Anticipating staffing and budget needs for sophisticated building management systems

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1. Introduction – Sophisticated Building Systems

Sophisticated building systems in new or renovated schools provide advantages in air quality, environmental efficiency, and acoustics, and generally require a greater level of attention to operation and maintenance than the less advanced systems they replace. Sophisticated understanding of mechanical, electrical, and computer-software controls systems is required to operate and maintain these new or renovated buildings, potentially requiring the hiring of new facilities personnel or new training for existing personnel — which means new costs. Similarly, more complex routine maintenance and the purchase of more sophisticated and numerous supply parts may create new costs. Finally, while these building systems are more energy-efficient, they may be more costly to run due to significant building upgrades, such as increased capacity for classroom technology, or air conditioning.

Active participation by school district facilities and business-office personnel in the planning, design, construction, and post-construction of new or renovated buildings, as set forth in these recommendations, will help districts control and plan for added costs.

These recommendations are compiled from many sources: the experience of districts who have worked with the MSBA to build schools with successful, sophisticated building systems; mechanical, electrical, and plumbing engineers who design these schools; consultation with the Massachusetts Facilities Administrators Association (MFAA); government and industry standards; and, guidelines for the operation and maintenance of schools and other buildings. The recommendations are intended to furnish districts with the right questions to ask, and to provide districts with context about when in the life of a project to ask these questions; the MSBA does not purport to have the answers to the questions, which will be different for each school district. These standards also do not address the additional challenges posed by the outbreak of communicable diseases such as the COVID-19 pandemic.

2. School District Personnel

Having the right school district personnel involved will be a crucial factor in understanding and controlling costs. Both business management staff and facilities management staff are integral to planning for the costs associated

with the new or renovated building. The facilities staff, in particular, will need to have specific core competencies.

To operate and properly maintain the new or renovated building, facilities staff will need thorough knowledge of:

- Electrical systems/Lighting Controls
- Computerized Maintenance Management Systems (CMMS)
- Heating, Ventilation, and Air Conditioning (HVAC) systems
- Mechanical and plumbing systems
- Boilers
- Maintenance programs standards
- Key performance indicators
- Materials management
- Building Management Systems (BMS)
- Emergency response procedures
- Hazardous Materials management
- Regulatory Compliance procedures

For facilities team members operating and maintaining the new or renovated building, relevant experience and education may include a Bachelor's Degree or equivalent related experience in mechanical engineering, electrical engineering, industrial engineering, or smart building technology. Along these lines, districts are advised to develop written job descriptions for custodial and maintenance staff that clearly delineate duties and responsibilities, as well as minimum qualifications.

Districts are encouraged to develop a training protocol for existing or newly hired staff including orientation, instructions on operating equipment and major building systems, and safety protocols. The time to start planning for staff training is during design, and training should be implemented no later than the construction and turnover phases of the project, when the designer, manufacturers' representatives, commissioning consultants, installers, and contractors are all still on site and available.

Staff may also require specialized training for health, safety, and code compliance, and training in how to improve the energy efficiency, air quality, and comfort of the school building.

Being well-trained and having this core competency will allow district personnel to operate and maintain complex building systems, as well as to participate actively and constructively in the design, construction, turnover and post-construction phases of the new or renovated building.

3. Vendors and Proprietary Systems

During the design phase, the district will determine how much of the operation and maintenance of the new building systems will be performed by district staff, and how much will be contracted to service providers. District business management staff and facilities staff will play an important role in this determination. Skillsets, required specialty equipment, and availability of existing staff to perform maintenance tasks must be considered in determining who will perform the work.

After building occupancy, district personnel may be called upon to manage certain vendor contracts. Even when the district is under contract with a vendor for maintenance of a particular system, not all maintenance of that system will necessarily be carried out by the vendor. Staff with requisite understanding of building systems will determine when specific issues can be addressed in-house and when to call an outside vendor. Involvement in the design and construction of the school will prepare district personnel to make these determinations. Proposals should be requested from the vendor who installed the system as part of the project, as well as from other qualified vendors to ensure that competent and cost-effective service providers will be engaged to perform the required services.

