefits a city's emergency management and resiliency by guiding emergency services along the best route, and by deploying resources more efficiently during emergencies or evacuations.

City planners and developers can also create net-zero communities supported by more efficient infrastructure. For example, offices use most of their energy by day; residences are just the opposite. Thus, a single district heating or cooling plant that serves both commercial and residential buildings may not need to be much larger than a plant serving just one or the other. It is also sometimes possible to share energy — for example, using waste heat from data centers. Communities in Europe such as Vauban, Germany have used district heating/cooling successfully for decades.

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[29] JLL Research Report, *Ambitious thinking: Smart cities*, http://bostonblog.jll.com/tag/ambitious-thinking-smart-cities/

[30] *Reactive technologies achieves a world first in smart grid innovation* https://www.reactive-technologies.com/reactive-technologies-achieves-a-world-first-in-smart-grid-innovation/

[31] Greber Anna "Building connected cities with new and existing IoT technologies", IBM developer Works, January 2018, https://www.ibm.com/developerworks/library/iot-lp201-iot-connected-cities/index.html

Smart cities need public and private sector collaboration

Buildings and cities reflect today's rapid technological and entrepreneurial progress. It is interesting to note, however, that linking smart buildings to smart city systems, has – up to now - taken back seat compared to areas such as transportation & mobility, security and street lighting.

Integrating smart buildings and smart city technology is the next frontier, for buildings constitute the basic fabric of a city. However, this requires cooperation by public and private sectors and utilities. This is only possible by demonstrating the benefits so that all may work together on a coherent strategy that will meet each one's goals.

In the end, buildings and Smart Cities can provide a modern, functional and highly productive life for citizens and employees that matters most. And as times rapidly continue to change, having a municipal plan that can be resilient and flex in response to future challenges such as climate change and potential public health concerns is essential.

Productivity is not a static concept, and smart buildings that are designed with the future in mind will contribute most to our collective future.

Smart cities and buildings in the time of the pandemic.

With the growing threat of infectious disease, smart buildings will play an increasingly important role. They will be able to help to detect and control the spread of infectious disease, facilitate the remote operation of the buildings in a lockdown and interact with the grid. With the trend towards self-isolation by the population at home, the role of connectivity for communication and entertainment is paramount. As many buildings such as offices, restaurants, theaters and cinemas, sport facilities are closed, the question single-use function design is raised. The need for distancing in shops also requires a re-examination of the way products are being delivered and distributed. In the long run, this may lead to changes in the way we live and work productively.

The immediate use of smart technology is in the detection and control of the spread of infectious disease**.** The use of temperature measurement equipment that integrates intelligent video, AI, and thermal imaging is becoming a part of epidemic prevention and control solutions. Installation of intelligent sensing equipment for epidemic prevention inspection at key locations reduces manual investment, infection risks and related costs. Information technologies have played a pivotal role in China's response to the novel coronavirus COVID-19 outbreak, such as proactive surveillance for rapid detection and diagnosis of infection, immediate isolation, rigorous contact tracing, quarantine of the close contacts, and exceptionally high awareness and acceptance of the measures among the general public[32].

Fever is the most common symptom of novel coronavirus infection and high-performance infrared thermal imaging could allow for rapid body temperature measurement of persons entering the building. High-performance infrared thermal cameras have been installed at the entrances of some major train stations and airports in China and elsewhere. The devices capture thermal images of people flowing in

[32] Deployment of Health IT in China's Fight Against the COVID-19 Epidemic
https://www.itnonline.com/article/deployment-health-it-china%E2%80%99s-fight-against-covid-19-epidemic

real-time and rapidly detect persons with an abnormal temperature. Tech companies are also proposing to use AI to establish the identity of passengers in the measurement area, allowing those suspected of infection to be immediately separated. These solutions have privacy implications. Employee monitoring technologies often receive significant pushback. For example, the Daily Telegraph had to withdraw desk monitoring sensors for space utilization tracking, while more recently in February 2020 Barclays was forced to scrap its program to monitor the amount of time staff spent at desks.

Building types such as hospitals have used white light disinfection LED technology, deployed washroom sensors to track whether staff are washing their hands for a sufficient length of time or reprogramed BMSs to manage indoor humidity levels to minimize the survival rate of viruses.

The policy of self-isolation at homes can particularly affect residents in single and multi-residential buildings. Apart from the work at home, education, "entertainment" and telemedicine internet feed, with the aid of app the residents could submit daily health status reports to a community worker designated for a section of the building or a district who would respond with a message, a phone call, or even a home visit accordingly. In the Guangzhou city app's 'I Need' feature helped the residents isolated in their homes for suspected infection to obtain daily necessities such as rice, meat, vegetables and medications. Such services could be incorporated as a part of the property management offering.

The "open building" approach to the design of buildings was conceived in the 60s' to enable buildings to be re-purposed during their lifetime, in line with social or technological change. Open building design seeks to co-ordinate inputs from different professions, users of the building, and other interests associated with the locality33. Where there may be lesser demand for offices, this may lead to re-adaptation of these buildings to multi-residential accommodation. Similarly, sports facilities or even shopping centers could be converted to hospitals. A related concept to open buildings is the coworking flex space. It may well be possible that the coronavirus may bring new coworking or multiple-use opportunities not only to offices but also to other building types. Booking and monitoring of the flex space will provide numerous opportunities for smart solutions.

Coronavirus is also bringing innovations to deliveries. Drones can now deliver medicine in Ireland while ensuring "zero human-contact" to vulnerable people locked in their homes[34]. Alphabet's Wing subsidiary has seen a "dramatic" increase in customers using their food and medicine delivery service, with more than 1,000 deliveries completed in only two weeks during which people faced lockdowns nationwide[35]. As Steve Jobs once said: "Innovation is the ability to see change as an opportunity – not a threat

[33] Open building, Wikipedia https://en.wikipedia.org/wiki/Open_building
[34] Coronavirus Delivers 'World's First' Drone Delivery Service, Forbes, Apr 3, 2020 https://www.forbes.com/sites/simonchandler/2020/04/03/coronavirus-delivers-worlds-first-drone-delivery-service/#7ff1b2e24957
[35] Alphabet's drone service delivers medicine during coronavirus pandemic, April 8, 2020 https://www.cnet.com/news/alphabets-drone-service-delivers-medicine-during-coronavirus-pandemic/

IV. Chapter 3: Next Generation Operations & Maintenance

By

Jiri Skopek

Objective

This section explores how the next generation of smart building operations, functionality and maintenance is utilizing the (IoT) internet of things to operate at full interconnectivity, functionality and efficiency. Smart building , operations, functionality and maintenance capabilities cut energy consumption and CO2 emissions, reduce maintenance costs and extend equipment lifetime. Various systems offer actionable insights, drive fewer complaints from occupants, decrease the need for unscheduled maintenance and reduce energy costs and carbon footprint. In the time of pandemic or other extreme events, smart buildings may offer autonomous operation.

For many people, the idea of a SMART building creates, and implies an image of a building with complex IoT applications that can only be understood, integrated and operated by a cadre of highly trained facility, IT, project management professionals. A similar apprehension existed with the first generation of buildings with BAS (Building Automation System)— i.e. an intelligent system of both hardware and software, connecting heating, venting and air conditioning system (HVAC), lighting, security, and other systems to communicate on a single platform. Most larger buildings today have a BAS system for significant energy saving and operational benefits it provides.

Smart Building Operations

The difference between BAS and the smart building operations

The difference between BAS and smart building operations is the ability to gather data, analyze and diagnose problems from multiple data input sources. Building automation systems (BAS) help facility owners conserve energy and optimize performance with controls that allow for examples like scheduling, occupancy and maintaining set-points. Smart building operations are just a step away from this, and simply represent a facility's ability to gather this data and change operational outcomes accordingly. The key is data acquisition, analytics, and diagnostics.

The transition to smart operations does not have to occur all at once but can be gradual and phased. For owners with a robust, and at some levels integrated BAS in their facilities today, transitioning to a smart building environment will be easier to accomplish.

The very first step is to install smart meters that can provide near-real-time energy usage data showing energy consumption, and in some cases, at what cost. This on its own has the advantage of improving a building operator's insights to save energy, reducing the carbon footprint, improving the longevity of equipment and reducing costs. Smart meters offer utility monitoring opportunities on a more granular basis toward the conservation of our natural resources. The systematic tracking and optimization of building energy consumption with visual dashboards can also help to change the behavior of building occupants. *Blueprint Chapter 6 – Interfacing with City Services and Utilities* provides further explanation.

The next step is to install sensors to monitor building performance in real-time. For example, industrial temperature sensors allow you to measure and monitor ambient, surface or water conditions in a room, machine or around the building, in real-time. This allows you to maintain optimum conditions and improve efficiency. Desk occupancy sensors detect and monitor the presence of people, in real-time.

The current technology, otherwise known as ***Big Data Analytics (BDA) and Fault Detection and Diagnosis (FDD)*** typically consists of a cloud-based analytical engine that receives and analyzes building data and communicates the diagnostic information, typically through a series of work orders. These are the terms used to describe the process of tracking and analyzing building performance and energy efficiency continuously and in real-time of heating, ventilation and air conditioning (HVAC) systems, lighting (for example daylight saving and shutting off lights in unoccupied zones), indoor air quality (IAQ) monitoring, smart elevators and so forth to alert the building operators of faults or inefficiencies within the building systems. To avoid being overwhelmed by too many notifications, algorithms can be put in place to prioritize and indicate the work orders that are a priority, and which will have the greatest positive impact on building performance.

Fault detection and diagnosis enable timely and targeted interventions in cases of faulty or under-performing building equipment. This equates to continuous commissioning. Smart building sensors are not limited only to energy usage problems but can also address other systems, for example, identifying water leaks, or waste bins that need emptying. In the longer term, BAS will soon become less important, as more and more equipment will be manufactured with integrated controls and sensors that can be wirelessly connected to the network and driven by a smart building software platform — like 'plug and play.

As more and more data and the skill set to collect them increase, the analytics will mature and reveal patterns and feedback mechanisms that will enable the development of data-driven knowledge and operations. Like self-driving cars, this may lead to self-operating buildings, where the analytic and diagnostic capabilities of smart buildings will allow for remote operation of the buildings. With the information relayed via the cloud about the operation of the building's heating, ventilation, air conditioning (HVAC) and lighting control systems, the building operator will be able to monitor and control the building operations remotely for energy consumption. This will also be valuable in the during pandemics. A digital twin manifestation of the building would further extend the building operators' capability to access all operational data remotely.

A combination of building automation and AI would further support a self-operating building that requires little to no human intervention. There are other advantages to using AI apart from a remote operation. AI would also be able to most efficiently maintain balanced thermal equilibrium[36] in a building under any circumstances while at the same time ensuring occupant comfort, saving money, and reducing the carbon footprint.

There are still barriers to smart buildings. They include a general mistrust of artificial intelligence and the significantly higher cost of deploying AI-powered platforms. While there is some progress, there is still some work to be done to integrate protocols for various types of equipment used in smart buildings. Machine learning algorithms and more advanced statistical algorithms are also being developed to perform increasingly complex learning processes. Notwithstanding, the challenges, the use of artificial

[36] Autonomous AI HVAC Technology: The Beginning of a New Era in Building Automation

intelligence in building management is a strong trend and the adoption of artificially artificial AI-powered BMS platforms is projected to increase especially in new design and construction.

Due to the widespread of cloud-based applications and smart building technologies, which are now linking cyber and physical infrastructure, cybersecurity controls are increasingly essential to protect occupants, building infrastructure, and smart building functions against cyberattacks. *Blueprint Chapter 4 – Cybersecurity Considerations* explores further this issue.

From preventative maintenance to predictive maintenance

The same integrated sensors that provide performance data — historical and in real-time — support a more predictive maintenance program by detecting failures before they occur. For example, the data may show that a fan coil unit has been running at 100% output for more than one month, at higher measured sensor temperature and therefore requires maintenance activities earlier than planned.

A review of the work orders that have been issued for each piece of equipment will identify the equipment that may soon need replacing. This proactive monitoring of devices and end points has a high return on investment for labor and product replacement. This then can be included in the capital plan. Another intelligence can be provided to the facility Inventory systems such that if one of the parts scanned out of inventory is taken for use, a replacement part is automatically ordered. This can create a recommended spare parts list to be kept on hand.

New Developments in Operations and Maintenance

Digital Twin

Looking to the future, many buildings and their systems will be replicated digitally via a so-called "digital twin", either as detailed graphic representations or in the form of data, so that whatever occurs in the building will be visible and controllable virtually and in real-time.

Digital Twin in the context of the built environment refers to a digital replica of physical assets (physical twin), places, processes, systems, and devices. This digital data can be used for a variety of purposes including building design, space management, operation and maintenance, the gathering, analysis and diagnostics of property data, creation of new services, and more. The digital representation provides both the elements and dynamics of the building in its entity, including systems and devices, as well as operation throughout its lifecycle[37].

While a digital twin consists of an exact representation of a building in the format of digital data, the easiest way to comprehend the data is by using a 3D model. This dual representation can cause confusion with BIM. BIM data enables collaboration and visualization during design and construction, but not during operations and maintenance. Thus, to create a digital twin for new construction it is possible to start with a BIM model based on the construction information (plans and data for the building). A digital twin represents how people interact with the built environment. It uses automated sensor technology for

[37] adapted from https://en.wikipedia.org/wiki/Digital_twin)

information updates to reflect real-time changes. For existing buildings the digital twin can be created with real-time sensor data from the building management system, data from HVAC systems, lighting, fire, security, and other environmental sensors, as well as data about the assets of the building and the people who use it, such as tenants, occupants, building staff, visitors, and other roles. This creates a rich virtual information model of an entire building, which allows for detailed and accurate analytics of maintenance data and asset usage optimization based on financial impacts and costs. This helps to operate buildings more efficiently by helping predict and avoid unexpected costs, identifying system inefficiencies and better estimating when replacement parts are needed. Running simulations on a digital twin reduces risks and helps system engineers make better business case for changes to the system[38].

Facilities Informatics and applied technology

Facilities informatics (FI) is the intersection of facilities, IM/IT, and management practices to improve operations, based on facilities-related data, information, and knowledge[39].

Facilities informatics has its origin in the medical field to organize and understand patient data – individually and in the context of population trends, for example, when a cluster of patients covered by different physicians may be experiencing similar conditions.

At the level of the individual patient, it keeps track of medical information electronically; informs physicians about how a patient's condition, local or remotely, is changing over time; provides insights during the diagnostic phase and the care process including information on potential treatments; automates pharmacy requests, and facilitates effective and constant communication between the patient and physician.

For hospital managers, this data offers a better understanding of the workflow of their hospital so that they can plan for predictable, not-readily noticed patterns in patients, and react more quickly to situations that are trending out of normal bounds.

