Reducing Infectious Disease Risks with Smart Building Technologies and Management Systems

White Paper 506

Version 1

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Executive summary

Global pandemics like COVID-19 put the transmission of viruses and the spread of infectious diseases at the forefront of concerns for commercial building owners, building managers, and their tenants. Even after a pandemic has receded, identifying and reducing occupant health risks remains a critical and necessary function of building operations teams. Carrying out this function successfully requires having an effective facility management program, as well as the right technology tools. This paper focuses on the technology aspect. We show how building management systems (BMS) and associated smart building technologies play a central role in identifying threats, reducing risks of infectious disease transmission, and monitoring for policy compliance.

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Introduction

As gathering places for human beings, there is always a risk of infectious disease transmission within buildings. When infectious disease risks are not factored into the design of buildings or assessed as part of operations, there is a greater likelihood that occupants can become ill resulting in not just harm to occupants, but also in lost productivity for the organization. Tenants increasingly understand the impact their workplace has on their wellbeing, now more than ever, and so they expect a safe and healthy environment[1]. Organizations are even facing lawsuits from tenants and employees who believe they contracted a disease as the result of landlord or employer negligence[2]. The global economic cost of infectious diseases on business productivity is tremendous. The COVID-19 pandemic has been forecasted to reduce global GDP by 3 to 8%[3]. Pandemics aside, one recent study calculated the U.S. employer cost of the 2018 flu season, alone, to be between $15.4 and $20.9 billion[4]. Not only is there a clear economic incentive to manage this risk, there is also a societal duty to help slow disease transmission. For pandemics and larger outbreaks, everyone must work together to slow transmission, minimizing the impact on global health, society, and the economy.

The recent pandemic has put a sharp focus on the facility operations program: i.e., site policies and procedures, communications with building occupants, and so on. The aim has been to minimize transmission by manually testing people upon entrance, keeping occupancy levels low, spacing people out, staggering shifts, keeping the site clean and sanitized, as well as asking occupants to follow certain rules. Authorities such as the World Health Organization (WHO), Center for Disease Control (CDC), the European Centre for Disease Prevention and Control, and ASHRAE have all published guidelines for employers to follow.

Healthy building certifications and rating systems have also garnered attention (e.g., WELL, fitwel, and RESET) as a means to give people confidence buildings are safe to occupy. What has not been widely discussed, however, is how to take advantage of a building management system (BMS) and related smart building technologies to detect, mitigate, and respond to infectious disease risks. That is the purpose of this paper. **Building controls integrated with smart building technology and applications can be enabled to help simplify, improve, and automate safety and infection risk management.**

First, we will briefly explain the nature of the threat in commercial building environments and will describe the methods of disease transmission. Next, we will show how building management systems and related smart building technologies available in the market today can help. These technologies can be used to not only detect threats, but they can also be configured to work together to actively respond to and mitigate health risks. These systems can further be used to monitor program effectiveness and compliance to health guidelines in place at the site. **Figure 1** illustrates what is included in such a system.

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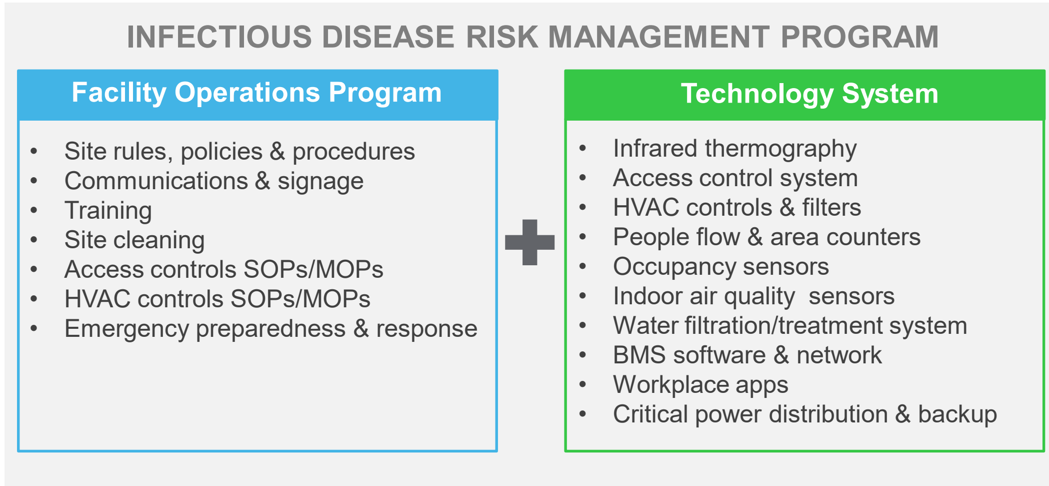
[1] https://www.linkedin.com/pulse/what-kind-tenant-experience-do-todays-tenants-want-gabrielle-mcmillan/

[2] https://www.advisory.com/daily-briefing/2020/08/03/covid-lawsuits

[3] https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/prioritizing-health-a-prescription-for-prosperity

[4] https://www.challengergray.com/press/press-releases/update-2-flu-season-cost-employers-21b

Figure 1
A comprehensive infectious disease risk management program is comprised of both the building technology system as well as the facility management program. The paper focuses on the technology system.