Proprietary systems may impact the ability of the district to maintain or repair systems with its own staff or using other long-term vendors with whom the district has worked. There are both advantages and disadvantages to proprietary systems. For example, if a district has a district-wide building controls system by which it operates all its other schools, any incremental cost associated with such a system in the new school may be justifiable. On the other hand, the installation of a particular manufacturer's systems or units may require maintenance by the service-division of the same manufacturer, locking the district into a particular contract more expensive than competitors' rates. This is particularly true of controls systems. Districts are encouraged to work with their designers to understand the implication for any future service contracts associated with the building systems they choose. The construction of a new school in a

district is a good opportunity to re-evaluate the benefit of establishing a district-wide controls systems with one vendor. In all situations, the equipment and controls specified and provided should be compatible with BACnet, or a comparable open-protocol communications protocol for Building Automation and Control (BAC).

4. Budgeting

District business managers and finance officers are encouraged to work with district facilities personnel and with the design and commissioning teams throughout the process of design, construction, turnover, and post-construction, to anticipate and shape budgetary considerations associated with operating and maintaining the sophisticated, new building systems. Contrary to the understanding of many, new buildings are likely to be more expensive to maintain than the buildings they replace due to increased electrical infrastructure, air conditioning, air exchanges/energy recovery systems, and technology infrastructure. Moreover, utility costs may be increased due to an increase in the overall size of the building. With the recent push to net-zero buildings and fossil-free fuels, it is particularly critical to develop accurate budgets for electricity. While developing these budgets, districts will have the opportunity to take into account models prepared by project consultants.

Air filters are an example of an additional cost to be anticipated while budgeting for a new or renovated school building. The air handling systems in such buildings are designed with increased air filtration to provide healthier air quality. The increased filter capacity creates a significant increase in cost as compared to the traditional filters in older buildings. The district should work closely with the construction team to establish annual filter costs for proper maintenance of equipment well before substantial completion.

Establishing temperature set points during design and getting “buy-in” from the new school users on these limits will help minimize one-off requests for changes to the operating system, and help the district anticipate and control its budget. Once set points are established, it is important to develop a plan for engaging building occupants to help them understand the implication of overriding set points. For example, communicating the cost and carbon footprint (CO_2 emissions) impacts of a

1-degree temperature change in a large school may be helpful in getting the users to adhere to the established limits.

In budgeting for the new building systems, the districts are advised to operate buildings as they were intended, in a cost-effective manner. Operational budgets can be controlled through a proactive maintenance plan of (1) written maintenance manuals, (2) preventative maintenance, (3) an inspection program, and (4) an automated/computerized work order system. Anticipating adequate budgetary resources for employing and training district facilities staff will also be an important aspect of the overall budget.

5. Proactive Maintenance Plan

(a) WRITTEN MAINTENANCE MANUAL

Working with the designer, manufacturers' representatives, commissioning consultants, installers, and contractors, district business and facilities staff are advised to develop a written operation and maintenance manual that is both robust and realistic. It is important to develop a maintenance system that takes into account both the needs of the system and the district's capacity for maintenance to meet those needs. When preparing the manual, particularly as it relates to preventive maintenance, districts must consider both the "ideal" budget that would provide for all services recommended in manufacturer's Operation and Maintenance (O&M) manuals, as well as a potentially more likely or "realistic" budget that will actually be approved. For example, the manufacturer may recommend service on a particular piece of equipment three-times per year; whereas available budget allows for only two service visits. Facilities staff must identify the most critical equipment when prioritizing preventive maintenance tasks.

District personnel should be involved in determining the format of the manual, including the extent to which the manual will be presented in electronic form with links to other components of the maintenance program. The contractor may be helpful in developing an operation and maintenance manual in a format that will be useful to district personnel.

The written maintenance manual for the new or renovated school building should be designed to engage a Computerized Maintenance Management System (CMMS) for preventive maintenance planning and tracking. An

integrated CMMS is generally used district-wide, and purchased separately from the school building project. Yet the controls system of the new or renovated building can be designed to provide alarms that directly interact with a CMMS.

A centralized CMMS allows for ease of scheduling across buildings, running reports for past activities, and identifying trends from maintenance data. A CMMS can also be used to estimate levels of maintenance effort for staff planning purposes and assist with maintenance budgeting. The CMMS should be fully operational during construction to allow the staff to immediately begin planning and tracking maintenance. Contractors are often able to pre-load all the specific aspects of the new building systems into the CMMS for district use.