A similar approach is now being developed for buildings and facilities management. The goal of facilities informatics is to develop wisdom from data to inform decision-making processes related to energy, maintenance, and capital programs. Some examples of facilities informatics applications include the design, development, implementation, maintenance, and evaluation of:

- hardware options
- communication protocols for the secure transmission of facilities data
- electronic facilities record systems (regionally, provincially, territorially, or nationally)
- evidence-based decision support systems
- classification systems using standardized terminology and coding
- work management systems
- facilities monitoring systems (e.g., computer-controlled BAS/EMS systems)
- digital imaging and image processing systems

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[38] What is a digital twin and how can it be used for smart facilities management? https://www.pressac.com/insights/what-is-a-digital-twin-and-how-can-it-be-used-for-smart-facilities-management/

[39] APPA Facilities Informatics Maturity Matrix Technical Report https://www.appa.org/wp-content/uploads/2019/04/20160630APPAFacilitiesInformaticsMaturityMatrixTechnicalReport-4.pdf

- geospatial systems
- telework and mobile technologies to facilitate and support remote diagnosis and treatment
- Internet technology for engaging customers
- methodologies and applications for data analysis, management, and mining
- facilities information data warehouses and reporting systems
- business, financial, support, and logistics systems

Facilities informatics can be viewed as a parallel to Enterprise Data Management (EDM), which is starting to be used by many organizations to integrate, govern, secure, and disseminate data from multiple data streams, including data that is being safely transferred among partners, subsidiaries, applications, and/or processes. Similarly, building data, for example from sensors monitoring energy and environmental conditions are increasingly becoming part of this process.

Channeling buildings and facilities data through the same data processing and storage as the organization data may cause conflicts between the organization's information technology (IT) and operation technology (OT) departments. The building data are being generally viewed in the IT world as low-grade data susceptible to hacking and the threat to cybersecurity. To progress and overcome such perception increasingly requires IT/OT personnel to work together.

Reduction of peak demand and increased resiliency

Peak demand is a period in which electrical power is needed for a sustained period at a significantly higher than average supply level. This often causes power "blackouts or brownouts”. Fortunately, it only occurs a few times a year usually on the hottest days or coldest days of the year, depending on the geography. However, with increasing frequency of weather events due to climate change such events are becoming more frequent. Traditional peak demand reduction techniques rely on cutting or reducing the use of certain building equipment such as elevators or A/C. Smart buildings may extend peak load reduction capabilities by offering the possibility to limit the need to invest in additional capacity to supply peak demand while improving the use and efficiency of existing resources. Blueprint *Chapter 6 – Interfacing with City Services and Utilities* further addresses how consumers can reduce or shift electrical usage during peak periods.

The integration of distributed energy resources (DER) in buildings that are 'grid partners' with utilities increases resiliency. For example, integration of microgrid consisting of photovoltaic modules, battery banks, and plug-in electric vehicles (PEVs) can reduce the peak load of the building as well as satisfy the PEVs load. The control strategy offers operational flexibility and the ability to take advantage of off-peak energy rates. This can be achieved through exploiting power generated onsite, local energy storage system, and the operational flexibilities of the PEVs via the vehicle-to-building alternative[40].

[40] Peak Load Reduction in a Smart Building Integrating Microgrid and V2B-Based Demand Response Scheme https://ieeexplore.ieee.org/document/8550711

Building interaction with the grid.

While climate change is losing its no.1. priority to the pandemic, both the pandemic and the climate crisis are problems of exponential growth against a limited capacity to cope. In the case of the coronavirus, the danger is the number of infected people overwhelming health care systems; with climate change, it is that emissions growth will overwhelm our ability to manage consequences such as droughts, floods, wildfires, and other extreme events[41]. The current brief reduction in emission due to coronavirus will not stop other catastrophic events which are already in motion. We need to build resiliency on all fronts. One such measure is a smart grid and transactive energy where buildings will be the heart of the future grid.

Smart Grid is an electricity supply network that uses digital communications technology to detect and react to local changes in production and usage. Changes in a Distributed Energy Resources (DER) network may be caused by the uneven generation by the renewables (wind and solar) as well as changes in usage by the energy consumers. To operate the smart grid needs both economic and control mechanisms to balance an electric power system. Such a mechanism is *transactive energy*.

The benefits associated with the Smart Grid include more efficient transmission of electricity and faster restoration of electricity after power disturbances as well as reduced operations and management costs for utilities, and ultimately lower power costs for consumers. Combined with renewable power and storage it also provides great resiliency which in times of pandemic or other catastrophic events increases the grid coping capacity. The capability to respond to the changing condition, "talking to the grid" requires a smart platform solution capable of supporting the management of a wide range of applications, including heating, ventilation, and air-conditioning systems; electric vehicles; and distributed-energy and whole-building loads. Platforms such as VOLTRON[42] are rapidly being developed and tested. They will be capable to respond to occupants' needs, produce and store energy, and communicate with the utility, grid and other buildings.

Smart grids have the potential to boost resiliency and catalyze the efficient and sustainable use of electricity. Real-time access to supply and demand transactive energy platforms, enabled by smart grids, could deliver a value of $632 billion to society higher than any other individual digital initiative[43].

Low voltage, Power over Ethernet (PoE) and DC microgrids

One concern that is now emerging is that digital technologies such as those used by occupants (particularly streaming) are warming up the planet. These are currently responsible for 4% of greenhouse gas (GHG) emissions, and expected to double by 2025 to reach 8%, which is equivalent to the current share of car

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[41] said Elizabeth Sawin, co-director of Climate Interactive, a think tank https://www.climateinteractive.org/

[42] Pacific Northwest National Laboratory: VOLTRON: Tech-to Market Best Practices guide for Small-and Medium-Sized Commercial Buildings, PNNL-25405, July 2016

[43] Forbes: World Economic Forum. "Global Action Needed To Protect Electricity Grids From Growing Threats" https://www.forbes.com/sites/worldeconomicforum/2019/04/29/global-action-needed-to-protect-electricity-grids-from-growing-threats/#2547e6052d28

emissions[44]. To counteract this trend is therefore important to look at other ways to decrease the energy consumption of buildings.

Direct Current (DC) microgrids and Power over Ethernet (POE) may offer a solution. Solar panels produce DC current, which is what computers, LED lighting and electric cars use. The advantage of a DC microgrid is that it can supply renewable energy to supply these end uses. Many innovative DC-run building components are now coming onto the market. For example, smart DC motors are being installed to replace inefficient and unintelligent AC induction motors on HVAC. These are more efficient, provide better control and are more durable than variable-speed-driven motors, which throttle back power by inducing a current in the motor, but which produce heat and other side effects from the electrical resistance. An example of a PoE building is the Marriot Hotel in Fort Worth[45]. DC microgrids can supply not only buildings but entire cities.

Benefits

Operational Savings

Incremental investments in smart building systems and their operation and management offer a good return on investment. Given that the main role of building managers is to save money gain and retain occupants, it is therefore not surprising that the main focus has been on energy savings — energy being a key controllable item — with energy management and information systems for energy monitoring, measurement and verification (M&V), demand management and HVAC optimization.

Admittedly, smart building technology requires a certain level of capital expenditure for installation, migration and interface with often dissimilar existing building automation or control systems. However, the cost of upgrades pales in comparison to the operational savings. As building components and installations become cheaper, and smart buildings need less on-site, hands-on operations, owners, occupiers, and investors in real estate are starting to realize that these systems are becoming essential to remain competitive in the marketplace.

For example, a large, global financial services firm installed low-cost wireless sensors and controllers on its branch facilities, which numbered in the thousands, to enable remote monitoring and control of HVAC and lighting systems. Energy savings averaged 13 percent annually, while savings from fewer maintenance technician visits added another 5 percent in overall operating expense savings[46].

In the short term, the business case for smart buildings is bolstered by the energy-savings potential of strategically chosen smart building features, and accurate service history and asset condition, which

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[44] "Climate crisis: The unsustainable use of online video" https://theshiftproject.org/en/article/unsustainable-use-online-video/

[45] Marriott Autograph Hotel in Texas to Become PoE Technology Showplace https://www.connectedremag.com/smart-buildings/proptech/marriott-autograph-hotel-in-texas-to-become-poe-technology-showplace/

[46] JLL Special Report, The changing face of smart buildings: The Op-Ex Advantage, http://www.pacificcontrols.net/pdf/JLL-Smart-buildings-final-hires.pdf

enables maintenance activities to be more efficiently scheduled, and accurate maintenance logs to ensure that operators only pay for work that was completed.

Operational savings appear to offer even greater savings with fault detection, equipment predictive analysis, predictive cleaning and so forth. Since every piece of equipment can be monitored and dealt with based on work orders, this provides a record of how many work orders have been issued on each piece of equipment. These records help to identify which equipment may need to be replaced as part of the capital plan. All of this dramatically reduces the time and cost of operations and maintenance with efficiency gains of fifty to seventy percent. For example, Microsoft is already using AI to improve operations on its eighty-eight-acre campus. Microsoft now also operates one hundred percent carbon neutral. Because buildings emit forty percent of carbon, these are the kinds of savings that are needed to fight the climate emergency and help cities and states meet their goals, such as in NYC NYSERDA's Retrofit NY or California's Low-Carbon Buildings Bill AB 3232.

Thanks to extraordinary payback periods of one to two years, it is no wonder that owners and investors are installing smart systems and engaging smart building management services to optimize the performance of their portfolios and maintain a competitive edge leasing faster because of lower operating expenses than their peers, and commanding a better price on sale.

Smart buildings also contribute to Return on Investment (ROI) that includes jobs, tax revenue, and higher quality of life. Blueprint *Chapter 1 – Value, Benefit and ROI Considerations* provides further explanation.

Incremental capital expenditure that offers a rapid return on investment (ROI)

Organizations that want to make their portfolio smart, do not have to do it all at once. A smart building expert can review the portfolio to identify the best ROI opportunities for example, from adding smart sensors and controls to existing equipment. As wireless technologies avoid the need for costly hardwiring and renovation, relatively small and incremental upgrades can give owners control of their investment in smart systems. Impressive savings can be generated in the short term as these systems reflag and reduce inefficiencies.

Here is one example. Some buildings use cool outside air or 'free- cooling' to reduce the amount of air conditioning that needs to run. If the dampers that allow the cool air to enter become inadvertently stuck in a closed position, then the free cooling may not be working at all without anyone being aware of it. Without the free cooling, the air conditioning may be using far more energy than needed, even though the occupants may not feel the difference. This situation could go undetected for months. A smart building management system would detect this in real-time and send an alert to fix the problem.

Smart building management services can also be scaled up or down according to for how many facilities data analysis and reporting the owners and investors want, with fees that are generally priced based on the number of wireless sensors and data points tracked.

None of this removes the role of property or facility managers from the equation. The advantage of allowing machines to monitor machines 24 hours a day is that it releases building operators to address more pressing tasks. This is especially valuable where many small buildings are being maintained by only a handful of facility managers.

Summary

With buildings consuming 40% of energy, smart technology will contribute to much needed operational efficiency, leading to significant carbon reduction and a good return on investment due to enhanced occupant retention and value. Smart buildings that integrate renewable energy will also become the heart of the future grid as noted in the *Blueprint Chapter 6 – Interfacing with City Services and Utilities*. However, the integration with the cloud-based services and application continues to present security threats which can be addressed as described in Blueprint *Chapter 4 – Cybersecurity Considerations*.

V. Chapter 4: Cybersecurity Considerations

By

Colin Dunn and François Bégin

Overview of Cybersecurity Risks Associated with Smart Buildings

> *"The rise of the Internet of Things (IoT) and the declining costs of sensors and cloud computing are disrupting the building industry as more organizations retrofit or build out new smart buildings. There are numerous benefits of smart building technology ranging from occupant comfort and safety to improved efficiency and sustainability. However, the proliferation of smart building technology increases the risk of a cyberattack on vulnerable endpoints that need to be protected. In most cases security has not been built in when it comes to deploying smart building point solutions, thus expanding the risk exposure. Organizations must take a security-first approach to deploying smart building technology and migrate to a security fabric architecture to improve the organization's security posture". (IDC InfoBrief sponsored by Fortinet)*

The big push to adopt IoT and remote connectivity has resulted in many connected buildings with insecure remote access. Building automation systems can be a vector for cyber-attacks where potential attackers gain entry to corporate networks through HVAC systems, elevator operations, lighting, water supply, alarm systems, security devices, access systems, power supply and the list goes on. Criminals gained access to Target's corporate information systems through inappropriate credentialing to an HVAC contractor. Russia took down the Ukrainian power grid and has infiltrated much of the US energy infrastructure. Each system and device, including its multiple versions and iterations, has its own level of cybersecurity risk. The gradual elimination of human intervention in the IoT world implies a machine-to-machine (M2M) environment where all physical systems that can interconnect and intercommunicate through an IP network can be the entry point of, or victim to, a cyber breach.

In recent years, cyber security measures have often simply focused on protecting traditional information technology (IT) systems and providing tighter controls on information security in general—often aimed at safeguarding personal and corporate data. But with the rise of smart digitization technologies and the ability to extract value out of previously disconnected or "air-gapped" **operational** technology (OT) systems, these systems are now part of a world they weren't originally designed for. As such, the OT environment may be plagued by misconfiguration, vulnerable embedded hardware and software, poor cyber security practices, outdated network components, and lack of general cyber security awareness.

Many OT systems are experiencing cyberattacks similar to IT networks. IBM Managed Security Services (MSS) data shows a 110% increase in attacks on industrial control systems since 2016—a threat landscape predicted to grow at a phenomenal rate to 2020 and beyond. Kaspersky, a Russia-based Cybersecurity firm has issued an official warning that every 4 out of 10 automated buildings are vulnerable to cyber-attacks since the computer systems which are controlling them are affected by malware[47]. Frost Sullivan's Building Automation System table below, illustrates some of the more common vulnerabilities.

