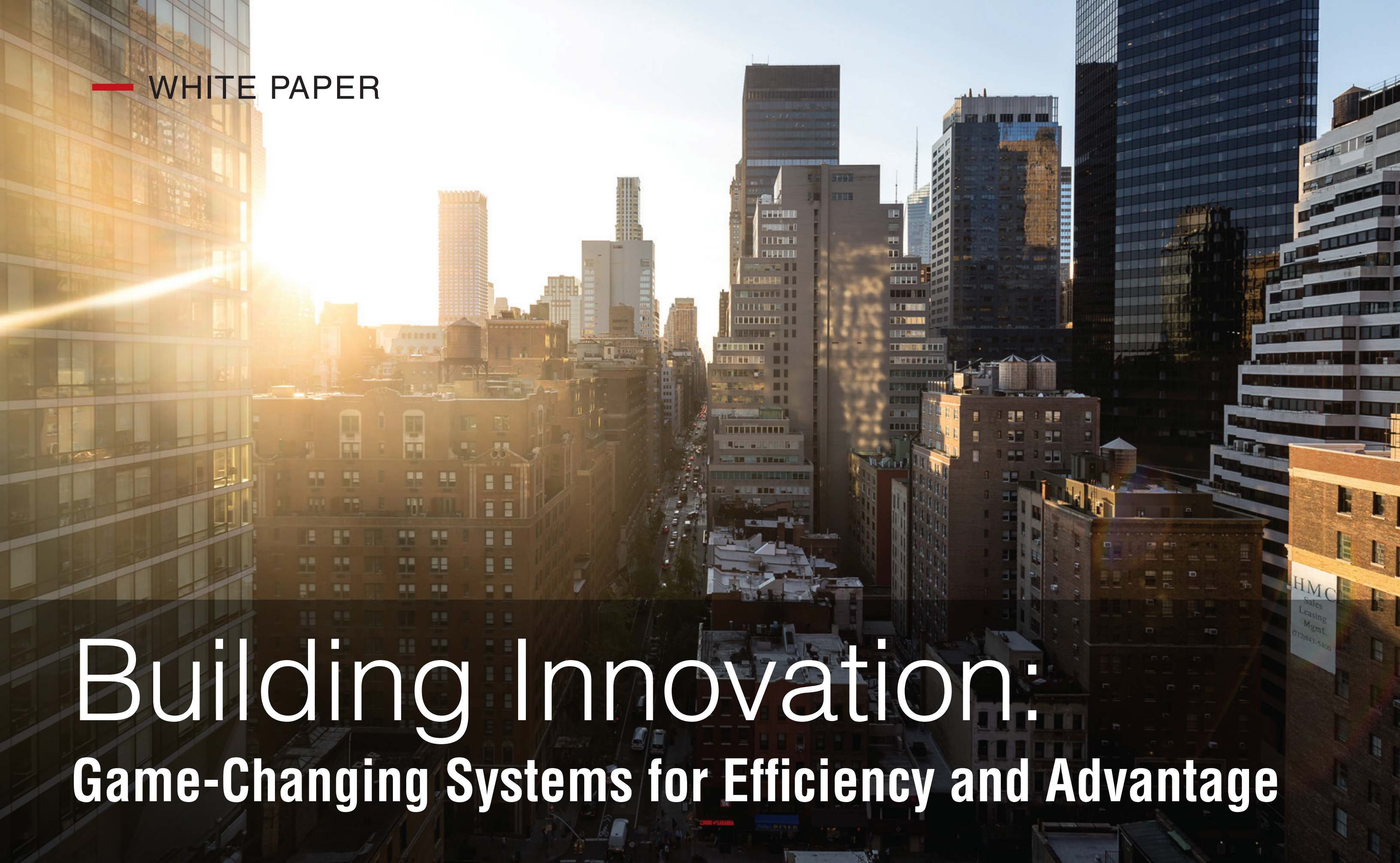
WHITE PAPER



Building Innovation:

Game-Changing Systems for Efficiency and Advantage

With innovative design approaches, architects and engineers deploy building system solutions—including vertical transportation, HVAC and UPS systems—to bring new efficiencies and competitive advantages to clients.

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Building for Efficiency:

Systems Approaches Boost Profitability

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WITH INCREASING COMPETITION among building teams for the best commercial and institutional commissions, leading firms in the architecture, engineering and construction (AEC) fields are finding innovative ways to bring design advances, experiential improvements and significant gains in efficiency and sustainability to their projects. Driving the adoption of these advances are today's increasingly competitive outlook and the need for more sustainable and differentiating building solutions.