Nature of the threat

Infectious diseases are caused by pathogenic microorganisms, such as bacteria, viruses, parasites, or fungi (i.e., mold spores). They can be spread, directly or indirectly, from one person to another through airborne particles[5]. In a commercial building setting, infectious agents typically enter the building through infected people, but theoretically could enter through ventilation ducts (e.g., pest infestations) or through the water supply. The CDC further clarifies direct as having two modes with indirect being further divided into three modes of transportation[6].

Direct

In direct transmission, an infectious agent is transferred from an infected host (where microorganisms normally live) to a susceptible host by direct contact or droplet spread.

Direct contact occurs through skin-to-skin contact, kissing, etc. Direct contact also refers to contact with soil or vegetation harboring infectious organisms.

Droplet spread refers to spray with relatively large, short-range aerosols produced by sneezing, coughing, or even talking. Droplet spread is classified as direct because transmission is by direct spray over a few feet, before the droplets fall to the ground.

Indirect

Indirect transmission refers to the transfer of an infectious agent from a reservoir to a host by suspended air particles, inanimate objects (vehicles), or animate intermediaries (vectors).

Airborne transmission occurs when infectious agents are carried by dust or droplet nuclei suspended in air. Airborne dust includes material that has settled on surfaces and become resuspended by air currents as well as infectious particles blown from the soil by the wind.

Vehicles that may indirectly transmit an infectious agent include food, water, biologic products (blood), and fomites (inanimate objects such as handkerchiefs, bedding, or surgical scalpels).

[5] https://www.who.int/topics/infectious_diseases/en/

[6] https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section10.html

Vectors such as mosquitoes, fleas, and ticks may carry an infectious agent through purely mechanical means or may support growth or changes in the agent.

The National Institute for Occupational Safety and Health (NIOSH) developed an "Hierarchy of Controls" (**Figure 2**) as a means of determining how to implement feasible and effective infectious disease control solutions for your building. It is endorsed by the CDC[7]. The Federation of European Heating, Ventilation, and Air Conditioning Associates (REHVA) promotes a similar hierarchy of controls.

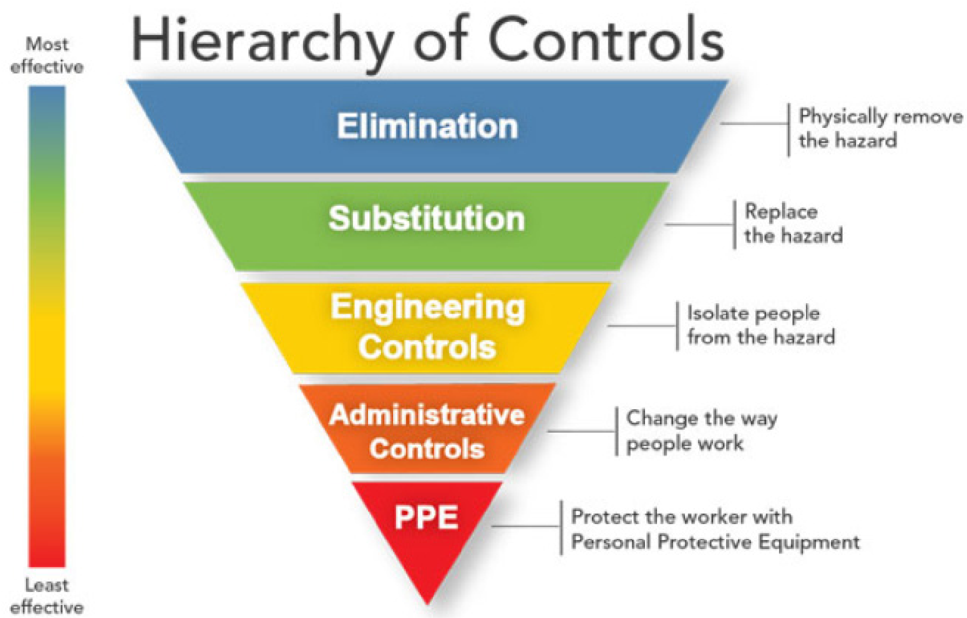


Figure 2
Hierarchy of controls from the National Institute for Occupational Safety and Health (NIOSH).