47 *Faro*, Nearly Four in Ten Smart Buildings Targeted by Malicious Attacks in H1 2019

BAS/BOS Infrastructure and Cybersecurity Threats

Cybersecurity Breach Incidents	Impact Areas	Cyber Defense Components	Preventative Aspects
• Systems failure • Nuisance tactics to life-threatening damage • Infection by viruses or malicious software • Theft or fraud by staff or attacks by unauthorized outsiders • Unintentional damage caused by authorized third-party service providers because of cybersecurity compromises affecting their own infrastructure	• Users • Remote access by operators/third parties • Physical access to connected devices, networks, and apps • Integration platforms • Communication gateways • Wireless access • Bring-your-own-device (BYOD) access	• Identity validation • Endpoint device security • Network security • Data security • Multi-layered security • Dynamic cybersecurity hub	• Access to a fire system (allowing the trigger of a false alarm to evacuate the building) • Access to a security system (allowing unauthorized access) • Access to communication networks • Access to utility-installed devices • Hijacking the BAS for blackmail (ransomware) to damage property or to destroy or steal sensitive data

Source: Frost & Sullivan

Figure V-1. BAS/BOS Infrastructure and Cybersecurity Threats [Source: Frost & Sullivan]

As stated by Larry O'Brien, VP of Research at ARC Advisory Group, *"there is a drive to deploy more lower cost sensors, both wired and wireless, to gather as much data as possible. At the same time, the industry has a considerable installed base of legacy building automation systems, applications, devices, and networks that must be managed, maintained, and gradually modernized."*

Review of Practical Options

> *Pervasiveness of technology, ubiquitous connectivity, and an increasingly evolving machine-to-machine (M2M) environment will continue to impact and influence how smart buildings are operated, which will raise the need for protection against cyber risks quite significantly. A delayed head start not only poses huge challenges in dealing with this complex issue but undermines the value and adequacy of initiatives that could potentially be used to ward off adversarial impacts. Irrespective of such shortfalls, however, inaction is no longer an option for the smart buildings industry. (Frost Sullivan – Cybersecurity in Smart Buildings)*

Since everything is, or will soon be "connected," what is good smart building cyber hygiene? Ongoing convergence of OT and IT systems in buildings has led to a review of the definition of physical systems within a smart building. In this regard, the National Science Foundation and NIST have attempted to classify the hybrid IT and OT systems as cyber physical systems (CPS). CPS are defined as integrated, hybrid networks of cyber and engineered physical elements; co-designed and co-engineered to create adaptive and predictive systems, and respond in real time to enhance performance. CPS is essentially coined to represent the transition and evolution in systems from industrial revolution/physical systems to the Internet revolution/cyber systems and, at present, evolving into industrial Internet revolution/cyber physical systems.

As is the case for personal and financial data, good OT / IoT cybersecurity practices start by implementing a rigorous risk mitigation strategy (identify, protect, detect, respond, recover). A key starting point is to avoid jumping into discussions of how to defend or what technologies to deploy. Decisionmakers should start with discussions of what citizen service is to be improved, and why connectivity might help advance that offering. When increased connectivity appears to be the answer, ask whether process improvement to an existing system might be more effective. At times, low-tech solutions like air-gaps and phone calls among maintenance staff may be appropriate. Other time, using the power of cloud-based predictive analytics can better inform city maintenance teams without handing control to the machines. However, some of these advancements through IoT and artificial intelligence are so compelling that the risks are worth the cost of mitigation. Cybersecurity solutions currently being offered to the smart buildings industry combine IT and physical security options, in addition to technology deployment approaches that attempt to detect anomalies and reduce vulnerabilities for IT and OT staff. In reviewing such technology options, it is important to begin by looking at a building's critical vulnerability areas that gain top consideration.

The scale of damages in a cyber-attack can inflate significantly when open systems and converged networks are overlaid with IoT. A key attribute is the inseparable relationship of device and data brought together through aggregation in the cloud that can be compromised in the event of a cyber breach. One approach is to aggregate and encrypt data locally at the building level and not push it out to the cloud. But if the goal of deploying IoT-based systems, and "digitalizing" legacy equipment is to reduce lifecycle costs, improved asset management can only be truly achieved in an edge to cloud environment, where regular streams of integrated data drive better, more timely decisions. So, the goal should not be to stovepipe OT-derived data, but to welcome integration of these edge-based systems, while ensuring that they can't be used as attack vectors.

Designing for the Future

As Larry O'Brien at the ARC Advisor Group puts it: *"Assets are increasingly connected, driving the need for secure remote building monitoring and management. Owner-operators must also get a better perspective of the kinds of potential vulnerabilities that exist among their installed base of cyber and control system assets. Data flows must be planned and monitored, possibly making it necessary to use one-way data diodes".*

Thus IT/OT convergence is both inevitable and desirable, as it extends asset life, reduces O&M costs, increases safety and security, and improves occupants' comfort. But as building automation systems become ubiquitous, and co mingle with enterprise-level systems, new processes and tools need to be adopted to embrace this new reality:

- Greater integration of IT and OT teams through joint management and training;
- Enterprise-wide understanding and assessment of critical assets;
- Cohesive and coordinated risk mitigation and response;
- Continuous management of <u>all</u> cyber-assets, vulnerabilities and threats regardless of source or vector;

- Secure building monitoring and management by "hardening" ICS, SCADA and building automation system protocols, through the combined use of hardware (data diodes[48], firewalls) and software solutions tailored to the vulnerability and criticality of asset classes.

The rise of the Internet of Things (IoT) and the declining costs of sensors and cloud computing are disrupting the building industry as more organizations retrofit or build out new smart buildings. Buildings can only be "smart" if they are safe, which increasingly implies cyber-safe. One simply needs to revisit the Target episode to understand how an attack on the HVAC monitoring system compromised credit card information of 40 million customers and other sensitive enterprise data. The number of vulnerabilities in internet-accessible ICS components across all manufacturers continues to grow while the number of devices proliferate. According to a 2018 Review of ICS Vulnerabilities by Positive Technologies, the number of vulnerabilities in the products of leading manufacturers grew by 30 percent compared to 2017. The share of critical and high-severity vulnerabilities increased by 17 percent. Furthermore, "*on average, vendors take a rather long time to fix vulnerabilities (more than six months) Elimination of some vulnerabilities—measured by time from vendor notification to release of a patch—can take more than two years. For end users, such protracted responses increase the risk of exploitation of device vulnerabilities.*

More than 220,000 ICS components are available online, which is 27 percent higher than in 2017. Most of them are automation system components. Such systems are mainly located in the U.S., Germany, China, France, Italy, and Canada, even though lawmakers have long been concerned about the security of such devices and systems. For example, the International Organization for Standardization (ISO) has recently published new guidance to reduce the risks of cyberattacks on machinery." [49]

Our buildings are also visited, both physically and virtually, by those who cross many network boundaries from home to restaurants to work. These occupants include not only tenants and guests, but the staff that operate our buildings. During a crisis, such as that presented by COVID-19, we have seen teams rapidly bring together tools and approaches to keep businesses moving and keep supplies flowing… at times bypassing pre-established protocols for expediency. Access to critical systems may be tightly controlled under normal conditions, but these work-arounds can involve home computers, personal cell phones, and public wi-fi. When planning for the future, be sure to account for the resilience of staff and their willingness to be productive.

Smart building technologies offer many benefits, but also create a broader attack surface and risk due to the increased numbers of devices and connected assets. Both physical and cyber security should be at the core of any investment in smart building technology. Cybersecurity considerations and planning should be an enterprise-wide, integrated effort, involving key stakeholders, that encompasses all classes of assets connected to the internet. ICS and more broadly IoT devices are not primarily designed to be cyber-secure. Thus, they need to be integrated with security-centric technology if they are to safely deliver the promised benefits. By integrating cybersecurity considerations early in the planning stage, our connected infrastructure can best serve occupants safely and efficiently.

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[48] *"Data Diodes Protect Critical Infrastructure", www.fend.tech/about-diodes*

[49] *Positive Technologies ICS Security: 2017 in review*

Next Steps…

Conducting a thorough assessment of ones' own property which includes the building systems, other operations focused systems and platforms, third party systems and applications, communications infrastructure may seem daunting, costly and time consuming. But, as detailed above, the cost of not doing so both for one's own operations and those of building occupants can be significant and sometimes immeasurable.

As a first next step, SBSC invites planning teams to review the *Cybersecurity and Privacy Risk Management Preparation Questionnaire & Handbook* (See Blueprint Appendix). Based on the NIST Cybersecurity Risk Management Framework, it outlines core issues of which companies need to be aware. The Handbook portion acts as a guideline for information gathering and assessment.

Municipal citizens are intimately tied to and increasingly digitally connected to the buildings in which they live work and play. It is incumbent upon the public and private organizations that manage the broader built environment to be vigilant and diligent in their active pursuit of cyber protection.

> *"Investing in smart buildings is good business, but investing in cybersmart buildings—that's great business. Without security, the truly transformative benefits of connectivity and automation are at risk. embracing cyber security means protecting your customers and your bottom line." (Sedar Labarre, Vice President, Booz Allen Hamilton)*

Additional Resources:

Building Cyber Security: www.buildingcybersecurity.org

Whole Building Design Guide: https://www.wbdg.org/resources/cybersecurity

Sources:

Faro, Cassandra. "Nearly Four in Ten Smart Buildings Targeted by Malicious Attacks in H1 2019." *Kaspersky Cyber Security Solutions for Home & Business*, 20 Sept. 2019, usa.kaspersky.com/about/press-releases/2019_smart-buildings-threat-landscape.

Positive Technologies. "ICS Security: 2017 in Review." *ICS Security: Vulnerabilities and Trends 2017*,

Positive Technologies, 1 Feb. 2018, www.ptsecurity.com/ww-en/analytics/ics-security-2017/.

VI. Chapter 6: Interfacing with City Services and Utilities

By

John Coluccio, Heather Ipsen

and Manfred Zapka

Introduction

As noted in the *Introduction* of this blueprint, smart buildings and the technology they house are the fibers that weave the cloth of a "Smart City". Individual technologies placed in individual buildings are certainly beneficial in many ways as is detailed in *Chapter 2 – Organizational and Individual Productivity and Wellness*, but they must be woven together at a larger scale to create a truly "Smart" city. A critical consideration that is often overlooked when aiming to create this "open mesh network" of connectivity, is the relationship that governments and property owners have with utility companies. Understanding the resources that are needed to create a Smart City, the resources that are available to do so, and the monetary and environmental costs associated with these resources is the driving force of fostering such a relationship. In short, it is simply difficult for a city or utility company alone to build an entire Smart City; however, together they capitalize on their respective areas of expertise to weed out the less beneficial smart technology solutions and discover those that best suit the needs of their citizens.

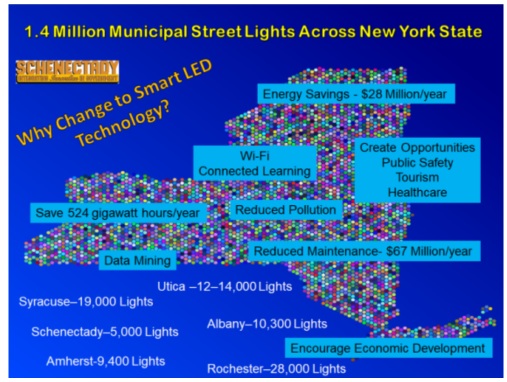
This chapter of the GCTC Smart Building Super Cluster Blueprint will discuss some of the opportunities relative to city services where utility companies, local governments, and property owners can – and in some cases, already do – partner to improve operational efficiency, save money, and conserve resources. The first section will outline recommended areas of focus for city services, and the second section will outline recommended areas of focus for utilities. The third section discusses the National Grid/ City of Schenectady REV Demonstration Project as a case study of the possibilities of partnership between a city and a local utility company. The final section provides a brief review of the chapter.

City Services

A city provides its residents with a multitude of necessary services every day. A Smart City enhances and improves upon the efficiency and delivery of those services by embracing the numerous advancements that have been made in Smart Technology over the past few years. Outlined below are a few key recommended areas of focus for cities looking to capitalize on the opportunity to adopt a new, smarter mode of operation.

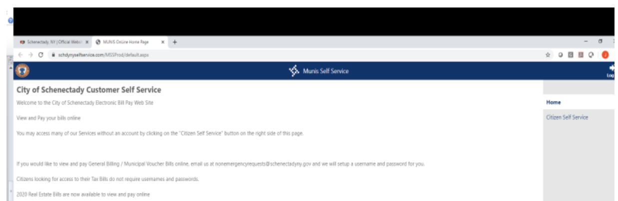
Smart City Services

Lighting



Smart LED lighting is being used by many municipalities today not only to reduce costs and monitor energy usage, but also to improve the overall maintenance of their lighting infrastructure. Why stop there? These lighting controls should be installed at municipal facilities for the same reasons. LEDs have a lifespan anywhere from 10 to 15 years and typically do not require maintenance for many years after installation. For additional savings, ballasts that are dimmable should be used in the installation. With Smart lighting controls, dimmable LEDs can be controlled by an application, enabling the output to be adjusted based on certain schedules and or activity.

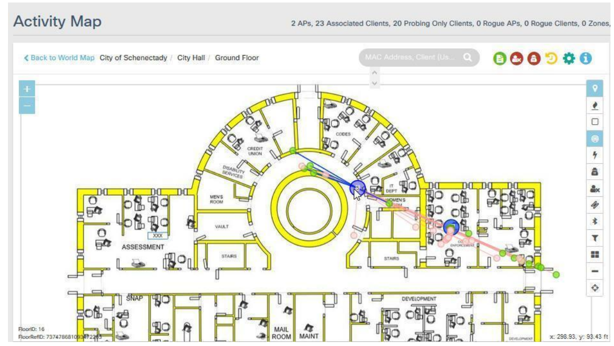
Payment kiosks / Online Payments



Kiosks are located in many different places today. They can provide information about a location, give directions, charge cell phones, and in Smart Communities, they can provide a way for residents to pay municipal bills. A payment kiosk in a municipal building can therefore eliminate the need for an extra cashier or clerk in an office. There are applications for users to pay tax bills, water bills, building permits, and other bills. Kiosks should thus be strongly considered alongside online bill viewing and payment.

Location analytics

Wireless devices know where their users are at almost all times. This provides technicians with the ability to evaluate the use of anonymous live location data for a number of positive outcomes. The best placement of Wi-Fi access points in and outside of buildings can be determined in this way. Building owners can look at not only coverage holes, but also areas where additional devices are needed to make sure there is enough bandwidth for users in their network. This technology can further assist during times of evacuations or shelter in place periods. It can help confirm the location of employees (or students in the case of schools) to relocate them to safety faster than with traditional location methods. Of course, keeping constituents informed on what information that is being collected needs to be a priority in any



deployment using this technology. Data privacy is an important issue that must be addressed in any Smart City.

Electric Vehicle Charging Stations

Electric vehicles (EVs) are a smart investment for a city's residents, employees, and municipal fleets. They have numerous positive impacts for the environment and can lead to significant financial savings. Making a municipality EV-friendly, however, requires that infrastructure is incorporated into government facilities, as well as into the public street network. In the City of Schenectady, there are currently 18 charging stations and 8 City owned electric vehicles, with 10 more stations currently in design. The City's goal is to continue to add additional electric vehicles and stations on a yearly basis.