"In this industry, there is always a need for new technologies, reducing project costs and improving quality—all while also increasing productivity," says Achila Jayasuriya, a protection and controls expert with engineering design and consulting firm Primera, who points to Amazon's use of drones as a key example. "These are the 'outside-the-box' ideas that we need to be thinking about."

For construction project delivery and building infrastructure, these trends make innovation essential. Matching new aesthetic and design advances with increased efficiencies and integrating new building systems with visible or otherwise noteworthy enhancements have become more than hallmarks of the best buildings. Instead, they are now two prerequisites for winning prime commissions in the commercial and institutional markets.

Fortunately, a number of core building system advances—most having entered the commercial and institutional segments in recent years—are now driving competitive advantages for leading AEC teams. Three of those are considered in this white paper, with a focus on the technical innovations and documented system benefits presented by the categories. A final consideration is how AEC teams and client groups are partnering with building system providers in single-source or sole-source arrangements, as reported in the Houston Chronicle, to integrate custom solutions into more collaborative design and construction phases, while also delivering improved service and warranty coverage to the client.

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→ **Vertical transportation**. A wide range of newly integrated technologies are bringing advanced functionality to elevator systems. Commercial destination control suites reduce times for tenant waiting and traveling by up to 10% - 20% depending on peak loads, and they present AEC teams with new options for organizing building cores, and elevator risers as well as improving overall building architecture. Many of the passenger interface technologies are more advanced, with modern aesthetics that complement current architectural trends. In addition, novel machinery and automated operating methods have improved ride comfort by smoothing movements and reducing vibration. Perhaps more essential to building efficiencies and differentiation has been the adoption of destination control systems as well as integrated audiovisual (AV) equipment and elevator systems without machine rooms.

→ **Uninterruptible power supply (UPS) systems.** Uninterruptible power supply (UPS) systems. Meeting the need for more resilient buildings and commercial and institutional complexes that can ride out severe weather episodes and peak demand cycles, new UPS systems are now more highly reliable. Among the most valuable innovations are innovative high-reliability UPS configurations with very small footprints and flat efficiency curves, meaning higher efficiencies in a range of loading conditions and therefore a lower total cost of ownership (TCO) and improved power usage effectiveness (PUE). In many cases, AEC teams are adding uptime consulting and UPS specs to projects that previously would leave those details to IT consultants. Many say that the capability often helps win commissions for resiliency-focused building projects.

→ **Heating, ventilation and air-conditioning (HVAC) systems.** Heating, ventilation and air-conditioning (HVAC) systems. Over the last decade, a broad range of advances related to energy efficiency, sustainability, and occupant health and wellness have opened doors for improving building environments and reducing life-cycle costs. Among the most valuable advances are variable refrigerant flow (VRF) HVAC systems. Invented in the mid-1980s, these systems are similar to ductless mini-splits, delivering conditioned refrigerant directly to a space requiring conditioning rather than conditioning air in a central location and moving it where needed. Like variable frequency drives and variable air volume systems, VRF systems offer significant efficiency gains of up to 25% and greater when using heat recovery technology, according to a report by the U.S. General Services Administration (GSA).

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These three system areas are discussed in this white paper, with particular attention given to how recent advances improve reliability and efficiency, as well as, in some cases, the sustainability, resiliency and even profitability of a client's building project. In addition, the paper reviews best practices in collaborating with vendors and system providers to optimize these gains, with attention to service and support approaches currently being adopted by leading building owners and developers. Some of these downstream approaches are shown to boost system operations and value over time, while also reducing punch-listing and callbacks for AEC teams.

The white paper also confirms through case studies and application data the value that project teams can exploit by integrating building solutions from Mitsubishi Electric within these three categories. In particular, the systems are shown to contribute to sector-leading efficiencies and low maintenance needs for systems applied to both new and renovated buildings.

TECHNICAL INNOVATION

Whether for new building construction or reconstruction and retrofit situations, leading AEC firms evaluate technology use based on case studies, proven application data and track record. Studying critical product and building measures—including operating variables and related competitive factors—helps determine the return on investment (ROI) for the owner-investor group.