A useful maintenance manual addresses all aspects of maintenance, including:

- Minimum custodial and routine maintenance standards that govern day-to-day operations
- Standards and benchmarks for effective maintenance
- Preventative/predictive maintenance plans and schedule
- Operating instructions for specialized equipment
- Instructions regarding emergencies and protocols regarding safety
- Protocols to maintain healthy air quality and building comfort

(b) PREVENTATIVE MAINTENANCE

Preventative maintenance is vital to all school buildings but may be particularly challenging given the aforementioned budget challenges, and the unfamiliar nature of many of the new systems that maintenance staff will be called upon to maintain. Given the challenging parameters of new building systems, districts are encouraged to begin early in the design phase, and to continue throughout the construction phase, to define the activities that must be performed at regularly scheduled intervals to prevent premature failure and to maximize the useful life of the building systems and facility. Preventive maintenance applies to the entire building, including site features, and all its building systems and components.

In developing the operation and maintenance manual discussed in section (a) above, and in cooperation with the designer, manufacturers'

representatives, commissioning consultants, installers, and contractors, facilities staff are encouraged to compile a complete list of the building components, including usage, location, warranty information, and model type. The contractor, subcontractors and commissioning consultants may be instrumental in this work, as well as in creating the manual itself.

(c) INSPECTION PROGRAM

As early as the design phase, district facilities staff are encouraged to develop an inspection program for the new building systems; such a program is the cornerstone of the preventative maintenance program. The initial inspections also serve as an opportunity for the facilities staff to become familiar with the building, and should be orchestrated by the Owner's Project Manager, and performed in conjunction with the designer, manufacturers' representatives, commissioning consultants, installers, and contractors, as appropriate.

Inspection of all systems should be conducted on a regular basis and include examination of predetermined building components. Because there is often limited time available for this work, these inspections can be made more manageable by assigning certain tasks to the custodians who work in the schools. Since they work in these buildings every day, they can perform initial checks by "putting eyes" on the systems. Maintenance and management staff can follow up when issues are reported. Standardized checklists for the components facilitate the process as they enable inspectors to collect consistent information and complete thorough inspections. This method enables year-to-year comparisons that can be applied uniformly by individuals responsible for the inspections. The District is encouraged to develop:

- Standardized forms and checklists and a standard condition rating system that allows inspectors to observe building components logically and record data uniformly.
- A detailed schedule of inspections for each building within the district and all building components within each building.
- A methodology for storing and retrieving the data collected.
- A link to the district's work order/capital program plan for deficient items found during inspections.

(d) COMPUTERIZED WORK ORDER PROGRAM

Districts are encouraged to adopt a work order program that is integrated into a Computerized Maintenance Management System (CMMS), as discussed in section (a) above, for preventive maintenance planning and tracking. Use of such an integrated maintenance management system allows a district to set maintenance schedules, work orders, and reminders, which interface directly with the Building Management System (BMS), discussed below. Although preventive maintenance tasks can be managed using a manual system, a CMMS increases efficiency and the capacity to perform analysis. Cloud-based systems can be purchased at reasonable costs, which require no hardware/software and are user-friendly.

The district is encouraged to budget for such a work order system to be configured to systematically track planned and completed maintenance activities, including both scheduled preventive maintenance and also emergencies.

Whether the job originates as a problem communicated by building users or as part of a planned maintenance project, a work-order system provides uniformity in planning maintenance jobs. Using work orders for upcoming preventive maintenance tasks helps schedule the work and assign responsibility among multiple maintenance projects.

These best practices apply to both internal employees and outsourced service providers. Contracted services must conform with the district's expectations and guidelines, including their use of the district's CMMS system to track the performance of both preventive and reactive maintenance work.

6. Design and Construction Choices

During the design phase, the district will be called upon to make choices that will impact the long-term maintenance costs of the building. Participation by district personnel from both the business management and facilities management staff is important. Upon completion of the design, budgetary and facilities staff will continue to play an important role throughout construction and post-construction, where important decisions impacting functionality and cost will continue to be made.