Electric Vehicles (EVs) have lowered the City's carbon footprint significantly since 2017. In 2019, the City saved over 13,260 kg of CO2 from entering the atmosphere – the equivalent of 33,000 miles driven in an average passenger vehicle. The City's charging stations are well-utilized by the public and City employees: the peak number of charging sessions was 445 in July and August 2019, and the average number of sessions for all of 2019 was 336. Currently there is no charge for public electric charging, so the cost of electricity dispensed averages about $150 per month for the City's fleet and public use combined.

Smart City Communication Platforms for City Services

Public Wi-Fi

The ability to connect to the internet on a moment's notice is a privilege many people take for granted. For some, the internet is only available in areas that have public Wi-Fi. Communities need to determine how to provide smart city services, such as internet access, to low-to-moderate income residents. Public Wi-Fi can help facilitate community engagement, more efficiently deploy social services, and enable internet-based medical applications to those that do not readily have access to the internet. A community's open public Wi-Fi can also potentially provide "connected learning" for students. A Pew Research Center survey from October of 2018 indicated that nearly one in five teens cannot finish their homework due to the lack of internet access.[50] In rural areas this number is strikingly higher. Having internet access is necessary to help engage lower income students and households, potentially driving positive results in the classroom. This issue is highly important considering the recent global pandemic – which greatly increased the need for internet access for all – and should thus be considered in any smart city deployment.

The use of Public Wi-Fi should not, however, be performed in a vacuum, rather it should be rolled out using a well-developed, holistic plan. This plan should use new and old infrastructure to connect disparate systems, thus obtaining more value from the high cost of installation and maintenance. Municipalities need a plan to connect building facilities and systems, street cameras, and environmental and other analytic sensors to their networks in a safe and secure manner. These networks can be used to transmit data that is housed in on-site smart buildings equipped with IoT sensors and platforms to employees out in the field, or to the public if necessary. The system can also be used to send police body camera and in-car videos to smart buildings and analysts. Police officers could monitor live video feeds from their patrol cars as well, which can provide them with crucial information before they arrive on the scene of an emergency. This solution empowers first responders to make informed decisions with proper data along with giving them instant access to information for Smart City growth. With this technology in place to automate processes for local police department officers, they can collaborate more effectively to reduce their time spent on manual labor and patrolling to keep citizens safer.

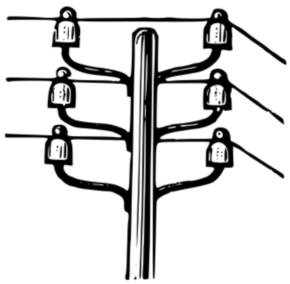
The GCTC Public Wi-Fi Supercluster [link] has created a "how-to" guide for deploying a Public Wi-Fi system within municipalities and should be used as a tool to assist in evaluating a potential deployment[51].

Fifth Generation Cellular Wireless (5G)

5G has begun to launch in a number of markets throughout the country. It brings with it increased wireless speeds up to potentially 10Gbps along with reduced latency allowing improved responsiveness. 5G operates on three different bands: low band (< 1 GHz), mid band (1 to 6 GHz), and high band (24 to 53 GHz). The high band version of 5G is a small cell, dense network that requires the installation of many more transmitters than the current technology (and by one estimate, 400 times as many as 4G), along with many miles of fiber optic cable. As a result, cellular carriers have feverishly contacted municipalities to discuss the ability to use a city's infrastructure to install their cell equipment. A municipality's landscape of street lighting, utility poles and traffic signal poles make them a prime target for co-locating 5G (and in

[50] https://www.pewresearch.org/fact-tank/2018/10/26/nearly-one-in-five-teens-cant-always-finish-their-homework-because-of-the-digital-divide/

[51] https://pages.nist.gov/GCTC/uploads/blueprints/20170823-GCTC-PWSC-Public-WIFI-Blueprint-FINAL-v2.pdf



many cases 4G) equipment. The low and mid bands of 5G, however, can operate from existing cell towers. That said, they have the less speed than high band. So, within a rollout of 5G, it is best to have low, mid, and high bands in operation.

Municipalities should be ready to discuss the placement of 5G in their communities, as it brings many opportunities for economic development, shared service potential, and revenue potential. Of course there are aesthetic and local zoning concerns that would come along with the technology's deployment. Several cities, including Smart Cities such as Columbus, Ohio, have already acquired limited 5G coverage in select areas of their community. These 5G access points promise to provide visitors and residents with high speed internet connection in crucial locations, such as schools and airports, in coming years[52].

The GCTC Wireless Supercluster [Link] is actively working on a document that will provide much needed additional information to help decipher this transformational technology and has already published a paper entitled, "The Municipal Internet of Things (Iot) Blueprint." This paper outlines some potential use cases for evaluation.[53]

Digital Signage

Government facilities that utilize digital signage in common areas are able to create a superior experience for their visitors. It is also possible to personalize content for visitors. For instance, if a new visitor were to swipe a badge or card when entering a building, or scan a QR code, the sign could be programmed to display information that is specifically helpful to that person (e.g. displayed in a particular language, or suggestions on where to go). Digital signage can provide directions to specific offices or meeting rooms or provide information on upcoming events, and they often help to form the first impression for a visitor entering a building. These displays can be tethered together and controlled by a wired or wireless connection, eliminating the need for staff to create and/or change static signs throughout a building or campus. Installing these displays at entrances or in gathering areas provides an opportunity to have a captive audience, and will improve a visitor's initial experience with local government. Digital displays can incorporate civic calendars, digital media, and also

[52] https://www.verizon.com/5g/coverage-map/?AID=11365093&SID=78494X1529245X01e809c75647f21139d83e3728341d04&vendorid=CJM&PUBID=100035010&cjevent=f2b7bc9da1d911ea804e02590a240610
[53] *https://pages.nist.gov/GCTC/uploads/blueprints/2019-Municipal-IoT-Blueprint-GCTC-WSC-FINAL-Jul-2019.pdf*

be used in emergencies to notify employees and visitors of specific facility or community concerns.

Video Conference Equipment

Similar to digital signage, video conferencing equipment should be considered in any municipality or campus with multiple on- and off-site buildings. Connections made between these buildings provide ample opportunities to save money and enhance staff efficiency and well-being. For example, the City of Schenectady use this system to virtually connect four Fire Stations together to perform daily training. This virtual connection alone saves thousands of dollars per year on fuel costs. Before having this system in place, fire department vehicles and personnel would have to regularly drive to our main station in order to have classroom training sessions. Now they are connected virtually, with the same level of interactivity made possible by two-way video and audio. Not only is the City saving on fuel costs, but we are also able to maintain the apparatuses in their own running districts during the required fire and EMS training in case of emergency. Future applications may include incorporation of virtual reality (VR) and augmented reality (AR) technologies to enhance user experience and broaden education opportunities.

Smart Street Lighting Technology

Streetlight infrastructure is the perfect platform to deploy smart city technologies and services using connected devices and a low bandwidth wireless network. This approach is aligned with the utility industry as a whole. Changing inefficient HID lighting with LED streetlights is a good place to start, but what if a streetlight was capable of more than simply lighting a street? Municipalities across the country are looking toward streetlight assets to lower civic costs, increase efficiencies, drive economic growth, engage citizens, and improve city life. Partnership with a local utility company is critical to taking this step toward becoming a smarter city.

Utilities

It is not just cities that are embracing Smart Technology to improve the services they provide; utility companies across the globe are also taking advantage of innovative technology solutions to provide better uninterrupted electrical supply networks. They are enhancing resiliency with new generation of distributed energy resources – energy storage, microCHP, and even Non-Wire Induction Alternatives. This section will highlight recommended areas of focus for utility companies that want to aid municipalities in becoming smarter.

Grids

The way energy is generated and distributed has significant impacts on how cities and municipalities can operate, as well as the costs associated with their operation. With recent developments in grid technology, there are increasingly more ways in which utility companies and municipalities can improve a community's ability to receive power and increase energy savings.

Demand Response

Electric utility companies can implement demand response programs where consumers are able to reduce or shift electrical usage during peak periods. There are time-based rates and even financial incentives that may reduce costs for building owners. Advanced smart meters can easily be installed and monitored along with facility generation equipment to reduce or eliminate the potential for downtime.

Microgrid – Public, Private

In cities across the country, various groups are undertaking Community Microgrid projects. A Community Microgrid uses localized distributed energy resources (DER), such as renewable energy, to power a local grid area of up to several thousand consumers. Microgrids are of interest to many communities because they can provide critical facilities with electrical power during widespread outages, brown outs, black outs, or substation failures. Additionally, Community Microgrids can participate in demand response events to assist utility companies with maintaining service levels. There are, however, challenges associated with Microgrids because there is potential for back-feeding into a spot network (with no direct ties to the street grid). Uncertainty in supply and the ability to store excess energy, especially in relation to weather unpredictability, can also pose a challenge to the efficacy of Community Microgrid operations.

Smart Grids

The term "Smart Grid" refers to the capability of bidirectional information flow between the utility company infrastructure and the end user equipment. Smart Grids allow utility companies to better manage their systems, to prepare for peak energy events, more quickly identify outage information, and help customers adjust their energy usage. Many advanced, effective metering and monitoring technologies are now available for use by building operators and/or utility companies.

Communication networks monitoring substation operations have made it possible to continually (and remotely) monitor critical infrastructure, and now utility companies can provide alerts in a fraction of the time as they have been able to in the past. GPS combines network monitoring information with asset location information to pinpoint deficiencies in these systems and direct operations in real time. But these operations are not limited to utility companies. Critical infrastructure within municipal buildings and campuses can be monitored in the same way. Building generation, backup fuel supply, Uninterruptible Power Supply (UPS), and heating, ventilation and air conditioning (HVAC) operations are all standard devices that can and should be monitored to improve efficiencies, help reduce energy costs, and lower overall operation downtime. Two technological solutions of note are Advanced Metering Infrastructure (AMI) and Automatic Meter Reading (AMR).

Advanced Metering Infrastructure (AMI) technology exists in millions of smart meters across the United States. These meters provide both utility companies and customers energy usage data that they can tie into their energy management systems and use to assist with budgeting. Building operators can shift their high energy usage operations to off-peak hours, and in many cases take advantage of off-peak pricing to reduce costs.

Automatic Meter Reading (AMR) technology allows meters to be read with up to 100% accuracy without customer intervention. Rather than having utility companies enter a home or business to read meters, the job can now be completed remotely via wireless networks deployed throughout communities. AMI is also being leveraged for behavioral programs that engage customers and personalize their energy utilization. Coupled with today's "smart" speaker devices, AMI is opening up a new way for customers to control and automate their homes with connected lighting and occupancy-based controls.

Solar and Wind Renewable Energy Systems

Solar and wind energy systems provide minimal impact on the environment and should be certainly be considered when looking to offset or reduce electric loads. However, these systems need to be monitored to ensure operations that return investments for their owners. Net Metering and Remote Net Metering results should be reviewed in order to understand the benefits of a renewable energy system. There are companies in the market that can provide guidance in this area. Live data can be sent to cloud-based systems where vendors can review it and provide recommendations to help reduce operating and utility costs. In New York State, The New York State Energy Research and Development Authority provides funding to offset a portion of these costs.

Transactive Grid

Transactive Grid is considered by some to be the future of grid operations. Transactive energy is defined by the National Institute of Standards and Technology (NIST) as "a system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter." Utilities are developing Distributed Energy Platforms (DSP) that provide location-based grid services compensation for distributed energy resources and dynamic demand management. This platform utilizes "blockchain technology"[54] to manage transactions on the sale and purchase of energy resources.

Smart Grid technology may also facilitate individualized control of energy use and distribution through transactive energy. Transactive energy would allow customers to market energy they generate to other customers on the distribution system. This would reduce power and optimize consumption and service level impacts by allowing for automatic and more rapid adjustment of building services (e.g. cooling, heating, lighting, etc.). Transactive energy would thus provide support for DER systems and buildings with active control technologies, even those connected to a microgrid. That said, significant challenges arise with greater interoperability. Because transactive energy creates an environment that fosters distributed, decentralized energy nodes that are controlled by a vast number of people on the demand side, a significantly more complex network of controls is created. Regulating and maintaining such a complex network could prove to be a difficult task.

Regardless of the challenges involved, the Pacific Northwest Smart Grid Demonstration Project provides a great example of the possible benefits smart grids and transactive energy can provide in practice. The project deployed 55 different technologies in various communities across the Pacific Northwest, testing solutions including smart meters, battery storage, voltage controls, and transactive controls. In one study area, a utility company used transactive signals representing the current and near-future availability and predicted price of power. They updated and sent the transactive signals out every five minutes. The project's smart grid technologies were designed so that when transactive signals predicted peak power demand and high costs, power use would decline. When the project team ran models simulating extreme events, such as a surge in wind energy and a nuclear power plant outage, the transactive controls worked accordingly. Their study shows that transactive energy not only provides viable electricity supply solutions during critical times and can lower energy costs, but it also empowers end users by giving them an active role in their power usage[55].

Demand Dispatch and Smart Grids

In today's traditional "supply dispatch" model, load and generation are balanced by equating load to consumer demand and by dispatching power produced at central energy generating plants to satisfy that demand. The "demand dispatch" model builds upon the supply dispatch approach by adding on the support of "behind the meter" resources. Creating energy through onsite (renewable) generation is therefore important, but equally important is providing an electricity supply that saves on expanding new centralized power generation (plants). Moreover, because renewable energy input can make power supply less predictable, it is increasingly

[54] https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8202.pdf
[55] https://www.pnnl.gov/news/release.aspx?id=4210

important to find a way to rapidly balance power in the grid. Demand dispatch makes this possible by allowing for direct control of customer loads. Demand dispatch considers what load adjustments can be made before generation, as well as whether those load adjustments improve grid optimization and are consistently dispatched as needed. Demand Dispatch can therefore help enhance reliability, peak load management, and energy efficiency, lowering the price of electricity[56].

The demand dispatch approach to electricity supply requires smart grids and smart buildings to optimize grid operations. Smart devices installed in buildings that directly interface with occupants and their demand for energy services are thus highly important. The relevant technologies in buildings, which enable demand dispatch, will be more obvious to occupants since they will change, to a certain extent, the perception of what to expect with an uninterrupted supply of electricity available at any moment.

As such, demand dispatch will require some form of behavioral adjustment by the consumers of electricity, as expectations are shifted from supply dispatch to demand dispatch. For example, under the present supply dispatch approach, if a customer wants to start high power demand appliances inside their home, such as a clothes dryer, it is expected that the machine will start as soon as they press the “on” button. Under the demand dispatch approach, however, if a customer pushes the “on” button nothing would happen if there is no power capacity available to power their machine. Instead of the dryer starting immediately, their request for power would be put into an online demand queue. Then when the power can be allocated to them, the dryer would start.

Interconnected power consuming equipment in our homes will have to play a significant role in supporting the transition to a demand dispatch model. Buildings that utilize smart technology will be integral in this process as well.