Disease control measures that operate at the higher levels (top of the funnel) are recognized as being inherently more effective at controlling and managing threats. Many, if not most, of the items in the Facility Management Program (see **Figure 1**) would fall under PPE (personal protective equipment) and Administrative Controls. For example, requiring workers to wear masks, wash their hands frequently, and stay "socially distant" would fall under the PPE and Administrative Controls category. On the other hand, the items under the Technology System portion of **Figure 1** – the subject of this paper – fall within the top three tiers of the funnel. **Although controls and management at the Engineering Controls layer and above are more expensive to establish than administrative controls, they are more effective and save money over time.**

There are fundamentally three kinds of infectious disease-related "threats" that building management systems and smart building technology can detect and respond to:

- infected people
- environmental conditions that increase risk of disease transmission
- occupant distribution patterns violating guidelines or policies

The next section will explain how to detect them with smart building technologies.

[7] https://www.cdc.gov/niosh/topics/hierarchy/default.html

Note there are **air filtration and air disinfection devices that serve to capture or kill viruses, bacteria, and mold spores** in buildings. They are not considered smart building tech per se and, so, are not within the scope of this paper. The **Appendix** lists these technologies that building owners should consider deploying as part of their infectious disease risk management strategy. When properly deployed, configured, and maintained, they will reduce the risk of disease transmission. Of course, the use of these devices alone will not fully eliminate the risk. They should always be used in combination with other facility management program best practices along with the smart building tech and controls described in this paper.

Threat detection: Infected people

The first step in defending against virus and disease transmission within a building is to identify sick people (visitors, suppliers, vendors, occupants, etc.) before they are in close proximity with other occupants. Of course, there should be a policy in effect and communicated to all visitors and occupants that if someone shows symptoms of illness, they should stay home. However, some may ignore this policy, or they may not be aware of being ill.

As a result, there is guidance from health and governmental authorities prescribing that people's core body temperatures are measured upon entrance. This is typically done manually by a person using a hand-held, non-contact infrared thermometer (NCIT) that is fast, easy to use, noninvasive, inexpensive, and somewhat reduces the chance of spreading illness between the tester and the tested person. Because an operator is required to be close to the person being tested, there is still a risk of infecting the person giving the test. They typically determine core body temperatures by measuring the infrared radiation emitted from a person's forehead. Although not as accurate as some contact thermometers, they have become relatively effective with accuracy rates of 97% to 99%[8]. Note, however, that an infected person does not always exhibit a fever.

New infrared temperature scanners have emerged that, although more expensive, can accurately record core body temperatures without the need for an operator being near the person being tested. Also, importantly, these new solutions integrate with building management systems and controls to provide automated responses when people test positive for a fever. **Figure 3** shows an example solution from World Wide Technology that uses an Intel micro PC along with optics that measures thermal energy radiating from the eye canthus[9]. By eliminating the need for an operator and by automating building control responses, these new thermal imaging scanners further reduce the risk that a potentially infected person will spread disease to other occupants. Recommended use cases showing how this integration could work are explained in the next section.

To help ensure the thermometer will provide accurate measurements, select one that has been certified by an independent organization such as the U.S. Food & Drug Administration (FDA) or National Institute of Standards and Technology (NIST). The Therapeutic Goods Administration (TGA) of Australia is another example of an organization that certifies a thermometer's stated accuracy in measuring core body temperatures.

[8] https://www.npr.org/sections/health-shots/2014/10/15/356398102/how-a-no-touch-thermometer-detects-a-fever

[9] "either corner of the eye where the upper and lower eyelids meet" https://en.wikipedia.org/wiki/Canthus"

Figure 3
This example from World Wide Technology is an infrared temperature scanner capable of taking occupant core body temps autonomously. Known as the Tested Elevated Thermal Signature Detector (TESTD), it measures core body temperatures by measuring thermal energy at the corner of the eye using LIDAR and applying built-in AI/ML algorithms. The system can be integrated with building management systems for automated building control responses to test results.

Threat detection: Environmental conditions that increase risk of disease transmission

This section explains how air temperature & humidity, air flow, fresh outside air, as well as water temperature and flow affect the risk of disease transmission in buildings. And it will explain how smart building technologies and management systems can monitor for and detect conditions that increase that risk.