(a) PRE-DESIGN

Even before entering the design phase, districts are advised carefully to consider their contractual relationships with Designers, Owner's Project Managers, and Contractors or Construction Managers, to ensure that responsibility for a properly functioning building management system is accurately defined and assigned. Districts should clearly indicate to the Project Team any building systems that they currently have, and for which they require proprietary procurement as part of the project, such as BMS systems. While all parties play a role to make sure the building systems operate properly, accountability that is not specifically assigned to individual parties can result in finger-pointing and unresolved issues. The contracts themselves must clearly define which party has ultimate responsibility for designing the system, and for ensuring that the installation of the building systems meets the design intent. Responsibilities such as inspection, testing, and trouble-shooting must be clearly defined so they can be included clearly in system specifications for the equipment and associated controls.

(b) DESIGN PHASE

During the design phase, the district is encouraged to work with its designer to understand the long-term operation, maintenance, and system replacement costs. District facilities and budgetary personnel will be integral to: (1) choosing the right systems; (2) foreseeing post-construction costs of operation and maintenance; (3) estimating cost and timing for replacement of key aspects of the system as they reach end of service life and, (4) making sure the systems are understandable to those who will operate and maintain them.

The building codes drive a high level of energy efficiency in construction, and many districts have their own higher standards when it comes to building environmentally-sustainable schools. Yet all environmentally-sustainable solutions do not come with the same maintenance requirements, and districts are advised to be as specific as possible in identifying their local requirements so as to anticipate costs. In general, districts should consider use of proven systems that have been successfully used in schools for many years. Caution should be used whenever considering new or emerging technology that does not have a track-record. Districts are encouraged to visit newly constructed schools with similar

systems, to gather accurate and reliable feedback from the facilities and business personnel at these schools.

(i) LIFECYCLE COSTS

The designer will present the district with a Lifecycle Cost Analysis, which will detail various proposed building systems and take into account the cost of installation, the cost of operation and maintenance, the cost of replacement of key components, and projected returns and savings based on energy efficiency. Districts are urged to have qualified facilities management and business management personnel actively involved in the analysis of projected operation and maintenance costs during the Lifecycle Cost analysis.

Operation and maintenance cost estimates are a projection based on the specific past experience of operation and maintenance costs associated with each of the proposed building systems. District personnel are encouraged to carefully study and to fully understand the basis for these estimates. How did the designer derive its numbers for past experience? What was the type, shape, and layout of building used when modeling such experience? How large a sample of building types did the designer use?

Using both the operational costs and the maintenance costs presented as part of the Lifecycle Cost Analysis to understand each proposed building system is one of the best ways for a district to choose the building systems that are best for the district. The system with the lowest operating costs may not be the system with the lowest maintenance cost. Accordingly, districts must carefully consider the expected maintenance budget that will be approved when evaluating these criteria. For example, a slightly less-efficient system may be a more appropriate choice for a district where maintenance budgets are more challenging.

(ii) ESTIMATING SYSTEM COSTS

One way that designers model the costs of installing building systems is by estimating the costs of each component of the equipment, generally assigning a number of "points" to each piece of equipment. Then the total cost of the system is derived by multiplying a fixed unit cost (for example, $2000) per point. Districts are encouraged to work with designers to develop a similarly specific, quantifiable approach to extrapolating

operation and maintenance costs from the specific pieces of proposed equipment. Districts should closely model and assess each element of the energy-efficiency infrastructure, such as photovoltaic technology or geothermal wells.

New systems generally require more maintenance than the old systems. While new building systems generally cost more to operate and maintain than the systems they are replacing, not all new building systems will have the same maintenance costs. For example, chilled beams have fewer moving parts than VAV units, so may have a lower maintenance cost.

Reaching out to staff in other districts that have similar systems to those proposed for a new project is also an excellent way not only to obtain cost information, but also to understand how the systems have performed and any issues that other districts may have had operating them. It is good practice to ask the designer and/or contractor to provide contact information for business and facilities staff in districts with similar installations.

One of the greatest cost savings during the design phase will be to make good choices for the district in order to prevent post-construction costs associated with expensive new systems that do not function as designed, or which the district will not be comfortable operating as designed.

(iii) BUILDING MANAGEMENT SYSTEM

Building systems that regulate the air quality, temperature, and environmental impact of a building are generally designed to function automatically through a Building Management System (BMS), which coordinates all the building equipment.