Energy Storage systems

Utilities, municipalities, and operators of smart buildings need to consider the best (and smartest) way to provide energy to citizens. Renewable energy is a crucial consideration in providing energy services to power buildings and their smart technologies. Batteries and thermal energy solutions can help offset the limitations of renewable energy sources. They should be considered in critical facilities where the potential exists for brownouts or blackouts because they can assure constant voltage to mission-critical devices.

[56] https://netl.doe.gov/sites/default/files/Smartgrid/DemandDispatch_08112011.pdf

Building as a Battery

Batteries have been used in communication networks for years. Technology today affords opportunities for incorporation into even the average facility that require continuous uninterrupted service. They can be installed in buildings to maintain lighting, data centers and/or other critical systems. The demand for more efficient batteries for electric vehicles is improving the storage capabilities of batteries, as well as reducing their size. These systems can also be integrated with renewable energy sources, such as solar power, to provide constant electricity during peak load periods.

Thermal Energy Storage

An Integrated Thermal Energy Storage System (ITESS) using chilled water can provide additional sub-cooling for an air conditioning system's condenser, thereby increasing the capacity of the entire system and providing significant reductions in electric demand and consumption. ITESS uses a dedicated chiller to cool a thermal storage tank, typically at night when electricity demand and rates are lower. This thermal reservoir is used the following day to sub-cool refrigerant leaving the condenser. This additional cooling increases the cooling capacity and decreases electrical demand during hot days for an existing or new vapor compression system.[57]

Weather Related Conditions

Wind, Rain and Snow

No electric utility company is totally immune from weather related issues. Wind, rain, snow and ice events can wreak havoc on networks. Part of many Smart City deployments include obtaining detailed information of weather events, down to street level, with specialized environmental sensors. Sharing this information in real time with utility companies can give advance notice of weather events, and the data can be used as a tool to understand historical events to better plan in the future.

Flood Events

Many local governments deal with flooding of streets on a routine basis. Having up to the minute information on conditions can help reduce the costs associated with flooding events. Smart City technology provides opportunities for sensors to be placed in a community where flooding is historically common, particularly for those areas within the 100-year floodplain. Notifications from these sensors can be routed to the appropriate staff before an emergency occurs. Streets can be closed earlier to prevent property loss and remediation can start quicker. Understanding the timing of these events from a historical perspective can also help us to plan better and even eliminate future issues.

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[57] *https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Other-Technical-Reports/17-17-Integrated-Thermal-Energy-Storage-for-Cooling-Applications.pdf*

Water Conservation

Managing natural water resources is an important commitment of any community. Smart sensors can monitor homes for leaks and are even used in some communities to help monitor vacant homes. These sensors can communicate in a variety of ways, including cell service, 6lowpan, Wi-Fi, ZigBee, and LoRa. Smart sensors that detect leaks should be considered in any Smart City deployment, as they can prevent dangerous situations from arising in both residential and commercial areas.

Other smart devices are also available to monitor the amounts and times property is watered. These devices can help eliminate waste, particularly in areas where water is used on large scales, such as golf courses.

Onsite Wastewater Treatment and Recycling

The supply of ample and healthy water is becoming a key resource management challenge in municipalities across the world. Water, however, is not always regarded as the valuable resource it is, and there is too much waste. Smart buildings have the potential to change this view.

In smart buildings, water can be used more than once as recycled water for certain applications, such as irrigation, toilet flushing and other grey water applications. By recycling water, valuable potable water drawn from exhausted aquifers and other sources can be reserved for immediate consumption by building occupants.

Storm water (e.g. rainwater) can be harvested for grey water applications as well. In fact, water use trends suggest that rainwater is increasingly being used as a substitute for potable water where it is deemed safe.

Wastewater recycling is a relatively new practice, but it has great potential, since the availability of recycled wastewater does not depend on intermittent rainfall. Oftentimes, during a drought the demand for irrigation is the highest and the availability of scarce rainfall is at its lowest. Availability of recycled wastewater, on the other hand, is more predictable since the amount of wastewater is directly linked to the use of potable water.

There are new technologies that treat wastewater onsite (e.g. at the building level) rather than in centralized treatment plants. Stepping away from the old centralized model of treating and managing wastewater not only saves precious water resources, but also saves communities significant amounts of money and reduces overall energy usage.

Economic and Financial Considerations and Opportunities

Energy Monitoring

Smart Building technologies create opportunities in utility monitoring on a more granular basis to help conserve natural resources. The use of Real Time Energy Management (RTEM) and Fault Detection and Diagnostics (FDD) is emerging into mainstream solutions to assist with tracking and addressing operational opportunities. Connected lighting and occupant-based controls, for example, are becoming affordable off the shelf technologies.

Fire and Intrusion Detection

Communication systems used by utility companies and local governments can monitor and detect fires and intrusions, not just in commercial buildings, but also in vacant houses. Fires in vacant homes cost communities hundreds of thousands of dollars annually. Low powered battery and solar devices are now on the market and can be placed in targeted locations, even those that do not have electrical power, to help reduce the risk of fire and break-ins. These devices can allow for remote monitoring of vacant residential and commercial properties, potentially saving communities significant amounts of money and reducing urban blight in the long run.

New Form of HVAC

The demand for HVAC is ever growing as people move towards urban centers, global temperatures go up, and the world population becomes more affluent. But the increasing need to provide mechanized cooling bears significant challenges, since basic cooling technologies (e.g. vapor compression cooling) have not changed significantly and cannot solve the problems of energy efficient and healthy indoor temperature control. The photo below dramatizes the trend of increasing demand for cooling, while the use and further development of energy efficient HVAC technologies and their applications in buildings cannot keep up.

The inevitable trend of increased HVAC capacities will level an enormous demand for electrical power. This will present challenges for power grids that are not sized for high additional demand.

Source:

https://www.green-cooling-initiative.org

The green cooling initiative provides data on the expected growth in cooling and refrigeration. Their forecast predicts energy demand will increase by as much as 100% in certain countries under the business as usual (BAU) assumption.

New approaches to reduce electric demand for AC and lower carbon output are necessary. There are new technologies that could drastically improve energy efficiency, while also increasing occupant comfort and health. The process of separation of sensible and latent loads is a key technology approach, where cooling and removal of excess humidity is achieved by two different HVAC processes and equipment. However, these new technologies are replacing deep-rooted processes of old technology (i.e. conventional HVAC), which could pose challenges to their initial adoption.

Gas Detection

Utility companies are evaluating the LoRa or NB-IoT networks that they are using for advanced metering infrastructure (AMI) for methane gas leak monitoring. Real time monitoring for leaks provides the opportunity not only to improve air quality and operational efficiency, but also to recapture resources and help mitigate global climate change.

Public/Private Partnerships – Performance Contracting

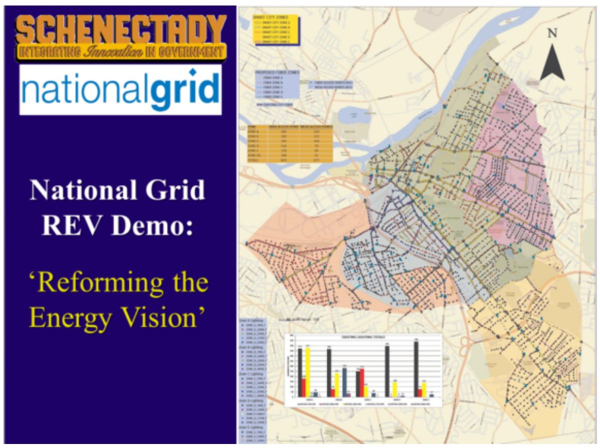
Opportunities exist for both public and private enterprises to become more efficient in energy usage without incurring upfront capital costs. Many national companies use a “Performance Contracting model,” where they evaluate facilities for potential improvements and contract with building owners for installation of new state of the art equipment. The energy savings can be used to pay for the upgrades over time.

Opportunities to reduce costs and incentivize reduced energy usage

Technology is available that allows AMI to be placed inline or within individual devices to meter their electrical usage. Not only could this evaluate the efficiency of a refrigerator, for example, but it also could be used to charge that refrigerator at a different cost rate than a 65” flat screen television, or another connected device.

National Grid / City of Schenectady REV Demonstration Project

The National Grid / City of Schenectady REV Demonstration Project is a current example of the vast array of opportunities presented by forming a partnership between a city and a utility company. The City of Schenectady has partnered with local utility company, National Grid, on a "Reforming the Energy Vision" (REV) Demonstration project to not only become a Smart City for the benefit of local residents, but also in hopes of providing a replicable business model for other cities and utility companies across the country. This project includes replacing 4200 lights with much more efficient technology, while adding a number of smart technologies tailored to the needs of the city's citizens, employees, and visitors.



Many communities like the City of Schenectady are looking for opportunities to save energy and become more efficient in the services they supply to residents and businesses. Converting HID lighting to Wi-Fi and/or other communication enabled LED Smart Lighting will produce savings, improve maintenance, enhance public safety and public works, empower employees, and conserve natural resources. This technology also fosters innovation in government and the community. While one of the main objectives of this project is to reduce energy consumption, emerging technology allows the City and their partners to use this project as a platform for real change. Data will be collected and disseminated to users via Smart City platforms housed in city buildings, which will allow staff to make educated decisions in countless areas. A city-wide network will enable us to more fully integrate our facilities into the same network. Monitoring building operations as well as vacant properties will help reduce maintenance costs.

Integrated utility-grade smart meters will be capable of automatically submitting usage without human intervention and will help reduce incorrect billing by keeping accurate inventories. The "chips" inside these meters are as accurate, if not more accurate, than the meters used by the utility company and located in our homes and businesses.

Current New York State Public Service Commission Tariffs (PSC 214) that govern the costs of Municipal Street lights in New York State do not provide for the opportunity to use or even test them, and as a result the project is currently limited to flat rate calculations, which nullify any savings. Reviewing wireless metering capabilities will be a key part of the REV process.

By the City's own calculations, the yearly energy savings with a switch to Smart LED is estimated to be over 2 million kilowatt-hours of electricity. Greenhouse gas calculators from the EPA show this as a reduction of 1,546 tons of carbon dioxide, equivalent to over 3.3 million miles of passenger car travel saved every year when the entire project is completed. Since dimming is a built-in capability of Smart Lighting networks, the potential exists to reduce usage during peak electric use times in order to help prevent brownouts and help balance loads across the grid.

A Smart City deployment is extremely important for the future of municipalities like the City of Schenectady, as it will help show the role a local government can play in improving and enhancing citizens' increasingly digital lives. Learning more about how smart building technologies in everyday operations is a critical step in developing and maintaining any Smart City operation.

Recommendations and Conclusion

This section is meant to be a guide to any city and/or utility company looking to improve the way they operate and deliver services to citizens. There are a daunting number of technologies that can be adopted in a Smart City project, and it can be difficult to decide where to invest time, money, and efforts. The recommended areas of focus, as detailed above, are:

City	Utility
Smart City Services • Lighting • Payment Kiosks / Online Payments • Location Analytics • Electric Vehicle Charging Stations	Grids • Demand Response • Microgrids – Public, Private, PPP • Smart Grids • Solar and Wind Renewable Energy Systems • Transactive Grids • Demand Dispatch and Smart Grids
Smart City Communication Platform • Public Wi-Fi • 5G • Digital Signage • Video Conference Equipment	Energy Storage • Building as a Battery • Thermal Energy Storage
Smart Street Lighting Technology	Weather Related Conditions • Wind, Rain and Snow • Flood Events • Water Conservation

	• Onsite Wastewater Treatment and Recycling
	Business Models • Energy monitoring • Fire and Intrusion Detection • New Form of HVAC • Gas Detection • Public/Private partnerships – Performance Contracting • Opportunities to reduce costs and incentivize reduced energy usage

As the National Grid/ City of Schenectady REV Demonstration Project case study shows, by working together to harness the power of the wide variety of smart technology available on the market today, cities and utility companies can lead the way in creating smart communities worldwide. Even if it takes building just one Smart Building at a time, there is plenty to gain from investing in smart technologies that cater to the needs of citizens.

VII. Chapter 7: Mobility

By

[Yuri O. Gawdiak]

Contributing Editor: [Jiri Skopek]

Introduction

Mobility has been a constantly evolving critical feature of human civilization. Major changes and advances in mobility have been linked to the advent of new power sources (animals, wind, steam, fossil fuels, super dense batteries, etc.).

We are now in another major acceleration phase of new transportation capabilities enabled by increasingly dense, and powerful, electric based propulsion systems as well as advances in: communication, navigation, and command & control. In addition, increasingly intelligent systems are being developed and integrated creating an emerging capability of autonomous operations. National Aeronautics and Space Administration's (NASA) Urban Air Mobility concept is an example that has been enabled by these new technology capabilities. [Figure VII-1]

Figure VII-1. NASA's Urban Air Mobility Concept

Smart Buildings will both leverage this new evolution in mobility as well as enable and enhance it by acting as key departure and destination nodes with advanced capabilities and structures.

New Mobility Modes and Operations

New mobility modes are being driven by two relatively new vectors: increased battery power and density and autonomous systems.

Electric Systems

Increased battery power is leading to a whole new range mobility systems that are radically resizing mobility capabilities to better fit actual passenger and cargo demand. These systems can include a range of vehicles from bikes, to scooters, to mopeds, and other unique and custom designed delivery systems [Figure VII-2]. This new capability is being enhanced by networked intelligent services enabling on demand capabilities: providing the right vehicle, at the right time, at the right place. This capability begins to obviate the high cost of flexibility evident in today's automotive concepts where passenger cars[58] are designed for an average of 4-5 passengers, but are mostly occupied by 1.67 individuals[59].

