Building Automation and Control Systems: A Facility Manager's secret weapon?

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ABSTRACT

Background and aim - This paper presents a perspective on the interaction between Building Automation and Control Systems (BACS) and facility management. BACS have the potential to improve energy efficiency and comfort, while assisting the facility management department. However, certain uncertainties hamper the mass implementation in office buildings.

Methodology - Relevant literature is analysed to provide a comprehensive overview – of the current state-of-the-art -, in addition to preliminary insights from interviews with facility managers, on which the authors viewpoint is based.

Results - Results from literature reviews indicate that BACS can support facility managers with strategic decision-making and finding a balance between energy efficiency and comfort levels. However, the efficacy of BACS implementation is strongly case dependant. Challenges with BACS, such as obsolescence and interoperability are found in literature and backed by interviews already performed. These challenges will be examined in the B-CLIC research.

Originality - To our knowledge, there is no previous research conducted on the benefits and challenges concerning facility management and BACS. The aim of B-CLIC in quantifying costs of smart building technologies over the life cycle is unique.

Practical or social implications - A future aim is to provide a holistic design view of LCCA and the energetic impacts of BACS. Facility Managers, Energy Service Companies (ESCos), BACS manufacturers, etc. could benefit from this because there is more certainty about their operation and costs in practice.

Type of paper – Viewpoint paper

KEYWORDS

Facility Management, FM, Building Automation and Control Systems, BACS, Smart buildings, energy performance, LCCA.

INTRODUCTION

Given that buildings are responsible for 30% of global final energy consumption, the need to improve their energy performance is evident across various building types (Delmastro, 2022). For instance in office buildings, where facility managers have a vital role in ensuring sustainable environments that offer optimal comfort to occupants. Traditional measures for reducing energy consumption of buildings include minimizing thermal transmission, increasing the efficiency of technical installations, installing

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renewable energy sources or reducing energy loss through air leaks (Li *et al.*, 2013). A more recent development is the implementation of Building Automation and Control Systems (BACS) which could support a facility manager in the tasks to reduce operational energy consumption. EN 52120-1 describes BACS as a system comprising all products, software and engineering services for automatic control, monitoring, optimization for operation, human intervention and management to achieve energy-efficient, economical and safe operation of building services and is often referred to as a Building Management System (BMS) (NBN, 2022). BACS can ensure efficient control of heating, cooling, ventilation, domestic hot water, lighting and shading while maintaining or improving comfort. These systems typically comprise hardware components, i.e., sensors, actuators, interfaces, servers and controllers, and communication protocols, i.e., BACnet, Modbus and LONWORKS combined with software for energy management (Domingues *et al.*, 2016a). Thus, BACS can assist a facility manager with making strategic decisions about the sustainability of a facility through all kinds of collected data regarding time-related energy consumption (Pun *et al.*, 2017a). Despite its significant potential, a BMS is a complex system, and components are susceptible to malfunctioning and security risks (Aste *et al.*, 2017; Graveto *et al.*, 2022). As a result, maintenance costs can become unforeseeably high and due to the rapidly evolving market, not all replacement parts remain available.

This paper will delve deeper into the benefits and risks of BACS for FM in office buildings. After the state-of-the-art concerning the potential of BACS for FM and energy savings, the viewpoint of the authors will be provided about what changes are necessary to unleash the full potential of BACS.

LITERATURE STUDY

Benefits and challenges of BACS for a facility manager

Historically, facility management and maintenance were regarded as ancillary expenses. However, research from Pun et al. (2017) found that non-optimal maintenance planning can lead to 18-30% of additional maintenance costs . BACS, a more recent development, has potential benefits in supporting facility managers to realise a cost effective and more sustainable way of maintaining buildings (Atkin and Bildsten, 2017; Osma et al., 2015; Pun et al., 2017).