Air temperature & humidity

Because infectious diseases are often transmitted person to person through airborne respiratory droplets and aerosols, a building's HVAC system and the sensors used to monitor indoor air quality play a key role in detecting and managing the risk. Recent scientific studies have shown that **higher temperature and humidity levels inhibit the viability of viruses**, regardless of whether it is airborne and suspended in liquid or dried on a contaminated surface[10]. On top of that, it has been shown that low ambient temperatures and low humidity levels can impair a human's natural barrier function and innate resistance to viruses like influenza[11]. However, higher temperature and humidity levels might reduce the effectiveness of UV-based air disinfection technologies and could cause human comfort issues, as well as the formation of mold. The science on the impact of temperature and humidity on virus transmission has been somewhat mixed. More scientific studies are needed to have a definitive recommendation on specific HVAC settings and operational protocols. ASHRAE, therefore, has refrained from "mak[ing] a broad recommendation on indoor temperature and humidity for the purpose of controlling infectious disease. Practitioners may use the information…to make building design and operation decisions on a case-by-case basis." That being said, ASHRAE in their general guidance for commercial buildings makes a general recommendation to keep relative humidity levels between 40% and 60% while maintaining dry bulb temperatures within the comfort ranges indicated in ANSI/ASHRAE Standard 55-2017. Their preference is to be at the higher end of the dry bulb temperature range.

[10] Mechanistic insights into the effect of humidity on airborne influenza virus survival, transmission and incidence. Marr Lo et al. J.R. Soc. Interface (2018) 16:20180298.

The effects of temperature and relative humidity on the viability of the SARS coronavirus. Chan KH et al. Advances in Virology (2011) ID 734690

[11] Low ambient humidity impairs barrier function and innate resistance against influenza infection. Kudo E et al. PNAS (2019) April 4.

Air flow

The **movement of air through the HVAC system** can also facilitate the spreading of infectious diseases that become aerosolized over longer distances. Air currents pick up respiratory droplets/aerosols and move them throughout the building resulting in contact with other occupants. As previously mentioned, air filtration and air disinfection devices can help mitigate this threat, but it's not foolproof. The correct control of air movement is therefore important, especially when there is a known risk of infection. For example, in kitchens or bathrooms the air should be removed from the area to prevent odors from impacting other occupants. The same principle applies to infectious agents. Removal is the best solution. This requires control of the airflow to ensure the space remains in a negative pressure to enable the correct flow of air. This also applies if activities surrounding a building generate potentially harmful gases such as at airports. Airport terminals should be positively pressurized so that gases and odors created by jet engines and ground control traffic, etc. don't leak into the occupied areas within the terminal.

ASHRAE's Epidemic Task Force states, "Ventilation and filtration provided by heating, ventilating and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air…**In general, disabling of heating, ventilating, and air conditioning systems is not a recommended measure to reduce the transmission of the virus.**"[12]

It is not just about moving air, but it is also important that fresh or clean air replaces air in a space, and therefore **air exchange rate or air changes per hour (ACH) should be monitored and controlled**. This refers to the number of times per hour the air inside a space is replaced. Keeping air moving in a building and replacing the air in all of its spaces helps remove air-suspended contaminants. The CDC published a table that shows the time required to remove airborne contaminants at a given ACH rate[13]. For example, at 2 ACH, it took 207 min to remove the contaminants. However, at 8 ACH, it took only 52 minutes thereby showing the effect of higher ACH rates. However, while healthcare facilities might be designed for these higher ACH rates, typical buildings are designed for 1-2 ACH depending on occupancy levels. To achieve 8 ACH for them would require significant capital expense (CAPEX) and result in much higher energy costs. **If cost prohibitive, relying more on appropriate filtration and using technologies like UV-based air cleaning or bipolar ionization would be a better strategy versus trying to achieve higher ACH rates.**

Fresh outside air

Bringing in fresh outside **air** is another key mitigation strategy in that it dilutes the stale inside air. And for many buildings, this might be much easier to do. This reduces concentrations of airborne virus or bacteria that may exist in the building. Unless you are in a healthcare or lab space, there generally isn't a supply air code requirement, per se. That being said, ASHRAE 62.1 does provide guidance on airflow rates based on room size, occupancy level and usage that is used by consulting engineers to define air flow rates for the building being designed. Regardless, increasing the amount of fresh air in a building is being encouraged as a means to reduce infectious disease risks. Also, ASHRAE provides specific guidance on airflows and ACH for healthcare facilities that could, in theory, be applied to other building types as well. In fact, in the midst of the COVID-19 pandemic, many buildings like schools and retail commercial buildings have begun to adopt healthcare-level indoor air

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12 https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-filtration_disinfection-c19-guidance-9.15.pdf

13 https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#tableb1

quality management practices. Again however, the limitations of your existing building and HVAC design might inhibit your ability to significantly increase the ACH without incurring significant retrofit CAPEX and energy costs.