Each unit of equipment within a building system comes with its own software that manages the internal functionality of the equipment. This equipment-specific software, or controls system, interfaces with the BMS, which is a system-wide controls system. In this way, the BMS allows the equipment to integrate with the other equipment and building systems comprising the building system as a whole. As mentioned previously, it is important during design to ensure that all specified equipment is BACnet compatible, or compatible with an equivalent open-protocol communications protocol.

The BMS provides the user interface which the building staff will access to establish the operational schedules, defining when the heating, cooling, ventilation, or lighting systems begin to operate, and the rate of operation for various operating modes, such as startup mode, occupied mode, or unoccupied mode. The BMS will also be used to maximize the most efficient settings and to troubleshoot the system for operational issues.

The BMS employs technically complex software which may be difficult for district staff to access or modify. Moreover, as stated above, a BMS is normally a proprietary system and may require a specific, dedicated vendor contract. Understanding not only the functionality of the BMS, but also the contractual vendor implications of such systems is an important aspect of the design phase. Districts are encouraged to work with their designers to understand whether certain Building Management Systems or controls systems require maintenance by specific vendors, thereby excluding other vendors, perhaps even excluding vendors working in the old school building that is being replaced, or even precluding some forms of maintenance by the school staff itself. Training on the BMS for facilities staff working in the new or renovated school is probably the most important of all training. There are also different levels of training required. Custodians who open the building and use the system to check for alarms may only need limited training; whereas, facility managers or maintenance staff may require a higher level of training that allows greater use and manipulation of the systems.

To the extent the BMS and controls systems are proprietary and limit the ability of the district staff to make changes or respond to issues, the district is encouraged to work with designers, contractors, installers, and manufacturers to understand not only the mechanisms (often alarms and user interfaces) by which the district will be alerted to issues, but more importantly, the means at the district's disposal to address issues that arise. To what extent can the district diagnose and address issues in the controls software that may arise?

In addition, closed proprietary systems may preclude upgrades or changes that involve units or components from all manufacturers other than the manufacturer of the proprietary system. A solution to avoiding such closed systems is to specify an open building management system, such as one that requires all equipment and software to be compatible with BACnet or

its equivalent. This means that a district can create a building system with equipment and software from multiple manufacturers.

Similarly, while many manufacturers produce BACnet-compatible (or equivalently compatible) units, installation of non-compatible units may make it more difficult to integrate the new units with the controls software of other units of equipment and with the BMS itself.

(iv) MODES AND SEQUENCES OF OPERATION

It is vital during the conceptualization and design of the building, that the staff who will eventually operate and maintain the building be involved in selecting the functionality and modes of operation (including start-up, occupied, and unoccupied) that are best for the school. School administration staff should be involved in discussions about temperature set points and how much change (in terms of degrees) will be allowed (if any) on the room thermometers by the room occupants. The building staff must understand what the system is designed to do, so they can identify errors that may arise during operation. When issues arise in the operation of the building, the staff must understand which issues they can address themselves, and which issues may require the services of an outside vendor.

To ensure that systems function as designed, the district must provide the designer with its desired modes of operation during design. Once the modes of operation are set, sequences of operation must be developed to support the modes of operation. A sequence of operation is the order in which units of equipment are designed to operate. The district should work with the designer to standardize the sequences of operation to limit the need for controls contractors to interpret them. Such standardization helps ensure the design intent is met during construction, leaving less room for building systems to malfunction or diverge from the intended sequence of operations.

(v) FUNCTIONAL TESTING

Functional testing should be specified by the Designer in the construction documents to ensure the tests of individual units of equipment integrate with the testing of the full system. Districts are advised to work with their designers to specify four-season testing, rather than specifying testing

which relies on simulation. Districts are advised to secure designer participation in these tests.

(vi) ONGOING COMMISSIONING

Districts may also consider "ongoing commissioning." Building Management Systems provide data analytics and fault-diagnostic software that can significantly automate functional testing, and allow for sustained analysis of systems' functionality. This automated, sustained "testing" may be considered "ongoing commissioning," and may be a useful supplement to the on-site tests generally performed by commissioning consultants.