BACS have many benefits for facility managers, such as support with data-driven strategic decision-making in function of increasing the life expectancy of the building (Domingues et al., 2016). BACS collect and analyse large amounts of physical data, e.g., temperature, daylight illuminance and air quality. This data is combined with historical data, occupant behaviour, project information, weather data, etc. to support the facility manager with selecting the correct setpoints and creating a better maintenance plan to improve the energy consumption, the comfort level for occupants and the life cycle of the different components of BACS. This supports the facility manager to combine contrasting goals, such as an ideal comfort level and optimal energy efficiency (Domingues et al., 2016; Ramsauer et al., 2022). A well-equipped BACS assists in reducing operational costs through preventive maintenance and condition-based maintenance. An even more efficient form of maintenance could be possible by adding Fault Detection and Diagnostics to BACS, resulting in the ‘predictive maintenance’. This can lead to savings of

5-30% according to Dong et al. (2014). With predictive maintenance, it is possible to avoid defects and breakdowns in for example HVAC, lighting and blinds, because it notifies the facility manager in real time when and where maintenance is needed based on anomalies in the data. These anomalies are detected by comparing current data to historical data. If a facility manager responds adequately to the alarms of BACS with Fault Detection and Diagnostics when it detects an upcoming defect, possible breakdowns of the system can be avoided, leading to a better efficiency of the organisation in the building and a higher comfort level for the building occupants. In addition, it improves the sustainability of a building by extending the service life of materials and installations, this results in less waste being produced.

However, predictive maintenance requires a higher initial investment in BACS relative to a reactive maintenance approach. In addition, predictive maintenance is also a relatively new concept, which means it is still under development due to the complexity of the system to autonomously determine when and where maintenance is necessary (Bouabdallaoui et al., 2021). Other challenges in BACS are caused by rapid developments in technology, such as developments in the storage capabilities as well as the intelligence of BACS due to the ever-growing amount of collected data that needs to be analysed and stored. Another challenge is the risk of obsolescence, which means that parts of BACS are no longer supported for maintenance in their original state because there are no resources or the components are too expensive (Alelyani et al., 2019; Lomakin and, 2016). In addition, obstruction of interoperability can happen because future technological developments cannot be predicted and anticipated for. This results in a system dysfunction because of different components being unable to exchange information (Declerq, 2021). Also, vendor lock-in is a challenge because this means a facility manager becomes dependable on a specific vendor for updates, expansions and maintenance. When a facility manager wants to switch to another vendor, he will face problems relating to high costs and time loss (De Oliveira *et al.*, 2017). Further challenges are reliability, due to design/operational/manufacturer failures, which could lead to defects in BACS (Abdulmunem and Kharchenko, 2017), and the complexity of managing the BMS increases due to occupant influence on BACS, which could lead to conflicting goals in terms of comfort and energy efficiency and lastly security risks are happening more and more resulting in threats to the correct operation of BACS but also to privacy issues (Graveto et al., 2022; Li et al., 2023).

Energy saving potential

To assess the saving potential of BACS, EN 52120-1 proposes BAC efficiency factors which quantify savings based on fixed factors depending on the level of automation, divided by energy-consuming domain (NBN, 2022). The level of automation is divided into classes A to D, where D stands for a non-energy efficient BAC and class A corresponds to high-performance BACS. Class C is the reference class, corresponding to standard BAC functionalities. The saving factors for office buildings are shown in table 1 below.

Table 1 BAC efficiency factors for office buildings in EN 52120-1 (NBN, 2022).

		D	C	B	A
Overall	$f_{BAC,th}$	1.51	1	0.80	0.70
	$f_{BAC,el}$	1.10	1	0.94	0.89
Detailed	$f_{BAC,H}$	1.44	1	0.79	0.70
	$f_{BAC,C}$	1.57	1	0.80	0.57
	$f_{BAC,DHW}$	1.11	1	0.90	0.80
	$f_{BAC,L}$	1.10	1	0.85	0.72
	$f_{BAC,Aux}$	1.15	1	0.86	0.72

Besides these generic factors, various research is conducted on the saving potential of BACS through Building Energy Performance Simulations (BEPS) or field studies. Ahmed et al. (2015) introduced demand-controlled ventilation in a Finnish low-energy office building and achieved savings of 7-8% of total primary energy compared to a constant air volume system. Lowcay et al. (2020) found savings between 12% and 91% of lighting energy by implementing occupancy and daylighting control, depending on sensor resolution, occupancy, location and window-to-wall ratio. Lastly, Kang et al. (2015) proposed a control system for an automated shading system coupled with heating, cooling and lighting demand. The results showed a decrease in cooling and lighting energy of respectively 40.8% and 19.6%. Although the energy saving potential is clear, the energy savings are case-specific and depend on the level and specifications of the BACS in addition to the considered reference case. The generic saving factors of EN 52120-1 may not be accurate as influential parameters, i.e., climate, orientation and occupancy (behaviour) are neglected.