Measuring air exchanges is done using airflow sensors or VAV boxes with built-in CFM measurement capabilities, which many have today. Where filters are also used to catch contaminants monitoring should be provided to know when the filters will become clogged and dirty, this is quite easy to achieve with differential pressure sensors across the filter unit.

Although authorities have largely refrained from issuing new specific quantified guidance on temperatures, humidity, CO2 levels, and airflow rates for non-healthcare buildings, the general guidance from ASHRAE in the context of COVID-19 has been:

- supply clean air to susceptible occupants
- contain contaminated air and/or exhausting it to the outdoors
- dilute the air in a space with cleaner air from outdoors and/or by filtering the air
- clean the air within the room
- avoid lower temperatures and humidity levels

Note that the Federation of European Heating, Ventilation, and Air Conditioning Associates (REHVA) provides a bit more specific advice in the context of reducing the risk of COVID-19 transmission in buildings.

Therefore, ambient temperatures, humidity levels, air flows, and CO2 concentrations should all be actively monitored to detect environmental conditions that are conducive to enabling a virus to survive longer and/or be passed around to occupants. Commercial **Indoor Air Quality (IAQ) sensors are used to monitor and detect environmental conditions that increase the risk of disease transmission.** These are small devices that might be wireless (battery-powered) or hardwired (low voltage). Typical items measured by an IAQ sensor include:

- Temperature
- Relative humidity
- Carbon dioxide (CO2)
- Volatile Organic Compounds (VOCs)
- Particulate matter
- Air pressure
- Light levels (Lux)
- Radon gas

Note that during the COVID-19 pandemic, ASHRAE recommended the disabling of CO2 demand control ventilation (DCV) controls to maximize outside air rates in buildings. These systems are designed to reduce energy by reducing ventilation when spaces are empty, or when occupancy is less than peak levels. These systems are fine to use for monitoring, but it’s not recommended as a control point in the midst of a pandemic.

They should be installed in hallways, meeting rooms, office spaces, rest rooms, and other places where people gather in the building. Many vendors offer these devices today. Attributes to look for when choosing a solution include:

- If pursuing a building certification (i.e. Fitwel, Reset, etc.), ensure the sensor resolution, reporting intervals, etc., meet the requirements of the certification.
- Connectivity (via a gateway) to your building management system and/or workplace apps using standard IoT and IT protocols to support analytics and automated action by the building controls based on live sensor readings.
- Connect data to your BAS so you can augment with your control systems to get batter accuracy of room level conditions. This allows your BAS to act accordingly

Water temperature and flow

Another environmental-related concern in buildings is the growth and spread of **legionella**, a bacterium that occurs naturally in water and soil. In stagnant, warm, untreated or under-treated water, these bacteria can grow and multiply. Renovations might disturb pipework resulting in the bacteria becoming an aerosol. In high enough concentrations the bacteria, when inhaled through aerosols or mists, causes legionellosis, an acute respiratory infection. This infection is commonly known as Legionnaire's disease. Pontiac fever, a milder form of illness, can also occur. Areas of concern in buildings are any system that contains water between 20°C and 45°C (68°F and 113°F) such as potable water, decorative fountains, HVAC supply and return water loops, and especially cooling towers.

Reducing the risk of water-borne respiratory infections involves making good design choices (e.g., locating cooling towers away from intake vents), as well as implementing good water treatment and other operational best practices including:

- regularly inspecting cooling towers and other water storage tanks for signs of corrosion, scaling, and algae
- treating cooling towers and water loops with a biocide program and replacing corroded parts
- monitoring and maintaining water temperatures that inhibit legionella bacteria growth[14]

Both the CDC[15] and ASHRAE encourage organizations to develop a water management plan that is outlined in ASHRAE's Standard 188-2018, "Legionellosis: Risk Management for Building Water Systems". The standard not only provides a framework for how to manage the risks, it provides some design and operational guidance around specific building systems including potable water systems, cooling towers, and condensers.

Detecting legionella bacteria requires having the water tested at a lab by specialists. So, the role of a BMS in this case is to monitor for and initiate controls for conditions that facilitate the growth of legionella bacteria. Although it can exist at lower temperatures, legionella grows best at a temperature range of 20°C and 45°C (68°F and 113°F). At 50°C (122°F) the bacteria stop growing and at 60°C (140°F) and above, legionella is rapidly killed[16]. The BMS should be monitoring for temperature and flow issues across the system but particularly at areas of the system where the flow may be stagnant or the water temperature is a concern (i.e., warm for chilled water and cooler for hot water systems). By also combining data from space utilization sensors, areas of low usage can be identified. This data can also add to the risk