Examples of key operating variables include historical callback rates, expected frequency of unplanned service calls and predicted efficiency gains, according to reports by Mitsubishi Electric. Other competitive factors may be critical to the client group, including qualitative measures such as comfort and aesthetics but also quantitative improvements, including increased net rentable area; reduced operating costs; and management of maintenance, repair and operations (MRO) costs during building operations. Savvy building teams know the importance of these "reliable and verifiable metrics" to owner decision making. For that reason, some project teams bring references to the table in project meetings, says Alex Argento, a green building materials specialist and executive with supplier PuraTerra. These include (a) third-party testing of building system properties; (b) manufacturer history and track record; (c) product benefit details; (d) project economics, including first cost, operating costs and total cost of ownership (TCO; and (e) references from projects that have already used the product.

Another challenge to address is the resistance of some client groups to adopting new and valuable technologies simply because they are unfamiliar with the systems or products. These barriers to employing new building systems have been reviewed, and "resistance of stakeholders to change and higher costs are identified as the most critical barriers to implementing," according to Hong Kong Polytechnic University's real estate expert Albert P.C. Chan, whose team undertook a global survey of AEC professionals on their willingness to adopt novel sustainability technologies. The hurdles for technology adoption fall into "five main interrelated components, which suggests the need for holistic and integrated strategies to overcome those barriers."

With these challenges in mind, a review of critical factors for three technology areas follows, with attention to the operating variables and competitive factors most frequently considered by building owner-developers.

Vertical Transportation

First, consider the example of escalators and elevators, which serve as one of the most visible and prominent tenant/visitor touch points. Issues of safety, reliability, cost, sustainability and aesthetics often drive AEC team choices. Yet increasingly, project teams are focused on traveling speed, proper functionality, brand image and even end-user frustration, which may impact their perceptions of building experience. Another essential operating variable is manufacturer callback rate, which can be compared to industry-standard callback rates—an average of about six callbacks per year per elevator. Leading manufacturers boast dramatically improved rates of about two callbacks per unit per year, according to Mitsubishi Electric, which has reported callback rates of less than one callback per year.

In terms of sustainability, elevator specifications seek to maximize energy efficiency in a number of ways. One of the latest techniques is using a regenerative converter on gearless traction elevators, generating power in loaded cars traveling in the down direction as well as in lightly loaded or empty cars that are traveling upward. The power generated is transmitted to the elevator system's distribution transformer and into the building mechanical, electrical and plumbing (MEP) systems, reducing energy use by as much as 35% as compared to elevators without this feature.

AEC teams should consider several other operating variables. For example, more than two-thirds of elevator callbacks are a result of door issues or malfunctions. To avoid these costs and associated downtime, newer elevator system designs "structurally isolate the door operation mechanism and apply a robust door operating system, which helps dramatically reduce the number of door-related callbacks," says the manufacturer Mitsubishi Electric. In addition,

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some utilize an efficient one-chip RISC microcomputer to detect variations in door load, wind strength and sediment accumulating in sill grooves.

Other operating variables to study include modernization rates (or likelihood of necessary modernization). At least one manufacturer has reported that it has not required a modernization of even one of its elevator systems in the last 30 years, maximizing elevator uptime, another key variable. Data like this is invaluable for project developers, owners and investors, according to AEC teams.

Advancing Design and Functionality

In addition to studying incremental improvements in elevator functioning, many AEC building teams are recommending and specifying a number of highly differentiating designs based on innovative vertical transportation approaches. Examples include spiral escalators, which are curved systems for indoor applications up to just over 21.5 feet of vertical rise. Such escalators create a dramatic visual impact and sensory experience while providing life-cycle performance comparable to linear (straight) escalators by the same manufacturer.

Other features of elevators are less noticeable but equally important. Enhancements such as mirrored cab interiors and AV systems in elevators help to reduce boredom and other negative associations in their buildings. They can also deliver advanced building functionality, including revenue streams for the owner.

Among the most significant functionality enhancements over the years has been the use of destination control, such as the Destination Oriented Allocation System, or DOAS, first introduced in 2002. Allowing for highly efficient elevator operation and end-user convenience, destination control "optimizes multicar elevator systems by allocating cars efficiently according to the floors that passengers input while waiting, helping to reduce both wait and travel times," according to the maker of DOAS. Destination control technologies maximize car allocation efficiency, including by directing passengers who are going to the same floor to use the same elevator. As a result, cars do not stop needlessly on floors being served by other cars, and a multicar systems algorithm reduces energy draw by creating the most efficient service schemes. Not insignificantly, these controls also relieve users of pressing buttons upon entering their elevator cars.