The range of duties of Facility Managers encompass monitoring, analysing and optimizing energy consumption (Lok et al., 2023; Shin et al., 2018). Therefore, it would be advantageous for Facility Managers to possess the ability to quantify the savings due to implementing BACS. The significance of BACS for FM will also intensify as the EPBD recast obliges that non-residential buildings should incorporate BACS when the effective rated output for heating systems or systems for combined space heating and ventilation is over 290 kW by 31 Dec 2025 (European Commission, 2018). In addition, the European Commission ensured the development of the Smart Readiness Indicator (SRI) which is a tool to rate the smartness of a building and raise awareness of the benefits of smart building technologies. This way, a long-term vision for increased energy efficiency, e.g., energy neutral by 2050 or earlier, can be drawn up at building or building stock level.

AUTHORS VIEWPOINT

BACS can emerge as a critical tool for optimizing energy efficiency and enhancing occupants' comfort in buildings. The implementation of BACS results in the creation of a substantial amount of data, which can provide facility managers with valuable insights into building operations, enabling them to identify areas for optimization. The potential downside of increased adoption of BACS in buildings is an unmanageable data flow, which could hinder the optimal utilization of BACS and become a burden for facility management. In order to extract useful insights, this data needs to be processed with a targeted approach. To this end, an increasing number of software providers are offering Integrated Workplace Management Systems (IWMS) and Energy Management Systems (EMS), which allow facility managers to aggregate and utilize BACS data more effectively, thus, exploiting the full potential of smart buildings. Min et al. (2016) state that an integrated management strategy focusing on proactive operation and maintenance is a key to success in reducing energy consumption. The utilization of IWMS has the potential to contribute significantly to the optimization of spatial organization and employee well-being, thereby enhancing the overall value proposition of an office edifice.

However, building owners of rented office spaces often fail to recognize the benefits of investing in energy-efficient measures, such as implementing an extensive energy management system, due to the absence of immediate financial benefits which results in a lack of funding for such projects. To address this issue, stricter requirements regarding the minimum energy management system need of buildings can be imposed. Furthermore, modern facility management is shifting towards strategic decision-making based on data, and as such, the responsibility for conducting maintenance activities is increasingly being outsourced to third-party service providers.

In addition, the authors consider that building automation manufacturers and service providers have a responsibility to take action to address certain challenges faced by the industry. These challenges include short product life cycles, inadequate interoperability, security concerns, and the issue of hardware or software obsolescence, which can erode trust in the industry. To combat these issues, the industry should focus on developing durable products that are optimized for operation by facility managers, while also being transparent about any additional costs.

From our perspective, the facility manager holds significant potential in advancing the sustainability goals of buildings and closing the performance gap during the building operation phase. This observation is corroborated by Curtis et al. (2017), who identified impediments in building ownership. The issue of building ownership is not always straightforward, and the influence of facility management on sustainability outcomes varies across contexts. Therefore, the availability of clear, objective, and quantifiable data is crucial to inform building owners about the potential return on investment. Curtis et al. highlight the absence of trusted, independent sources of information for energy conservation strategies, which is a challenge the B·CLIC research aims to address by providing manufacturer-independent and unbiased data. Improved cost estimations for facility management can also result from this effort, reducing the risk associated with maintenance contracts.

FUTURE RESEARCH

The Building Control Life Cycle Cost (B·CLIC) research project, originating from the University of Antwerp, endeavours to tackle the challenges posed by BACS, with the aim of providing facility management with informative data that facilitates a more expeditious adoption of BACS. The goals of B·CLIC include gaining a thorough understanding and provide decision support based on the energy efficiency and economic parameters of BACS, considering the complete life cycle of its components.

Notably, the researchers engaged in this project have not yet encountered any extensive research conducted on the life-cycle cost of BACS.

