International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Review Article)

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Engineering lifecycle management strategies for MEP systems in large-scale hospitality and infrastructure projects

Farhad Atakishiev *

Expert in design and implementation of large-scale infrastructure and hospitality projects. Azerbaijan.

International Journal of Science and Research Archive, 2024, 11(01), 2691-2694

Publication history: Received on 04 December 2023; revised on 26 January 2024; accepted on 29 January 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.11.1.0057

Abstract

The efficiency of building engineering systems is determined not only by the quality of design and installation, but also by the strategies used to manage their lifecycle. In large-scale hospitality, infrastructure, and public facilities, operating costs, downtime probability, and system resilience to failures directly depend on the quality of commissioning processes and the regularity of preventive maintenance.

This article examines engineering approaches to lifecycle management of heating, ventilation and air conditioning (HVAC), power supply, and water supply systems, including the impact of comprehensive equipment commissioning on capital and operational expenditures, as well as the relationship between preventive maintenance and failure risk. Special attention is given to facilities with high operational intensity and strict reliability requirements—such as hotels, medical centers, and multifunctional complexes.

Keywords: Lifecycle management of engineering systems; Commissioning quality; Preventive maintenance; reliability; HVAC performance; Operational risks; Facility management

1. Introduction

In modern construction projects, building engineering infrastructure forms the foundation of operational stability. Unlike the traditional approach focused mainly on capital construction costs, today the emphasis is shifting toward the lifecycle cost of engineering systems.

Practice shows that up to 70% of total engineering system costs are generated after the facility is commissioned. Therefore, the following aspects become strategically important:

- Quality of commissioning and integrated system testing
- Regularity of preventive maintenance
- Failure and equipment degradation management
- Modernization planning

This is especially critical for hospitality and infrastructure projects, where system downtime directly affects operational revenue and the reputation of the facility.

* Corresponding author: Farhad Atakishiev

2. Impact of Commissioning Quality on Lifecycle Cost

The commissioning process of engineering systems is a systematic verification of equipment compliance with design requirements, including functional testing, integration scenarios, and operational parameter tuning.

Insufficient attention to this stage leads to:

- Hidden automation defects
- Inefficient system balancing
- Increased energy consumption
- Accelerated equipment wear

The chart below shows the relationship between lifecycle cost and commissioning quality.

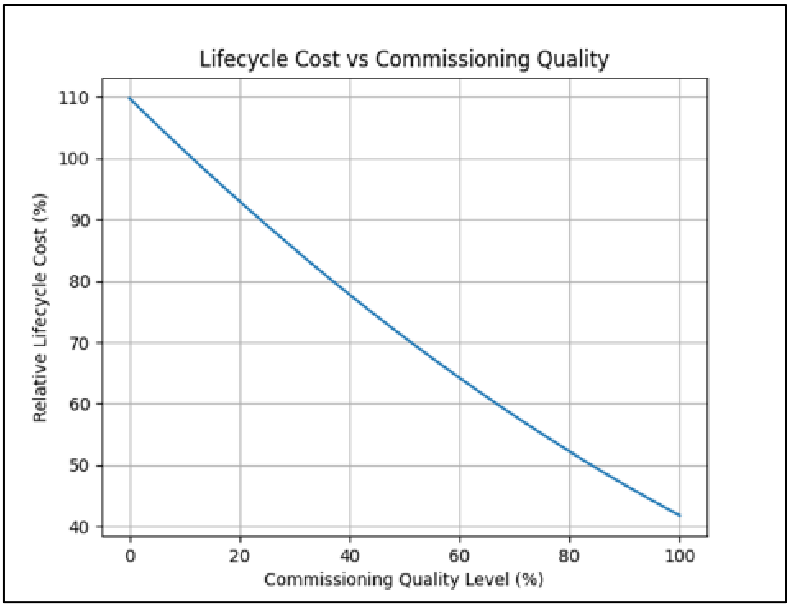

Figure 1 Lifecycle Cost vs Commissioning Quality

Engineering practice shows that investments in high-quality commissioning of systems can reduce operating costs by 15–30% during the first years of an asset's operation.