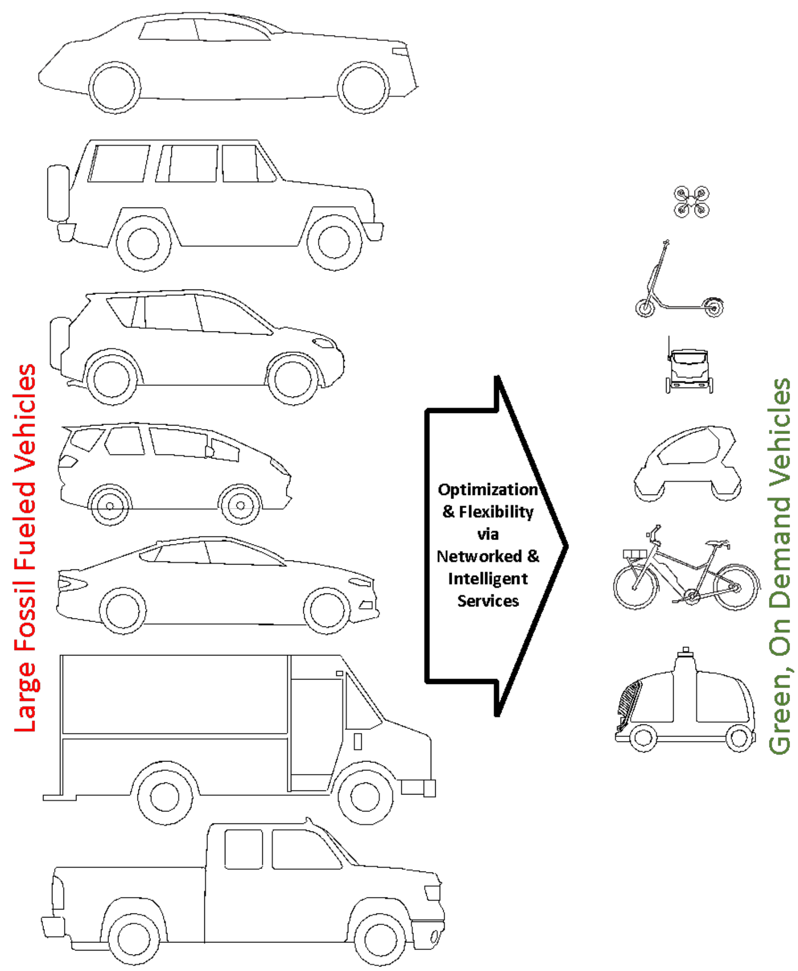


Figure VII-2. Transition to On Demand, Green, Load Optimized, Intelligent, Mobile Systems [Source: By Author]

[58] Crossover utility vehicles have become the most popular light-duty vehicle type. Their increased robustness and flexibility comes at the cost of decreased fuel efficiency over regular passenger vehicles. https://www.eia.gov/todayinenergy/detail.php?id=36674

[59] 2017 National Household Travel Survey by the Federal Highway Administration (FHWA)

The on demand services are further enhanced by support from smart buildings with local green power generation as well adaptable and reconfigurable spaces that can support and compliment these new mobility services at key demand locations by not only providing recharging/refueling capabilities, but also safe and efficient storage and docking of the systems when not in use.

Augmenting Smart Buildings with shared, local neighborhood mobility systems can also allow deliveries to be done more efficiently. Instead of large delivery vehicles having to visit each building and block traffic, large delivery vehicles can pause at the periphery of walkable neighborhoods and zones and have shared intelligent autonomous neighborhood UAS's and UGV's meet them there and make the final deliveries, freeing up the large delivery vehicles from having to wait for the UAS's & UGV's to return. That improves the delivery speeds, reduces congestion, noise, and emissions.

These trends are emerging from various socioeconomic drivers. The COVID-19 Pandemic response in Seattle in May 2020 is an example of one such community adaptation: "Seattle to permanently close 20 miles of streets to traffic so residents can exercise and bike on them."[60] This society's desire to make walkable communities naturally comes with collateral benefits such as: reductions in noise, energy usage, and decreased vehicle size and weights improving safety. Another example is a 2020 campaign platform for the mayor of Paris, "Every Street in Paris to be Cycle-Friendly by 2024, Promises Mayor – Should she get reelected as Mayor of Paris, Anne Hidalgo plans to turn the French capital into a myriad of neighborhoods where 'you can find everything you need within 15 minutes from home'.[61]"

These socioeconomic trends point to the need for smart buildings and cities to revise their architectural concepts to include more sophisticated and modern interfaces, docking, staging, and access methods for small drones, unmanned ground/air vehicles, and personal vehicle rentals, to provide local, on demand shared & public passenger/cargo capabilities. The successful implementation of more integral structural & services accommodations for smart buildings will help prevent scooters, bikes, and other systems from being carelessly left out in the streets, clogging operations, and getting prematurely damaged, but rather enable more safe & efficient building/neighborhood quality of life improvements by providing equitable and reconfigurable access and enhanced synergies for the new mobility operations & business models.

Autonomous Systems

The more fundamental change to mobility is the planning and development of increasingly autonomous, unmanned systems. [Figure VII-3] These systems are being built for an increasing number of environments, not only externally (air, marine, and surface), but also with within structures (confined spaces around buildings as well as within them such as corridors, pipes, ducts, and conduits of various kinds).

[60] https://www.cnn.com/travel/article/seattle-streets-closed-stay-healthy-trnd/index.html

[61] https://www.forbes.com/sites/carltonreid/2020/01/21/phasing-out-cars-key-to-paris-mayors-plans-for-15-minute-city/#cb77c4269521

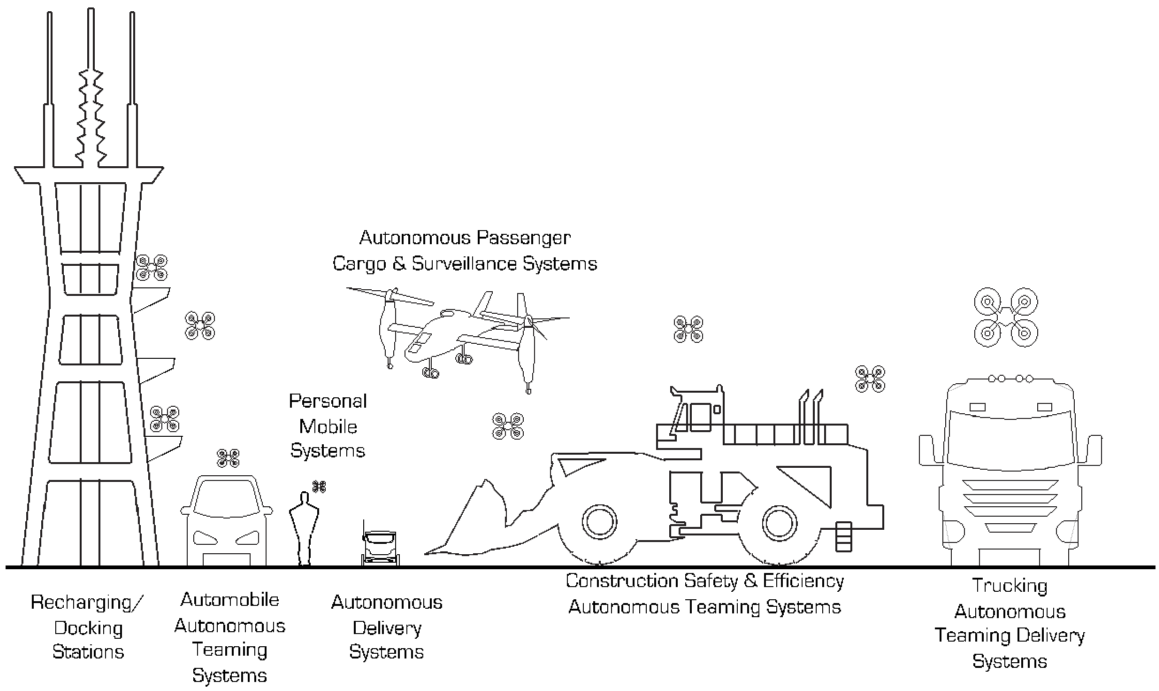


Figure VII-3. Increasing Autonomous Systems - External [Source: By Author]

New forms of increasingly autonomous mobility systems are at various stages of maturity and deployment providing enhanced or new capabilities in:

1. Automated Cargo Delivery
    a. Traditional: ground, air, and sea
    b. Last mile package delivery
        i. Airborne delivery to and from mobile systems
        ii. Internal Structures: Office/Desk/Work Station package delivery
2. Mobile Robotic Security & Surveillance Systems
3. Mobile Robotic Inspections
    a. External – buildings, sites and geographic locations
    b. Internal (small & micro UAS)
        i. Pipes
        ii. Vents
        iii. Conduits
        iv. Etc..
4. Mobile Robotic Cleaning Systems
5. Mobile Robotic Lawn Care & Landscaping
6. Automated Fire Fighting & Rescue Systems
7. Autonomous Site Coordination & Mobile Operations Safety Monitoring Systems
8. Personal Flight Following Systems
9. On Demand Mobility Services
    a. On Demand Autonomous Vehicle Rentals
    b. Autonomous Urban Air Mobility
10. Others

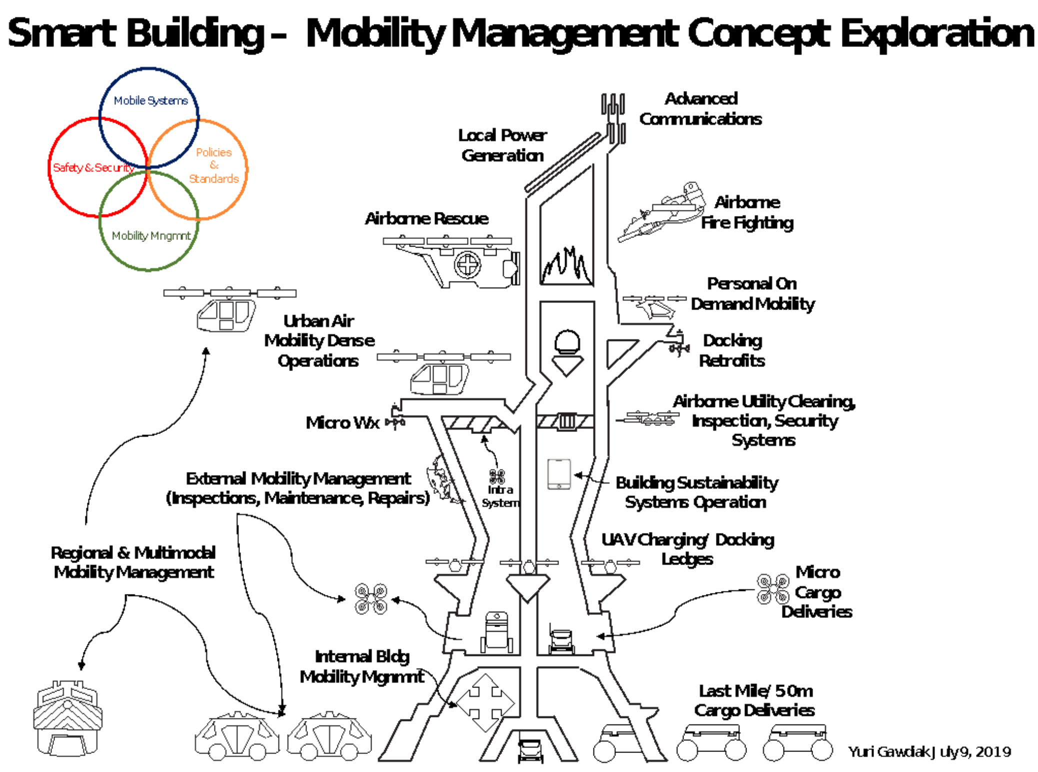


Figure VII-4. Increasingly Autonomous Systems - Internal [Source: By Author][62]

This is an unprecedent explosion of new modes of mobility. [Figure VII-4] The challenge to states, regions, communities and cities are immense. There is a very high risk of suboptimal designs and implementations if these changes are addressed independently and asynchronously. The Copenhagenize Index[63] has been developed to help rank the holistic aspects of cities to support bicycle-friendly transportation services. We're recommending for the Smart Building and Transportation Superclusters to build off the Copenhagenize Index and to expand it to cover these new modes and multimodal operations to better help track and manage efforts in this critical area.

Smart City Mesh Network

The proliferation of new modes of mobility including intelligent systems operating on, in, and around buildings will require building level traffic management capabilities merged with security and operations systems to ensure overall location safety and efficiency. [Figure VII-4] Integration of new mobility operations are a key evolving aspect of the Smart City Mesh Network, providing adaptive multimodal capabilities to best meet dynamic physical interaction demands. [Figure VII-5]

[62] Concept developed at the 2018 Global Cities Team Challenges Conference, Washington, D.C.

[63] https://copenhagenize.eu

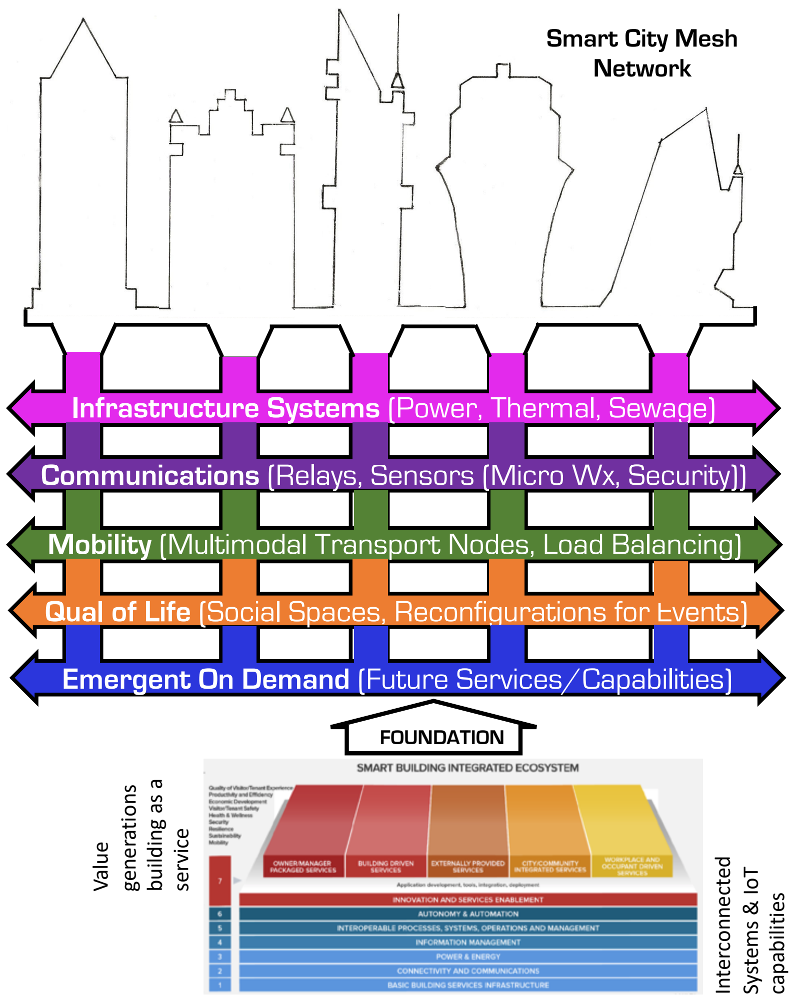


Figure VII-5. Smart City Mesh Network [Source: By Author]

This mobility adaptability is organized around:

1. Individual smart building level with reconfigurable entrances, loading zones, docking, and refueling/charging facilities for a range of vehicles;
2. Block/street/pier level with coordination of sets of buildings and shared systems to adjust larger mobility events, disruptions. Examples include creating temporary landing, parking, maintenance sites or adaptable staging or recovery areas where mobile systems can meet dynamic demand;
3. City level for city-wide accommodations to increase overall systems-of-systems efficiencies or adaptations to deal with emergencies and/or large-scale, unique events.