Currently, a review paper regarding the energy saving potential is published (Vandenbogaerde *et al.*, 2023). This paper concludes that the energy benefits of BACS are often unclear, and that current research mainly presumes an oversimplified reference case which leads to overestimations in energy saving potential. The review points out that influential parameters, i.e., climate, occupancy, occupancy behaviour and pre-set setpoints, affecting energy efficiency are often neglected in the BAC factor method. In addition, the paper compares the methodology of field studies to Building Energy Performance Simulations (BEPS), BEPS seems to be suitable for testing several combinations but strongly depend on the level of detail of the input parameters. Interviews and informal discussions with facility managers will occur where abovementioned challenges and uncertainties will be discussed.
This paper also references certain conclusions drawn from the other review paper, such as challenges with obsolescence, complexity, vendor lock-in and in a second review paper (van Roosmale et al., under review), critically examines the benefits and uncertainties of BACS for facility managers operability.
The energy saving potential will be assessed through Building Energy Performance Simulations (BEPS) where a greater level of detail can be achieved. These methods will be tested on case studies of office buildings containing BACS, after which the potential of BACS can be determined by defining a reference model with manual control and fixed setpoints.

To gather data on BACS costs and maintenance, a survey has been sent to facility managers, encompassing quantitative and qualitative aspects about BACS implemented in their buildings. The survey inquiries about automation types implemented, software and vendors used, service contracts and associated costs, energy consumption, component end of life, and facility managers' experience with BACS. Currently, the responses are being processed. Subsequently, in-depth interviews with facility managers will be conducted for further qualitative insights. The survey data will be analysed to draw conclusions on current practices with BACS, component life cycle, and maintenance costs. This information will inform a model to estimate the functional life expectancy of BACS components, taking into account maintenance and reliability aspects.

Next, the energy-saving potential results of BACS will be integrated with the maintenance and reliability model to determine the cost efficiency of different BACS strategies using Life Cycle Cost (LCC) analysis. This will aid in early design decisions for office buildings, including initial investment in BACS, operational costs for maintenance, software and energy consumption, costs for component repairs or replacement, and overall benefits achieved through implementation.

CONCLUSIONS

The Viewpoint paper draws attention to the critical role that Building Automation and Control Systems (BACS) play in optimizing energy efficiency and comfort levels in office buildings. The study examines the various challenges associated with BACS implementation, including reliability, maintenance, service life, and obsolescence, which can significantly impact LCC analysis.

Despite these challenges, the paper concludes that BACS offer tremendous potential benefits to facility managers. By reducing operational costs, increasing energy efficiency, and improving comfort levels, BACS can improve the bottom line for businesses while also contributing to a more sustainable future. However, the study also highlights the need for addressing the challenges of BACS implementation to ensure their effective adoption.

B-CLIC will provide insights into the challenges and potential benefits of BACS implementation, offering guidance to facility managers, ESCOs, BACS manufacturers, and other stakeholders on making informed decisions. This can enhance BACS adoption and effectiveness in achieving sustainable building operations.

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REFERENCES

Alelyani, T., Michel, R., Yang, Y., Wade, J., Verma, D. and Törngren, M. (2019), "A literature review on obsolescence management in COTS-centric cyber physical systems", Procedia Computer Science, Elsevier, Vol. 153, pp. 135–145, doi: 10.1016/J.PROCS.2019.05.064.

Aste, N., Manfren, M. and Marenzi, G. (2017), "Building Automation and Control Systems and performance optimization: A framework for analysis", Renew. Sust. Energ. Rev., Elsevier Ltd, Vol. 75, pp. 313–330, doi: 10.1016/J.RSER.2016.10.072.

Atkin, B. and Bildsten, L. (2017), "Editorial: A future for facility management", Construction Innovation, Emerald Group Publishing Ltd., Vol. 17 No. 2, pp. 116–124, doi: 10.1108/CI-11-2016-0059.

Curtis, J., Walton, A. and Dodd, M. (2017), "Understanding the potential of facilities managers to be advocates for energy efficiency retrofits in mid-tier commercial office buildings", Energy Policy, Elsevier, Vol. 103, pp. 98–104, doi: 10.1016/J.ENPOL.2017.01.016.