[14] https://fmlink.com/articles/nasem-regulations-guidelines-control-legionella/
https://claritywatertech.com/legionella-in-cooling-towers/

[15] https://www.cdc.gov/legionella/downloads/toolkit.pdf

[16] https://www.assurityconsulting.co.uk/knowledge/guides/what-do-i-need-to-know-about-legionella

mitigation strategy. The BMS should provide alarms and notifications to facility staff for any potential issues. Water heaters should be kept above 60°C. For water storage tanks where the water is relatively stagnant, a BMS can initiate a pasteurization cycle at set times that brings the water to 75 to 80°C (167°F to 176°F) to ensure all bacteria is eliminated. Manual flushing of taps can also be done at this time by facilities teams, or specialist design plumbing systems can be used to allow for full circulation of the system.

For a chilled water system, the primary issue to address is warm water stagnation in cooling towers and evaporative condenser coils. The BMS role is to monitor temperatures and flow of water throughout the overall system including the water distribution piping. Pipes that have been isolated or zone changed can be a problem for legionella growth. Note that water piping systems can be designed and employ devices that optimize the flow of water to enable a constant flow of water to reduce the risk of bacterial growth. Kemper, a water control system company, is an example vendor who offers flow splitters and balancing valves that help prevent water stagnation in pipes.

Threat detection: Occupant distribution patterns violating guidelines or policies

Amid the COVID-19 pandemic, world health and governmental authorities issued social distancing guidelines that require people stay at least 2 meters (6 feet) apart from each other to minimize the transmission of infectious disease from direct physical contact or respiratory droplets or aerosols. In turn, policies have been implemented within commercial buildings requiring occupants to remain socially distant, wear masks, and not use meeting rooms or gathering spaces like cafeterias. For some regions, governments have set a reduced maximum occupancy level based on a specific number of people per unit of floor area. In some cases, these restrictions have meant staggering shifts by time of day or day of the week to ensure occupancy levels remain at or below acceptable levels.

Of course, regardless of whether there is a pandemic or not, fire codes and safety standards limit the number of people allowed in a given space. Building managers should, therefore, continuously monitor and be aware of the number of people in the building at a given point in time. Smart building tech makes this much easier to do vs. using manual log-in sheets and having security personnel keep track. People flow counters, area counters, and occupancy sensors are three smart building technologies used to track and manage this. During a pandemic, they can be used to ensure occupants are adhering to social distancing requirements or staying away from areas that haven't been sanitized after use or are at risk of having been contaminated with a virus or bacteria. Concerns over right to privacy, however, might preclude the use of such tactics in certain situations and/or places.

People flow counters
Similar to an area counter, these are used at building (or perhaps floor level if leased) entry and exit points to count the number of people entering and existing a space. Bi-directional sensors typically used by these counters can detect the difference between an entry and an exit.

Area counters
These sensors measure the number of people in a given space at any given time. They work in a variety of ways including simple "break beam" sensors using light, WIFI sensors that detect occupant's mobile devices, video cameras, and thermal sensors. They are used not only to count people, but also to track and monitor the use of a space to help with optimization. Some manufacturers offer apps that enable occupants and facility managers to know in real-time the occupancy status of rooms and spaces in a building. This information could also be fed into a room reservation system, for example, through an API.

Occupancy sensors
These now ubiquitous room sensors detect the presence of people through either a passive infrared or ultrasonic (sees through objects) signal. Traditionally, they are used for detecting when someone walks into or leaves a room to signal turning lights on or off as an energy saving device. These sensors also come in a form factor designed to be mounted under desks to keep track of occupancy of individual workspaces. These could be monitored to ensure social distancing protocols are being followed. Also, room sensors could be used to ensure quarantined spaces remain unoccupied if the space is not already managed by an access control system.

Risk mitigation

The previous section focused on introducing the infectious disease transmission threats that building management systems and their associated sensors could monitor for and detect. In this section we describe how a well-integrated technology system reduces or mitigates risks. We'll describe some use cases to help explain.

BMS systems have been typically implemented as simple HVAC controls with maybe some minor integrations with lighting, fire and access control systems. Integrating these devices and sensors with your BMS and facility management apps helps, not just to identify, but also mitigate infectious disease transmission risks in your building. They do this either by controlling the systems they operate to prevent conditions that result in a risk (e.g., HVAC controls manage temperature, humidity, and fresh air exchanges) or they initiate actions to eliminate a threat once one is identified by the sensors (e.g., access control system locking entry doors and closing air duct dampers upon a positive test). Building controls can respond to these risks and threats in an automated fashion. The BMS can also document issues to provide a basis for corrective actions to be taken. In the case of policy and regulatory compliance, as well as in the event of any legal challenges, the BMS data can serve as the "source of truth".