Mobility Traffic Management Systems & Services

Historic Traffic Management Drivers

In terms of traditional transportation, a key feature, for safety and efficiency reasons, has been the implementation of traffic management control signage and active flow control systems. Traffic management is usually located in either areas of high density or where active right of ways need to be provided. Examples of these are surface streets with traffic lights, stops signs, or buoys in harbors, or airport & ramp towers using surface markers and digital systems to control local aircraft operations and flows. Typically, where there's low density or very complex individual operations we rely on humans to provide safe separation and integration. Examples are farms, warehouses, construction sites, open oceans, and visual flight rules with general aviation.

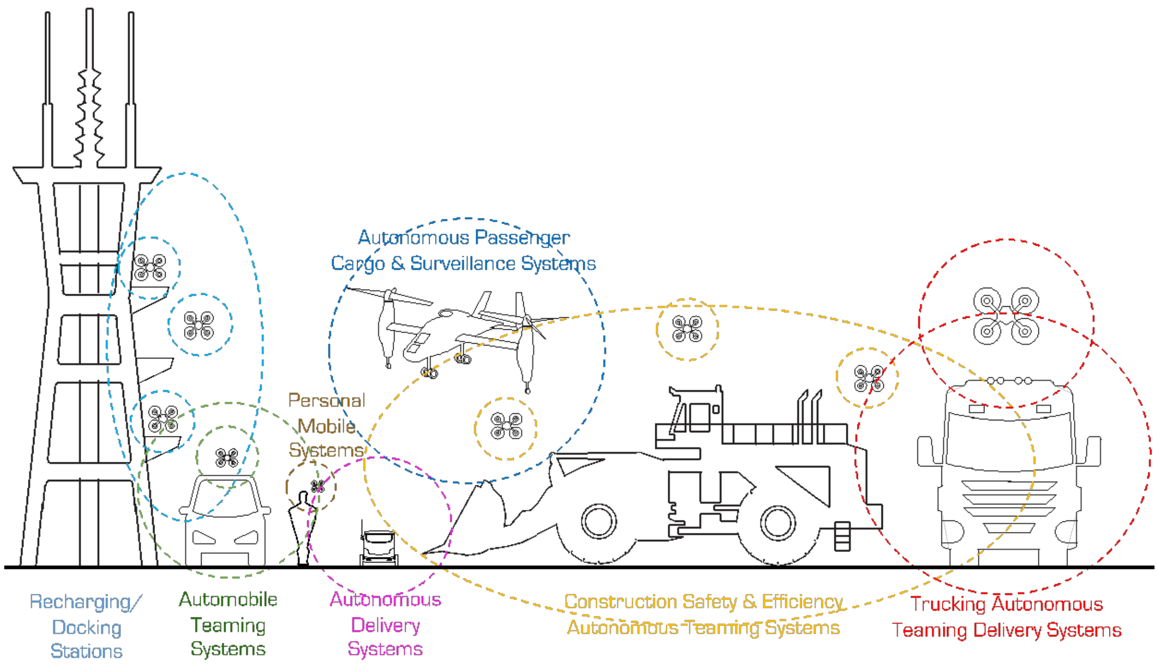


Figure VII-6. Interactions of Autonomous Traffic Management Systems & Services [Source: By Author]

New Mobility Management Systems

Figure VII-4 and Figure VII-6 depict the multiple layers of interactions of disparate mobility systems that will need to operate in an ever changing, overlapping, multi systems-of-systems environments. Local coordinated operations will need to be able to be spontaneously created as demand requires for occurrences with dense, multiple operators executing their responsibilities at: accident scenes, protests, social celebrations and other episodic locations and events that will require high levels of coordination and collaboration. To support these increasingly autonomous systems capabilities we'll need a mobility traffic management systems and services will need to allow for:

1. Systems to work freely, seamlessly moving from autonomous to highly coordinated mobility operations;
2. Operations in dense, multi system locations with overlapping areas of control and coordination between disparate operators and missions;
3. Coordinated, dynamic teaming systems in various custom configurations, swarms, and flock like assemblies;
4. The ability to move in out of various environments seamlessly (inside and outside of buildings, inside and outside systems/systems-of-systems); and
5. The ability to do coordinated graceful degradation for off-nominal conditions.

And as depicted in the Figure VII-4 and Figure VII-6 the management environments will range from micro locations: inside buildings, ducts, piping to external building operations, to coordinated block size activities, and up to: coordinated city, region, national and international operations. These operations will need to be integrated through the Smart Cities Network Mesh to provide status, configuration, and coordination information for successful, safe, and efficient mobility operations.

Benefits

Developing smart buildings with mobility as one of the integrated design considerations brings forth a broad range of civic outcome benefits as categorized in *Chapter 1 – Valuation, Benefits and ROI Considerations*.

Sustainability Environmental, energy, water and air quality management	Integrated Mobility Systems with Smart Buildings will enable greener vehicle systems to operate more efficiently by using local building solar generated energy to meet their power requirements.
Mobility Transportation, transit and traffic management	Integrated Mobility Systems with Smart Buildings will expand the number of opportunities and means for all systems and people to travel more efficiently. Smart Buildings with integrated communications and adaptive mobility support systems will help optimize and load balance transportation within dense regions.
Economic Development Business, employment and productivity	Integrated Mobility Systems with Smart Buildings will not only provide economic development during the transformational processes, but once those transformations are complete the enhanced mobility capabilities will be enablers and force multipliers to other economic activities.
Public Safety Welfare and protection from crime, hazards, and disasters	Integrated Mobility Systems with Smart Buildings will have integrated services and support systems that will enhance emergency services by providing new methods of delivery, including unmanned and airborne systems, as well as enhanced situational awareness for arriving first responders.
Resilience Hardening and continuity of services and operations	Integrated Mobility Systems with Smart Buildings using the Smart Cities Mesh Network are key to providing tactical and strategic region-wide resilience. Smart Buildings ability to reconfigure and adapt to support changing mobility requirements during off-nominal conditions will provide maximum flexibility and responsiveness to deal a wide range of challenges and recover to nominal operations as quickly as possible.
Quality of Life Standard of living, satisfaction and happiness	Integrated Mobility Systems with Smart Buildings by enabling sustainability, enhanced mobility, economic development tactical and strategic reconfigurability, and more efficient and reliable public safety all contribute to improved Quality of Life

Figure VII-7. Integrated Mobility Systems with Smart Buildings Benefits [Source: By Author]

Figure VII-7 provides the specific benefits of integrating mobility systems with smart building architectures.

Research Development & Integration

Smart buildings are at the nexus of these new mobility modes and operations. They are usually either the starting and/or end points of a given set of mobility operations. Given the broad scope of these interactions a private/public partnership is the ideal way to develop standards, identify technology challenges and work the various policy and guidelines needed to help insure a smooth, safe, and efficient evolution of new mobility capabilities integrated with smart buildings.

It is recommended that several federal agencies and communities of practice coordinate their activities in this area to maximize society's investments in these areas. Below is an initial, but by no means exhaustive list of initiatives and organizations that would benefit from strategic collaboration on mobility operations for smart buildings:

1. Global Cities Teams Challenge (GCTC)
    a. GCTC Transportation SuperCluster (TSC) & Blueprint
    b. GCTC Wireless SuperCluster (WSC) & Blueprint
2. Networking and Information Technology Research & Development Program
    a. Computing-Enable Networked Physical Systems (CNPS)

   b. Intelligent Robotics and Autonomous Systems (IRAS)
3. Department of Transportation (DoT) Intelligent Transportation Systems (ITS)
4. U.S. Department of Commerce, National Telecommunications and Information Administration
5. NASA Urban Air Mobility (UAM) Ecospheres Working Groups
6. Association for Unmanned Vehicle Systems International (AUVSI)
7. Others

Conclusion

The evolution of transportation and the current rapid increase of new modes of mobility is symbiotic with new thinking of the design and build of the built environment (municipalities and buildings) – trends in each affects the other in the mutual transformation and adjustment to new requirements and new opportunities for the built environment. For example, zero carbon emissions goals are affecting changes in private car usage within a city, which in turn is affecting design of buildings to more easily accommodate ride share and electric power.

The benefits of integrating new mobility modes with smart buildings have many synergistic benefits that can be most rapidly accomplished through private/public partnerships maximizing the innovative aspects of industry with federal, state, and local standards, policies and guidelines efforts. Those efforts coupled with, and informing federal and state infrastructure initiatives as well as government research and development investments will help enrich our smart cities & communities making them better prepared to take on the challenges and opportunities of the future.

VIII. Appendix: Cybersecurity and Privacy Risk Management Preparation Questionnaire

By

Deborah Shands

Contributing Editor: Limor Schafman

Smart Buildings: A Foundation - Appendix: Cybersecurity and Privacy Risk Management Preparation Questionnaire and Handbook

Questionnaire

Introduction

Smart Buildings integrate information and communication technologies with infrastructure to manage resources and to coordinate and improve services. *Building automation systems (BAS)* are used to control a wide variety of physical building infrastructure, including HVAC systems, lighting, water, and power. BAS may be more or less integrated with Building Management Systems (BMS), energy management systems, property technology, and tenant or occupant service applications. All of these systems may communicate over building-area networks and access the Internet through connections to broadband networks. We refer to this broad collection of systems and communication technologies as *Smart Building technologies*. As Smart Building technologies link cyber and physical infrastructure and transform dependencies among building systems, cybersecurity controls become increasingly essential to protect occupants, building infrastructure, and smart building functions. As data about individuals is collected, stored, processed and communicated among systems to enable personalized occupant services, privacy controls have also become essential.

Choosing appropriate cybersecurity and privacy controls requires a clear understanding of context regarding the building's purpose and the criticality of physical and cyber systems to that purpose. Risk management is a comprehensive process for addressing organizational risk throughout the lifecycle of a building and its many component systems. The widely adopted U.S. National Institute of Standards and Technology's (NIST) Risk Management Framework (RMF) [1] describes an actionable process for integrating cybersecurity and risk management activities into the lifecycle of system design and operations.

The RMF addresses risk management at three different levels to inform leaders and facilitate decision-making regarding risks to assets and operations. The first two levels, the organizational level and the mission/business process level, focus on identifying critical assets, making choices regarding risk tolerance, and identifying stakeholders, especially including third parties with important responsibilities for security and privacy. At these first two levels, the framework steps focus on preparing the organization to select, implement, and operate the necessary security controls to appropriately address risk in the context of the mission/business needs of the organization. At the third level, the RMF focuses on specific system components, requirements definition, system architecture, and more detailed technological controls.

While the RMF focuses primarily on cybersecurity, NIST has produced a draft privacy framework [2], with a process that parallels that of the RMF. An organization following the process in the privacy framework would first define a profile describing the desired privacy outcomes (informed by laws, regulations, organizational best practices, etc.) and identify information about individuals that the organization handles. The latter steps of the privacy framework address technology-dependent details such as access permissions and network segmentation.

This questionnaire, provided as a workbook in the appendix, focuses on organization-level and mission/business process-level cybersecurity and privacy risk management for Smart Building technologies, identifying critical assets and key stakeholders, and establishing risk tolerance. The document and process are agnostic to both the building's purpose (e.g., hospital, residential apartments, warehouse) and to the specific cybersecurity and privacy technologies that could be integrated with the Smart Building technologies. Completion of the workbook in the appendix addresses many of the tasks involved in the RMF *prepare* step and the privacy framework's *identify* step.

Organization Level Questions

The hierarchical breakdown of activities and tasks in the NIST RMF begins at the highest level with the organization. An independent organization will be held accountable through laws, regulations and contracts for the security (and privacy) impacts of the systems it operates. In the Smart Buildings space, a building owner or property management company is likely the most relevant organization. A large property management company may have multiple departments, each of which could also take on the role of an organization with respect to the RMF, but with a more focused scope than that of its parent organization. Subcontractors that provide specific building management services could also use the RMF to address cybersecurity within the scope of their operations.

The following questions are intended to help guide building management in gathering necessary information and making decisions necessary to prepare for executing the later tasks in the RMF.

Identifying stakeholder organizations and individuals

1. Building management/maintenance: Which organizations manage or maintain equipment for the building? Consider, for example, organizations that manage or maintain: HVAC system, fitness center/pool equipment, elevators, grounds, business center.
2. Service providers: Which organizations provide services on behalf of building management or tenants? Consider, for example, delivery services with direct access to facilities, custodial/cleaning services, security and reception services, facilities maintenance staff, and consulting services.
3. Utilities: Which utilities provide essential services to the building? Consider electrical power, gas, water, cable or satellite network.
4. Occupants: Which building occupants (organizations or individuals) will interact with building systems? Note that, for example, building sensors may detect the activities of individuals, either in their offices or in their personal residences. Building networks may carry the personal or business data of tenants.

Identifying the regulatory environment

5. Governance: What laws, regulations, and contracts influence the cybersecurity and privacy requirements for the building?

    - Consider federal, state and local laws. In some cases, international law may be applicable (e.g., the European Union's General Data Protection Regulation (GDPR)[3].
    - Consider laws related to organizations that maintain building equipment or provide services. For example, laws that protect data about individuals' energy use may limit collection of tenant data for building energy assessments.

- Consider laws relating to building or tenant functions. For example, in a hospital building, HIPAA protections for patient data privacy may affect plans to track locations of individuals for fire safety.
- Consider contracts with service providers and equipment maintenance providers.

Creating and communicating cybersecurity and privacy policies

6. Policy development: Who is responsible for writing the cybersecurity and privacy policies by which organizations and individuals that interact with the building must abide and that must be implemented via Smart Building technologies? Who is responsible for updating these policies in response to changing laws and regulations, new contracts, or evolving goals of building stakeholders?

7. Policy communication: Who is responsible for communicating about changes to cybersecurity and privacy policies with building stakeholders and with organizations responsible for policy implementation through building Information Technology (IT) and Operations Technology (OT). Consider, for example, the impact of a new privacy law that prohibits the collection of certain personal information about building occupants. What if the smart thermostats installed in the building collect that personal information?

Identifying sources of guidance and leverage

8. Guidance sources: Which sources of guidance will you use to evaluate cybersecurity and privacy risk and implement controls? Consider, for example, NIST's publications, available through its Computer Security Resource Center.

9. Leverage sources: What sources of leverage do you have to influence the cybersecurity and privacy characteristics of systems and services that interact with your building?

    - Consider aspects of your supply chain, including contracts with suppliers, contracts with service providers, procurement standards and processes.
    - Consider your response options if you learn that an operational system, product or service has unacceptable cybersecurity or privacy characteristics. Can you cancel the service? Remove and replace a system or product?