Declerq, B., Delvaeye, R., François, L., Grillet, D., Grosemans, M., Mathijs, A., Van Schel, P., et al. (2021), Interoperabiliteit, Compatibiliteit En Openheid Binnen Een Smart Building.

Delmastro, C. (2022), "Buildings – Analysis - IEA", available at: https://www.iea.org/reports/buildings (accessed 24 January 2023).

Directive 2018/844. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG

Domingues, P., Carreira, P., Vieira, R. and Kastner, W. (2016), "Building automation systems: Concepts and technology review", Computer Standards & Interfaces, North-Holland, Vol. 45, pp. 1–12, doi: 10.1016/J.CSI.2015.11.005.

Dong, B., O'Neill, Z. and Li, Z. (2014), "A BIM-enabled information infrastructure for building energy Fault Detection and Diagnostics", Automation in Construction, Elsevier, Vol. 44, pp. 197–211, doi: 10.1016/j.autcon.2014.04.007.

Graveto, V., Cruz, T. and Simöes, P. (2022), "Security of Building Automation and Control Systems: Survey and future research directions", Computers & Security, Elsevier Advanced Technology, Vol. 112, p. 102527, doi: 10.1016/J.COSE.2021.102527.

Li, D.H.W., Yang, L. and Lam, J.C. (2013), "Zero energy buildings and sustainable development implications - A review", Energy, Elsevier Ltd, Vol. 54, pp. 1–10, doi: 10.1016/J.ENERGY.2013.01.070.

Lomakin, M.I. and Murav'ev, A. V. (2016), "Managing the Process of Re-Engineering of Information Systems Based on Integrated Monitoring of Obsolescence", Measurement Techniques, Springer New York LLC, Vol. 58 No. 10, pp. 1102–1106, doi: 10.1007/S11018-015-0849-1/FIGURES/2.

Min, Z., Morgenstern, P. and Marjanovic-Halburd, L. (2016), "Facilities management added value in closing the energy performance gap", International Journal of Sustainable Built Environment, Elsevier, Vol. 5 No. 2, pp. 197–209, doi: 10.1016/J.IJSBE.2016.06.004.

NBN. (2022), "EN 52120-1 Energy performance of buildings - Contribution of building automation, controls and building management - Part 1: General framework and procedures", available at: https://edu.mynbn.be/nbnframework/index.php/pdfMeta/RO/589148?l=E (accessed 23 November 2022).

De Oliveira, R.R., Martins, R.M. and Da Silva Simao, A. (2017), "Impact of the vendor lock-in problem on testing as a service (TaaS)", Proceedings - 2017 IEEE International Conference on Cloud Engineering, IC2E 2017, Institute of Electrical and Electronics Engineers Inc., pp. 190–196, doi: 10.1109/IC2E.2017.30.

Osma, G., Amado, L., Villamizar, R. and Ordoñez, G. (2015), "Building Automation Systems as Tool to Improve the Resilience from Energy Behavior Approach", Procedia Engineering, No longer published by Elsevier, Vol. 118, pp. 861–868, doi: 10.1016/J.PROENG.2015.08.524.

Pun, K.P., Tsang, K.L., Choy, K.L., Tang, V. and Lam, H.Y. (2017), "A Fuzzy-AHP-Based Decision Support System for Maintenance Strategy Selection in Facility Management", Proceedings of PICMET'17: Technology Management for Interconnected World, Hong Kong.

Ramsauer, D., Dorfmann, M., Tellioğlu, H. and Kastner, W. (2022), "Human Perception and Building Automation Systems", Energies, MDPI, Vol. 15 No. 5, doi: 10.3390/en15051745.

van Roosmale, S., Audenaert, A. and Meysman, J. (2023), "Understanding the opportunities and challenges of Building Automation and Control Systems to support facility management – an extensive literature review", Journal of Facilities (Under Review).

Vandenbogaerde, L., Verbeke, S. and Audenaert, A. (2023), "Optimizing building energy consumption in office buildings: A review of building automation and control systems and factors influencing energy savings", Journal of Building Engineering, Elsevier, Vol. 76, p. 107233, doi: 10.1016/J.JOBE.2023.107233.