To be more effective in mitigating risks, the BMS should be well integrated with smart building systems, workplace apps, and business systems. This traditionally has not been how BMSs were deployed. **Figure 4**, from White Paper 500, *Three Essential Elements of Next Generation Building Management Systems (BMS)*, illustrates the difference between a traditional BMS deployment and a modern one that takes advantage of IT and smart building tech. These integrations enable coordinated, automated actions to document and respond to infectious disease threats.

The following sub-sections describe a few use cases for how these disparate systems can act in concert with each other to mitigate risks. Note, this is far from being an exhaustive list.

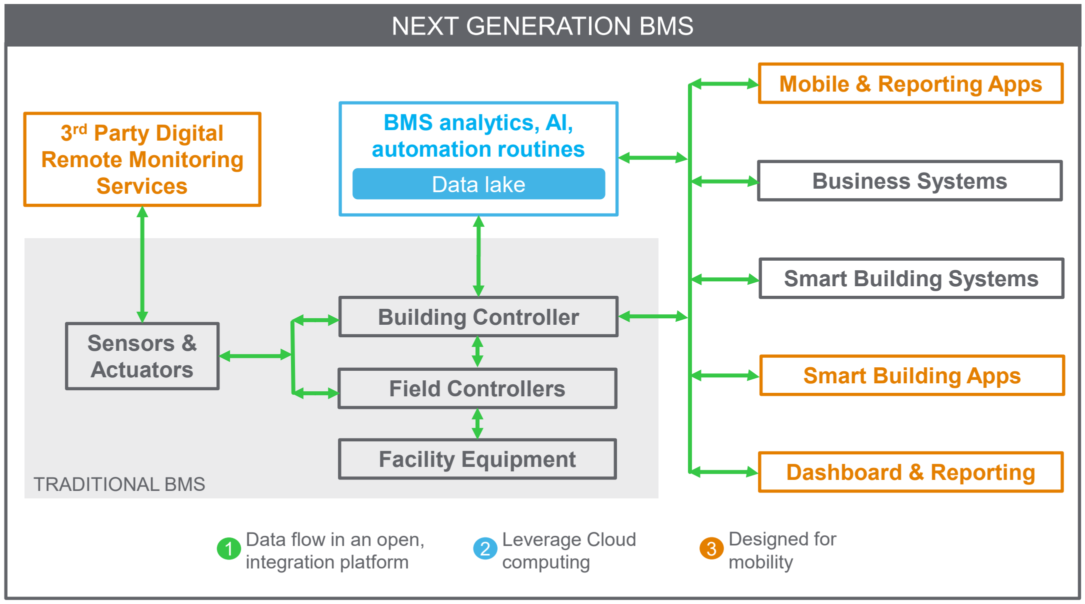

Figure 4
A high-level architectural diagram of a next generation BMS system that, unlike traditional BMS implementations, extends from the equipment to the cloud.

Use case: person enters building

A person enters the building and proceeds into a "mantrap" area or between a set of double doors. At this location…

1. People flow counter is activated upon entry and exiting of the building
2. Thermal imaging camera provides a scan of the individual
3. Reading is checked by camera against recommendations for GO / NO GO

No fever = GO	Fever = NO GO
• Signal is sent to access control system to allow person to enter while granting their access card normal access within building	• Access card is restricted preventing access • Lock-out for set time before fever re-test • Temperature & time of reading is recorded • Record of non-compliance is documented in access control system

Potential additional actions that could be taken to further minimize the risk of transmission:

1. Use a physically isolated area, if possible, for testing that is maintained at a negative air pressure to minimize risk of contaminated air moving elsewhere in the building.
2. Design the testing space so that air ducts can be closed and/or duct fans can be shut off when a person enters for testing. Status remains closed and/or off until a "GO" reading is achieved or "x" amount of time after the person being tested has exited the building.
3. Use the information to initiate notification of team members and close contacts if contact tracing protocols are in effect during a pandemic situation.

Use case: environmental alarm

An indoor air quality sensor issues an alarm for an unsafe condition (high VOCs, CO_2, particulate matter, etc.). A policy is configured by facility management as to what is safe vs. unsafe.