Identifying necessary staff skills and expertise

10. Expertise: Does your organization currently have the expertise to build and operate your building and meet (at least) your legal obligations for cybersecurity and privacy? If not, have you identified the roles that you will need to fill and sources for hiring or contracting to establish the necessary capabilities? Have you identified education or training resources to help current staff develop the necessary skills?

Ongoing operations

11. Operational oversight: Which organizations and individuals will be responsible for operational oversight of the cybersecurity and privacy performance of building systems? Who is responsible for ensuring that building systems and personnel are meeting legal

responsibilities? Consider who will respond to queries from law enforcement or city officials regarding any cybersecurity/privacy issues that may arise from building operations.

12. Implementing cybersecurity and privacy policies: Which organizations and roles are responsible for configuring building IT or OT systems to implement cybersecurity and privacy policies? Which operational organizations (IT and OT) and roles are responsible for communicating with building policy makers to ensure that technology configurations reflect current cybersecurity and privacy policies?

Mission/Business Process Level

In the Smart Buildings context, cybersecurity incidents that impact system or data availability or integrity can lead to building system failures (outages) or malfunctions. Incidents that violate the confidentiality of building, service provider, or tenant information may also have serious ramifications. Incidents that result in disclosure of information about individuals (e.g., residential tenants, employees of commercial tenants, building management staff, employees of building service providers) may have serious privacy impacts. The following sections describe an approach to identifying the most critical building systems, business- or mission-sensitive data, and private data of individuals that must be protected. Identifying and characterizing these items is an essential step toward planning, prioritizing, and allocating resources to protect them.

Critical Systems

The effect of failures in different building systems may range from serious, safety-critical impacts to financial impacts to a tenant or building owner to long-term damage to the physical building infrastructure. Identifying the mission-level criticality of each building system will later enable building system designers and operators to focus risk mitigation efforts on the most critical systems.

At the mission/business process level, it is essential to identify the major building systems/functions and whether that system/function is critical to:

- *Human safety:* Failure of the system could result in serious injury or loss of life for the building occupants
- *Business operations:* Failure of the system could jeopardize business operations. For example, the failure of a service metering system could prevent building management from billing occupants for resources (e.g., water, power) consumed
- *Tenant operations*: Failure of the system could jeopardize tenant business operations or day-to-day living of residential tenants
- *Third party operations:* Failure of the system could jeopardize the operations of third- party services (e.g., residential tenant services such as dry-cleaning pickup/dropoff, property maintenance services such as landscaping or swimming pool maintenance) operating on behalf of building management.
- *Business confidentiality:* Failure of the system could disclose sensitive business data (e.g., contract pricing or terms, salaries, partnership terms, planned acquisitions)
- *Tenant business confidentiality*: Failure of the system could disclose sensitive business data of tenant businesses

Note that system criticality is highly dependent on the purpose of the building and the occupants. The systems critical to the operations of a hospital building are very different from those that are critical to the operations of a shipping warehouse or a plant nursery. For example, an HVAC system outage in a refrigerated warehouse for storing frozen foods would have a very high impact on business operations; in a hospital, an HVAC outage could be a safety risk for patients; in an office building, an HVAC outage could be unpleasant for employees, though in extreme weather, employees might need to leave the building. The building mission context (e.g., the purpose of the building and some characteristics of its expected occupants) is necessary to identify the potential severity of a cybersecurity incident that leads to an HVAC system outage.

Table A-1 shows and example for an assisted living building for senior residents. Note that an extended outage of any building system may become a more serious problem over time.

Table A-1: Example building system criticality assessment for assisted living facility

	Human Safety	Business ops	Tenant ops	3rd party ops	Business Confidentiality	Tenant Business Confidentiality
Power monitoring		High	High		High	
HVAC controls	High	Low	High			
Lighting controls	High	Low	High			
Fire/CO sensors	High		High			
Security sensors	High		High			
Broadband network		High	High		High	High
Common WiFi			High		High	High
Landscape		Med				
Waste management		Med			Med	
3rd party service						
3rd party service						
City service						
First responder link	High					High

- *Power Consumption Monitoring:* Monitor the energy consumption of individual assets and building zones to identify waste sources and improve energy efficiency
- *Intelligent HVAC Control:* Measure temperature, humidity and air quality in remote building areas for decentralized, granular control of the HVAC system

- *Smoke and Carbon Monoxide sensors*: Interconnect alarm systems to trigger alerts to dangerous conditions and monitor battery life
- *Landscape sensors:* Provide data on landscape irrigation and other systems to detect leaks and optimize water use
- *Waste Management:* Monitor waste container fill-levels and optimize pick-up routes and disposal schedules
- *Third-party services*: Sensors and monitoring systems that support third-party services, such as sensors that monitor status of exercise equipment in on-site gym, managed by third-party service
- *City services*: Sensors and monitoring systems that support smart city operations
- *First responder link*: Sensors and monitoring systems (e.g., occupancy sensors) that provide information to first responders (e.g., police, ambulance, fire department) in emergencies

The workbook in the appendix contains a table template that you can use to identify critical systems within your building.

Personal data about individuals

The European Union's General Data Protection Regulation (GDPR) [3], adopted in 2018, is a comprehensive privacy regulation that protects the rights and freedoms of individuals with regard to the processing of personal data and movement of personal data. GDPR offers a broad definition of "personal data":

> 'personal data' means any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person

The United States Executive Office of the President, Office of Management and Budget [5] defines "Personally Identifiable Information (PII)" as:

> information which can be used to distinguish or trace an individual's identity, such as their name, social security number, biometric records, etc. alone, or when combined with other personal or identifying information which is linked or linkable to a specific individual, such as date and place of birth, mother's maiden name, etc.

In [4], the US National Institute of Standards recognized widespread inconsistencies in the definitions and use of the term "Personally Identifiable Information," so provided the following distinctions among similar terms:

> the phrase "personal information" is used to denote information from individuals, and "identifying information" is used to denote information that identifies individuals. Therefore, identifying information is personal information, but personal information is not necessarily identifying information.

Because the European GDPR impacts any organization that handles information about European individuals, even when those individuals are traveling outside of Europe (e.g., occupying a building somewhere outside of Europe), we use the GDPR terminology “personal data.”

Building systems may receive, collect, store, process, or send personal data about individuals that must be protected to prevent unauthorized disclosure or unintended aggregation. While building systems for a hospital may use sensitive patient diagnosis or treatment information (e.g., air exchange rates for rooms where patients with infectious diseases are treated), even buildings that serve more public functions (e.g., hotels, offices) may use or link to sensitive data about occupants. For example, some hotels offer a digital room “key” via a cellphone app that enables physical access to the guest’s hotel room and links to the hotel guest’s account, including information about the guest’s home address, phone number, credit card, past stays and future reservations. Many office buildings are accessible to employees of tenant companies via smart card (or phone app) readers that link to some form of employee record.

Personal data about individuals whose inappropriate disclosure could present a risk to privacy include, but are not limited to: identifying information (e.g., name, street address, email address, phone number, age, sex, marital status, biometric data), health information, genetic information, physical location information, communication (e.g., voice conversations, email or text messages, and app-based communication), relationships with other individuals (e.g., “address book” contacts) and personal habits (e.g., activity patterns, personal calendar). Information collected through building systems may also be used to infer information that individuals consider private. For example, data about energy use patterns in a residence could be used to infer personal habits of individuals. Aggregation of such data with identifying information could enable construction of a very detailed electronic dossier about an individual.

While a building’s immediate use of information about individual occupants may be benign, serious privacy problems may arise when that information is shared with third parties or aggregated through interconnected systems. Best practices for privacy protection include:

- Use as little personal data as possible to enable the necessary system functionality. Collect as little personal data as possible. Thoroughly delete such data from the system as soon as possible. Do not communicate personal data between systems, unless it is essential. Inhibit methods of linking multiple systems that store personal data to limit the breadth of impact of a data breach of one of the systems.
- Limit access to and carefully prevent unauthorized disclosure of any personal data that must be used or stored.
- Audit access to personal data and review logs of these accesses periodically to promptly identify and address unauthorized or unexpected accesses.

The example shown in Table A-2 indicates how each building system treats information about individuals. Shaded columns and rows indicate transmission of such information among systems. By identifying exactly which information is managed or transmitted to/from building systems, potential risks to privacy can be identified and addressed.

Table A-2: Identifying which systems receive, collect, store, process or send information about individuals

	Receives	Collects	Stores	Processes	Sends
Power monitoring	☒	☐	☒	☒	☒
HVAC controls	☒	☐	☐	☒	☐
Lighting controls	☒	☐	☐	☒	☐
Fire/CO sensors	☐	☐	☐	☐	☐
Security sensors	☐	☒	☒	☒	☒
Broadband network	☐	☐	☐	☐	☐
Common WiFi	☒	☒	☐	☒	☐
Landscape	☐	☐	☐	☐	☐
Waste management	☐	☐	☐	☐	☐
3rd party service	☐	☒	☐	☐	☐
3rd party service	☒	☐	☒	☒	☐
City service	☐	☐	☐	☐	☒
First responder link	☒	☐	☒	☐	☐

- *Receives:* The system receives information about individuals from another system
- *Collects:* The system collects information about individuals (e.g., data is provided by sensors or gathered from an app)
- *Stores*: The system stores information about individuals
- *Processes:* Information about individuals is used by the system in its processing
- *Sends:* The system sends information about individuals to another system

The workbook in the appendix contains a table template that you can use to identify how your building systems treat information about individuals.

References

[1] National Institute of Standards and Technology, *NIST Special Publication 800-37 Revision 2: Risk Management Framework for Information Systems and Organizations*.

[2] National Institute of Standards and Technology, *NIST Privacy Framework: An Enterprise Risk Management Tool, Discussion Draft of April 30, 2019*.

[3] Regulation (EU) 2016/679 *General Data Protection Regulation, adopted April 27, 2016*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679

[4] National Institute of Standards and Technology, *NIST Internal Report 8053: De-Identification of Personal Information,* October 2015. http://dx.doi.org/10.6028/NIST.IR.8053

[5] United States Executive Office of the President, Office of Management and Budget, *OMB Memorandum M-07-1616: Safeguarding Against and Responding to the Breach of Personally Identifiable Information*, May 22, 2007.

Workbook 1

Organization Level Questions

The following Workbook provides questions Organization Level questions with space for responses. Please complete all that is possible. Refer to the information and examples offered above for these questions to ensure completeness of answers. You may find it necessary to complete this in a separate document. Note and highlight for yourself and your team where answers are not complete. It is recommended that these become priority areas of focus.

Identify stakeholder organizations and individuals

1. Building management/maintenance: Which organizations manage or maintain equipment for the building?

2. Service providers: Which organizations provide services on behalf of building management or tenants?

3. Utilities: Which utilities provide essential services to the building?

4. Occupants: Which building occupants (organizations or individuals) will interact with building systems?

Identify the regulatory environment

5. Governance: What laws, regulations, and contracts influence the cybersecurity and privacy requirements for the building?

Create and communicate cybersecurity and privacy policies

6. Policy development: Who is responsible for writing the cybersecurity and privacy policies by which organizations and individuals that interact with the building must abide and that must be implemented via Smart Building technologies?

   Who is responsible for updating these policies in response to changing laws and regulations, new contracts, or evolving goals of building stakeholders?

7. Policy communication: Who is responsible for communicating about changes to cybersecurity and privacy policies with building stakeholders and with organizations responsible for policy implementation through building Information Technology (IT) and Operations Technology (OT).

Identify sources of guidance and leverage

8. Guidance sources: Which sources of guidance will you use to evaluate cybersecurity and privacy risk and implement controls?

9. Leverage sources: What sources of leverage do you have to influence the cybersecurity and privacy characteristics of systems and services that interact with your building?

Identifying necessary staff skills and expertise

10. Expertise: Does your organization currently have the expertise to build and operate your building and meet (at least) your legal obligations for cybersecurity and privacy?

    Yes ___ No ___

    If not, have you identified the roles that you will need to fill and sources for hiring or contracting to establish the necessary capabilities?

    Yes ___ No ___

    What are the needed capabilities and roles?

    Have you identified education or training resources to help current staff develop the necessary skills?

    Yes ___ No ___

    Name the education and training resources:

Ongoing operations

11. Operational oversight: Which organizations and individuals will be responsible for operational oversight of the cybersecurity and privacy performance of building systems?

(continued on next page)

Who is responsible for ensuring that building systems and personnel are meeting legal responsibilities?

12. Implementing cybersecurity and privacy policies: Which organizations and roles are responsible for configuring building IT or OT systems to implement cybersecurity and privacy policies?

    Which operational organizations (IT and OT) and roles are responsible for communicating with building policy makers to ensure that technology configurations reflect current cybersecurity and privacy policies?

Smart Buildings: A Foundation - Appendix: Cybersecurity and Privacy Risk Management Preparation Questionnaire and Handbook

Workbook 2

Mission/Business Process Questions

The following section of the Workbook provides questions Mission/Business Process Level queries. As shown in the main document, please complete this Building System Critical Asset Assessment. Identify the property purpose, and with that in mind, complete the grid with High, Med or Low ratings.

Building System Criticality Assessment

Property purpose and use case drives building infrastructure. Please describe the property type and purpose:

	Human Safety	Business ops	Tenant ops	3rd party ops	Business Confidentiality	Tenant Business Confidentiality
Power monitoring						
HVAC controls						
Lighting controls						
Fire/CO sensors						
Security sensors						
Broadband network						
Common WiFi						
Landscape						
Waste management						
3rd party service						
3rd party service						
City service						
First responder link						
Add as needed						
Add						
Add						

Identify System Usage of PII

In the grid below, identify which systems receive, collect, store, process or send information about individuals. Note all that apply. For an example and further information, refer to the Table 2 (page 8) in the main document.

	Receives	Collects	Stores	Processes	Sends
Power monitoring	☐	☐	☐	☐	☐
HVAC controls	☐	☐	☐	☐	☐
Lighting controls	☐	☐	☐	☐	☐
Fire/CO sensors	☐	☐	☐	☐	☐
Security sensors	☐	☐	☐	☐	☐
Broadband network	☐	☐	☐	☐	☐
Common WiFi	☐	☐	☐	☐	☐
Landscape	☐	☐	☐	☐	☐
Waste management	☐	☐	☐	☐	☐
3rd party service	☐	☐	☐	☐	☐
3rd party service	☐	☐	☐	☐	☐
City service	☐	☐	☐	☐	☐
First responder link	☐	☐	☐	☐	☐
Add as needed	☐	☐	☐	☐	☐
Add	☐	☐	☐	☐	☐
Add	☐	☐	☐	☐	☐