3. Preventive Maintenance as a Tool for Downtime Risk Management

The reliability of engineering systems is directly linked to the frequency of preventive maintenance.

A traditional reactive approach ("repair after failure") leads to:

- Unpredictable breakdowns
- High emergency repair costs
- Disruption of operational processes
- A shift toward preventive maintenance enables:
- Early detection of equipment degradation
- Reduction in the likelihood of cascading failures
- Optimized workload distribution for engineering teams

The relationship between downtime probability and the frequency of preventive maintenance activities is illustrated in the graph below.

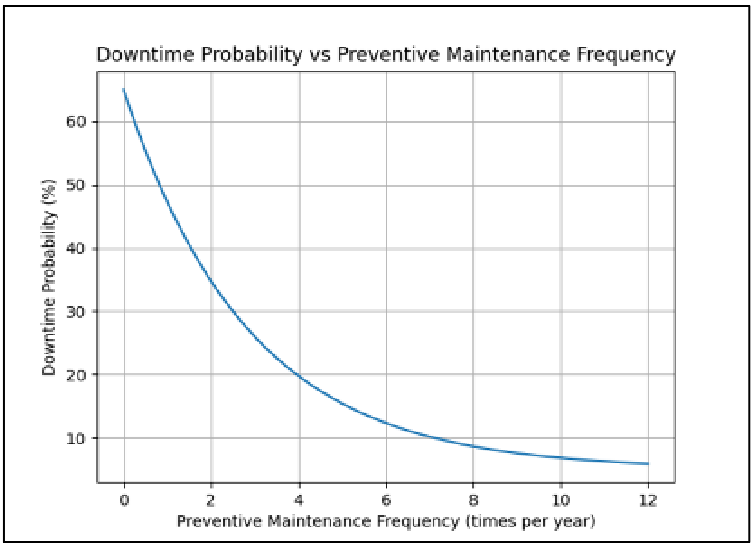

Figure 2 Downtime Probability vs Preventive Maintenance Frequency

As can be seen, increasing maintenance frequency reduces downtime risk exponentially at early stages, after which the effect stabilizes.

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4. Integration of Engineering Systems and Operational Resilience Management

Modern buildings represent complex, interconnected engineering ecosystems. A failure of a single component can lead to:

- Overload of electrical networks
- Disruption of indoor climate control
- Automation system failures
- Shutdown of critical services

Within lifecycle management, the following elements are of key importance:

- Scenario-based failure modeling
- Criticality analysis of equipment
- Development of redundancy schemes
- Real-time parameter monitoring

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5. Optimization of Operational Strategies

Efficient operation of engineering systems requires balancing:

- Maintenance costs
- Risk levels
- Equipment lifespan
- In practice, the following tools are applied:
- Criticality matrices for engineering systems
- Predictive maintenance based on data analytics
- Digital logs of failures and operational events

KPI systems for engineering departments

These approaches enable a shift from intuitive management to a structured engineering strategy.

6. Economic Impact of a Lifecycle-Based Approach

The implementation of lifecycle management for engineering systems provides:

- Reduced failure rates
- Predictable maintenance budgeting
- Improved energy efficiency
- Increased investment attractiveness of facilities

For hospitality and infrastructure projects, this is especially important, as system stability directly affects profitability.

7. Conclusion

Strategic lifecycle management of engineering systems is becoming a key factor in the sustainable operation of large-scale hospitality and infrastructure facilities. Practice shows that the majority of total costs and risks associated with equipment failures, energy inefficiency, and unexpected downtime are formed during the operational phase.

High-quality commissioning, regular preventive maintenance, and integrated management of interconnected engineering subsystems significantly reduce the likelihood of failures and improve the predictability of operational expenses. In conditions of high building utilization intensity, such approaches become an essential tool for ensuring project profitability and investment stability.

Systematic lifecycle management enables a transition from a reactive maintenance model to reliability-driven operations based on equipment criticality analysis, real-time monitoring, and preventive and predictive maintenance strategies. This forms the foundation for long-term efficiency and sustainability of modern built assets.

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