(vii) ALARMS

Building Management Systems are designed to communicate maintenance needs to the building staff through alarms. Building Management Systems are so complex, however, that alarms can be sent to the building maintenance staff in an unmanageable daily quantity. It is advisable, therefore, that alarms be organized, filtered, and communicated to district staff in an optimal manner. District maintenance personnel are encouraged to participate in establishing the optimal fashion for alarms to be delivered, as well as to understand how to alter delivery methods over time.

(viii) SUB-METERING

Electrical and natural gas systems are generally capable of sub-metering, allowing operators to optimize energy usage by metering each individual unit of equipment, as well as the system as a whole. This enables districts to isolate potential excess or inefficient equipment use, resulting in excess energy consumption. However, not all districts take full advantage of this potential or have staff prepared to engage in analysis of the results of sub-metering. Business managers and facilities managers are encouraged to engage with designers to understand the potential advantages of using their systems' sub-metering capacity.

(ix) LIGHTING SYSTEM

Lighting systems and lighting controls systems can be very sophisticated, but may have components that the district will not utilize, which may create unnecessary complication for the district. Districts are therefore

encouraged to fully understand the features of lighting systems and lighting controls systems, and to carefully weigh their utility.

Operation of the lighting system can be integrated into the HVAC system so that a single occupancy sensor triggers both lighting and temperature control. Districts should consider the pros and cons of such integration, because some systems which integrate both may sacrifice functionality for integration. In addition, for lighting systems, it may be advisable for the system not to turn the lights on automatically when people re-enter a space, but to require occupants manually to turn the lights back on, so as not to compromise lockdown procedures.

(x) TRAINING

Additionally, specifications should be crafted in such a way to allow district personnel ample and appropriate training on the new building systems and BMS itself; such training must be offered sufficiently early in the project, and may best be iterative, allowing time between sessions for questions to be raised after a period of routine operation of the building systems. (See Best PracticesGuidelines for Training Program.)

A district may wish to provide supplemental training or professional development to its maintenance staff, or even engage new staff with requisite levels of experience and expertise. Such staffing needs should be identified early in the project and anticipated when budgeting.

(c) CONSTRUCTION PHASE

During construction, it is critical to ensure that the controls systems, as installed, meet the design intent and the district's operational requirements

It is highly recommended that district personnel participate in regular construction meetings, and observe the installation and testing of the complex building systems, controls systems, and BMS. Such involvement fosters more extensive experience with the systems than can be provided by trainings alone, and also allows the district to participate in decisions that may impact future operation and maintenance costs.

During the construction phase, it may also be advisable to provide remote access to the designer and commissioning consultant to enable sustained and consistent monitoring.

(i) COMMISSIONING

Commissioning ensures that the new building, or new systems of a renovated building, operate as the owner intended, and that building staff is prepared to operate and maintain the new systems and equipment. The commissioning consultant is a third-party employed by the MSBA, with no contractual relationship to either the contractor or designer; their role is to help make sure the school district is provided with the building the school district expects.

Facilities staff are advised to actively participate in the commissioning process, with the support of the designer and Owner's Project Manager. The commissioning process exists to verify building elements and systems are installed and operating as designed and specified. The process focuses upon verifying and documenting that the facility and its systems, components, and assemblies are planned, designed, installed, tested, operated, and maintained to meet the district's project requirements.

(d) TURN-OVER AND OCCUPANCY

During the post-construction phase, the district begins to operate its new or newly renovated building, with its own staff and through service contracts. Only detailed understanding of the building systems, developed during the design and construction phases, will allow districts to determine which aspects they can maintain themselves, and which aspects of the system will require a service contract with a vendor. During the turn-over phase, the district can avail itself of learning opportunities from the contractor, designers, and commissioning consultants, to assess its readiness to manage systems in-house and assess its choice of service contracts.

The district is advised to plan for transitions and turn-over in its staff. Such planning includes the transmission of important documentation such as as-built construction documents, operation and maintenance manuals, training materials, and other important documents and material.

Participation in training and observing four-season testing during the turn-over and occupancy of the building will enhance the district staff's ability to operate and maintain the building.

As during the construction phase, it may also be advisable during the post-construction phase to provide remote access to the designer and commissioning consultant to enable sustained and consistent monitoring.