Just how effective is destination control? Based on simulations conducted by Mitsubishi Electric of a 16-floor building with six cars having 20-person load capacities, the DOAS technology cut average wait times by up to 30% during congested hours when compared to conventional systems. The controls also reduced incidents of long waits (those lasting 60 seconds or more) by up to 60% during peak times. Studies like these offer convincing reasons to adopt destination control, and it is steadily becoming the norm.

Aesthetics, Security and Safety

With the new generation of destination control systems have come a number of sleek, modern hall panels and user control interfaces. These contemporary designs help highlight the intelligence behind the systems, helping users adapt to the new paradigm. Larger touch screens are becoming more common, measuring 10 inches and larger with high-brightness displays and options for audio guidance to meet building design goals for accessibility and universal design.

In addition, life-safety and security consultants have demonstrated how destination control systems such as DOAS can be integrated with facility access-control systems to enhance overall security design. According to security integrator ESI, this strategy has been employed for major building projects, including the renovation of 680 Folsom, a 1963 building in San Francisco's Market District. The interface of destination control with building-wide security has helped deliver "energy savings, operational efficiencies and high-tech security functionality" for the client team, says ESI.

In these projects, building administrators and occupants employ either floor-access control or automatic call registration. Floor-access control limits passengers' choices for floor number selection based on credentials programmed into their proximity cards and readers. With automatic call registration, the proximity card and reader panel direct the user to an elevator car destined for an authorized floor number. Both are efficient, automated approaches that advance not only functionality but also elevator design: Inside the cars, passengers experience sleek control panel designs and smoother, faster rides to their desired floors.

In addition, recently introduced elevator systems and structural car frames are more robust and better assembled, reducing ancillary vibrations over the lifetime of the installed products. Next-generation elevator designs employ hoisting machine and door operator isolation, to ensure that vibration is not transmitted into the passenger cab. The components have been enhanced for smoother acceleration and deceleration gearing, as well as tighter guide-rail tolerances and increased motor control. Taken together with their advanced aesthetics and preprogrammed controls, the improved operations also help reduce callbacks and occupant complaints while they take the stress out of building operations.

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UPS Systems

The second area to consider in terms of building reliability and efficiency is the redundant power supply, essential to facility resiliency and, increasingly, to the operations of any modern commercial or institutional building. The UPS setup has become synonymous with uninterruptible operations and maximum uptime in certain building types, such as data centers, healthcare complexes and many enterprise settings, and also for vital public agencies such as emergency services. The use of reliable, low-maintenance UPS systems may further serve a client's business strategy, improving building profitability by attracting and retaining top tenants at market-leading rents and sale prices. UPS systems boost the ROI of the power solution, minimizing future capital expenditures and surprise costs.

In some markets, the use of resilient design principles is essential for Class A buildings. A confluence of factors has led to the need for building designs offering improved resiliency, including the vulnerabilities of regional power grids to seasonal outages. Another contributing challenge is the impact of severe weather on building services and systems, according to facility design and operations experts. "Build in redundancy for critical systems," advises Jennifer L. Chiodo, P.E., of engineering consulting firm CX Associates. "For the power supply, ideally serve these buildings from two separate utility substations or distribution nodes [and] emergency generators with significant fuel storage and provide batteries with solar charging capability."

Chiodo advises building owners, "Ensure that buildings can be islanded—separate from the power grid so that they can continue operation during outages."

Achieving these levels of redundancy, isolation and backup can be made more efficient and even more profitable for owners and developers. As the cost of downtime has skyrocketed for virtually all types of businesses, client groups often ask their AEC project teams for greater reliability in backup power. In addition to maximizing uptime, the building team "needs to understand the distinct challenges within a variety of market segments and deliver critical power solutions that provide excellent value in the areas of high efficiency, rapid deployment, total cost of ownership, scalability, premier service and support," according to a leading global supplier.

Over the years, UPS evolution has resulted in making the equipment smaller, lighter, more efficient, and more reliable. In 2008, transformerless designs appeared on the scene. These new systems, using insulated bipolar gate transistors (IGBTs) to handle high voltages, eliminated the need for a transformer to step-up the voltage following the inverter. Transformerless designs are now preferred and the norm across the industry, favored because they are smaller in size and lighter than their predecessors. A further advance has been the three-level topology, which utilizes three output voltage levels. The additional level promotes lower voltage stress on power semiconductors, leading to reduced switching losses and, for that reason, higher efficiencies. The latest innovation is the use of silicon carbide (SiC) as a material in the semiconductors. SiC reduces the size and weight of UPS modules while also boosting their efficiency, according to experts.