1. Sensor alarm is sent to the BMS, workplace or wellness management app
2. Sensor/BMS provides alarm location, type & severity to access control & HVAC controls
3. BMS checks occupancy

If occupied

Users notified of condition through workforce mobile app which receives alarm from BMS

4. BMS notifies access control system which restricts access to affected area
5. HVAC controls turn off duct fans or create negative pressure in affected area
6. BMS checks sensor(s) for return to normal state

Other examples

- Use people counters to automatically limit access to confined spaces by integrating with access control and public announcement (PA) displays
- Use people flow, occupancy sensors (people counting), and/or room booking system to initiate automated cleaning of common areas and workspaces by connecting to cleaning work management platforms
- Create real-time space or building health scores using IAQ sensors and report scores through PA displays and/or workforce apps
- Facilitate contact tracing using CCTV analytics to determine who was in close contact with an infected person
- Employ IoT-enabled ID badges to
  - Contact tracing in case occupant tests positive for infection
  - Record social-distancing violations
  - Record occupancy density maps for focused cleaning (i.e., high traffic areas get cleaned the more, etc.)

Monitoring for compliance

Not only does the BMS play a key role in identifying and mitigating risks, but it also plays a role in monitoring for compliance to infectious disease control policies and procedures. It provides a means for benchmarking performance over time. An effective way to benchmark and continuously monitor a building's readiness for occupants to return amidst a pandemic is to participate in the Arc Re-entry program.

"Return to work" readiness compliance

Arc Skoru Inc., a technology platform company affiliated with Green Business Certification, Inc and the U.S. Green Buildings Council, has created a set of tools that relies on sensors to help ensure it is safer to return to buildings amidst a pandemic. Known as Arc Re-Entry, the scoring program provides the tools needed to: (1)

document and benchmark infection control policies and procedures, (2) collect and analyze related occupant experiences, and (3) measure and track indoor air quality. The first two are done through surveys while the third relies on IAQ sensors and integration with the BMS or directly to the Arc platform.

The IAQ component of the score is based on measured sensor data that is input into the Arc platform. Calculating an IAQ score requires having sensors installed to measure relative humidity, carbon dioxide (CO2), particulate matter, and total volatile organic compounds (TVOCs). Traditionally the metrics for C02 and TVOCs were based on the concentration level of pollutants. For the Re-Entry program, however, the metric is based on the fraction of time that a concentration is above a certain threshold.

So, across these three components, the Re-Entry program's comprehensive score is based on a total of 120 different variables, or "meters" as Arc calls them. Arc provides a spreadsheet that lists and describes all of these program variables. For more details on the Re-Entry program, analysis, reporting, and how the comp score is calculated, see the Guide to Arc Re-Entry.

Occupant policy compliance

Building sensors and management systems can be used to monitor for compliance to established disease prevention-related policies aimed at occupants. The following lists several examples.

- Enforcing or tracking social distancing using ceiling mounted occupant sensors and analytic systems capable of tracking spacing between occupants while protecting privacy
- Detecting whether people are wearing masks using specialty sensors and AI-based analytics engines[17]
- Using workforce apps to communicate policies and guidance around the use of PPE, distancing, areas that are off limits, sanitation, occupancy limits, and so on.
- Heat mapping where people have been over time using occupancy sensors and analytics software to understand patterns and compliance to policies
- Using BMS and/or workplace app data to backup and confirm that environmental conditions and policies were being monitored and maintained in the event of a complaint or lawsuit (i.e., "defensible liability")

[17] Note this is an emerging technology that uses camera technologies to detect mask/no mask and log daily counts while reporting the net number of violations over a given population. This can be done without identifying the occupants to ensure privacy.

Conclusion

In summary, a comprehensive infectious disease risk management program is made of 2 fundamental parts: a facility operations program and a technology system. There is already much written guidance and defined best practices regarding the facility operations program – site rules, policies, procedures, etc. – from governmental health and various industry organizations. So, this paper focused on the technology system comprised of the BMS, workplace apps, and their integration with smart building technologies such as IAQ and occupancy sensors. A well-integrated and deployed technology system can help simplify, improve, and automate safety and infection risk management. Building controls integrated with smart building technology and applications can assist in detecting infectious disease risks, mitigating those risks, and providing the tools needed to monitor for compliance to infectious disease control policies and procedures. With such a comprehensive infectious disease risk management program in place, building occupants and tenants will feel greater peace of mind that their place of work is safer.

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Appendix

Devices that catch or kill viruses, bacteria, and mold spores

The following devices should be considered for deployment in conjunction with other best practices. Note some of these address both air and surface-borne viruses.

Air filtration

- Mechanical air filters
- High Efficiency Particulate Air (HEPA) filters
- Electronic air filters
- Gas-phase air cleaners
- In-room or portable air cleaners

Air disinfection

- Ultra-violet energy (UV-c)
- Photocatalytic Oxidation (PCO) and Dry Hydrogen Peroxide (DHP)
- Bipolar ionization / corona discharge / needlepoint ionization and other ion or reactive O2 air cleaners
- Ozone
- In-room or portable air cleaners

For more information see ASHRAE's "Filtration and Disinfection" bulletin.