Applied Technologies for Building Benefits

With better efficiencies, smaller footprints and weights, and enhanced capabilities for protecting end-user operations, UPS systems have become a significant selling point that engineering and architecture teams recommend to clients. In today's environment of increasing demand for cloud and colocation services, hyperscale megawatt UPS systems are often seen as a best-in-class facility feature to address the unique needs of colo and cloud data centers, with dense server usage and other critical systems. Medium-range UPSes, such as 750 kVA products with SiC, apply to data centers and facilities with loading of 1–5 megawatts. To back up smaller enterprise operations or IT closets, three-phase UPS systems serve loads of 10–80 kVA to extend system reliability beyond the facility's utility power room to offer high-performance power protection for end-user critical loads.

Reliability is the most important qualification for UPS choices, yet most manufacturers only estimate their UPS reliability rather than using accelerated testing or installed track record and customer history. Some market leaders provide detailed reliability data, including the installed base of 9900 Series UPS systems (Mitsubishi Electric), which have been verified to provide uninterruptible power supply that has sustained load-carrying capability of more than 99.999% throughout the product line's operational history.

Such unique products lend themselves to best-in-class building operations, thanks to their category-leading reliability, efficiencies and, ultimately, satisfaction of specific tenant requirements. The novel technologies boost ROI while reducing TCO.

HVAC Systems

A third area to consider in terms of top-level building reliability, efficiency and successful operation is the HVAC system, which is an ongoing cost to the owner and a common source of operational challenges. In addition, HVAC systems are central to achieving sustainability goals and supporting occupant wellness within a building. To that extent, HVAC infrastructure becomes a critical element in creating value for the project client.

The challenges and opportunities for MEP improvements are considerable. On average, 39% of energy use in commercial buildings is attributable to HVAC systems, according to Carl Ian Graham, P.E., of Viridian Energy & Environmental, Inc. High-performance HVAC systems can save 10–40% of energy, emissions and costs, and even greater savings up to 70% are possible through whole building design, Graham concludes in a report for the NIBS Whole Building Design Guide. Improved comfort and thermal control are essential to indoor environmental quality (IEQ) and a positive occupant experience. One example includes humidity control in warm climates, which addresses excessive humid air and moisture accumulation in materials, which in turn can lead to upper respiratory infections, asthma and other health challenges, according to experts in the industry.

Among the advances addressing these HVAC challenges in commercial applications are innovative, zone-based VRF cooling and heating systems. First, two-pipe VRF systems have been shown to speed installation as well as reduce piping and space requirements for the HVAC system while also improving building operations, says Llewellyn. The two-pipe VRF system design allows independent control of various interior zones, whether controlled by the occupants or the facility manager. In either case, the ability to control IEQ conditions has been shown to boost satisfaction and comfort among building occupants while minimizing operating and life-cycle costs. In addition, novel platforms are emerging to control building systems remotely, appealing to end users who value localized controls. Second, inverter-driven compressors are designed to boost the efficiency of VRF systems. By varying the compressor's speed to precisely meet each zone's conditioning requirements, the resulting increases in efficiency provide substantial cost savings for the owner and improved sustainable design opportunities for AEC project teams.

While heat recovery VRF systems already offer significant efficiency gains of up to 25%, the technology continues to advance. New products entering the market include improved air-source outdoor units, up to 30 tons in capacity, with zinc-aluminum flat-tube heat exchangers that significantly improve efficiency ratings. Not only that, the outdoor unit's footprint can be as much as 30% smaller than previous generation equipment from Mitsubishi Electric Trane HVAC US. This creates flexibility in building layouts and provides more usable exterior space for a building owner. These units also can significantly reduce the amount of refrigerant required for HVAC operations.

Summarizing the recent growth in the application of VRF systems, Buildings magazine reported, "With its improved flexibility making it viable for most types, sizes and locations of facilities, VRF systems have outpaced the growth of other types of HVAC technologies over the last decade, making up roughly 6–8% of all HVAC systems in the U.S. Its use in commercial facilities is expected to continue growing, fulfilling its status as the HVAC system of the future." On the installation and maintenance side for VRF systems, the use of preferred contractor networks can be essential to translating the manufacturer's strong record of reliability into better system design and installation, as well as improved MEP performance and facility operations.

COLLABORATION, SERVICE AND TRACK RECORD

Whether for elevators and escalators, HVAC systems, or UPS equipment, these valuable technology innovations are matched by new ways for AEC project teams and their clients to benefit from collaborative supplier partnerships. These contracting approaches may cover design assistance, installation oversight and building operations services. An increasing number of architecture and engineering firms, construction managers and contractors recommend these procurement and contracting methods to benefit the client over the long term. Many of the approaches are customized and exclusive, giving the client peace of mind while empowering suppliers to boost creativity and service benefits.

"These approaches help building teams find suppliers and product solutions that focus on the project circumstances and the owner's unique needs to supply the right system design—before, during and after the project delivery phases," says Kevin Miskewicz, director of commercial marketing for Mitsubishi Electric Trane HVAC US. According to the company, such alliances are marked by:

→ **Collaborative solutions.** The primary goal is that major building systems perform consistently. Starting with a reliable product and exacting installation methods contributes to this goal, but the provider must also emphasize the use of adaptive, custom solutions because they clearly meet the operational needs envisioned by the building project's AEC team, according to Mitsubishi Electric Trane HVAC US.

→ **Responsive service.** The manufacturer's or supplier's team of employees must share a basic commitment to serving the AEC team and the client owner or developer all the way from product recommendations and specifications through purchase and full life cycle of the installed systems.

→ **Partner relationships.** The study of partner relationship management (PRM) and partner-to-partner relationships by organizational experts has been applied to commercial building design, construction, development and operations. According to Mitsubishi Electric Trane HVAC US, evidence shows that stronger relationships with partners tend to accelerate innovation and increase profitability or create new revenues, or both, for the building projects and overall client portfolio.

According to IDC, entities that associated 30% or more of their revenue with partner-to-partner collaboration were the fastest-growing organizations, achieving 19% growth vs. about 10–12% for others. The partner model also supplies design and product solutions associated with innovative buildings and renovation approaches. For example, installations exemplifying the versatility and flexibility of VRF technology often result from partner-based project teams.

REDUCING OPERATING COSTS, BOOSTING VALUE

The supplier partner is also essential to reduced TCO, or total cost of ownership, which may be a key metric for some client owners and developers. In many cases, owners and end users can benefit from single-source or sole-source contracting agreements. Single-source approaches allow the owner-developer to move from vendor to vendor or, in some cases, to renegotiate with the originally selected supplier, providing alternatives if the initially selected supplier proves inadequate. Sole-source contracting can reduce the time needed for the owner-developer organizations to contact various vendors, solicit pricing and negotiate operating agreements. In sole sourcing, administrative costs are often reduced.

According to leading AEC teams, the basis for either type of partnership agreement must focus on (a) installed system lifetime horizon; (b) equipment reliability and maintenance track record; (c) system design impact on operating expenditures such as energy use, replacement parts and disposal costs; and (d) likelihood of unplanned expenditures—“surprise costs” that reflect poor system predictability.

Speaking to these specific factors for supplier alliances and exclusive contracts, reports by one global manufacturer demonstrate the specific variables most likely to affect TCO and therefore system ROI and overall building profitability. According to the studies, these factors have a similar influence on profitability for vertical transportation, UPS and HVAC systems, the three building systems considered in this white paper:

→ Equipment should be durable and competitive in terms of operations. Consider products designed with testing and track records indicating an advantage over competition offerings. This is a key path to reducing future and overall capital expenditures.

→ Study manufacturer and product claims for overall **callback rates.** The lowest overall callback rates ensure reductions in monthly and overall maintenance costs. Some leading suppliers can assure low or zero unplanned costs, increasing reliability and reducing uncertainty in building operations. (Examples include the elevator example cited above, with callback rates averaging less than one per year per elevator, compared to two callbacks per year claimed by competitive systems and up to five callbacks per year as documented by field studies and interviews by elevator consultants.)

→ Review manufacturer history for the **operating lifetime** of specific equipment and products. Some building products and systems for vertical transport, for example, provide functionality for 30 years or more, which compares favorably to industry averages of 15–20 years for the same systems by others.

→ Analyze **MRO needs** and quantify the costs of downtime. Investing in robust system design structures may be essential to ensuring that key parts will not fail during building operations, which is a source of unplanned costs and tenant disagreements. In addition, AEC teams can design buildings and make material and system selections with the aim of reducing overall maintenance expenditures and helping the client group avoid surprise costs.

With these benefits and a challenging economy at hand making competition among properties very tight, savvy building teams have found ways to leverage building systems as competitive resources in a number of ways. Not only do the novel systems offer significant gains in efficiency, they also drive varied benefits in building operations. As seen in the examples and studies cited in this white paper, a number of core building system advances are helping pave the way forward for AEC teams and their innovative building projects in commercial sectors.

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