



Benchmarking facilities operation and maintenance management using CAFM database: Data analysis and new results



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ABSTRACT

Operation and maintenance (O&M) activities of the constructed facilities are the longest part in the life cycle of the building. Similarly the energy consumption costs and the maintenance costs are the largest expense component for the property sustainment budget. The performance of these O&M activities needs to be measured annually and monitored to support long-term cost saving strategies. This study demonstrates the application of three dimensions (3D) object-oriented database supporting the facilities management benchmarking project. As case study the 3D object hierarchy of the Central Building of the Graphisoft Park in Budapest was presented. The objective of the current study may provide feasibility workflow diagram and prototype for organizations that start to collect benchmark data from their own buildings. The main objectives were to specify the access of data in Computer Aided Facility Management (CAFM) system, and to elaborate a methodology to gathering building O&M costs data with the core outcome that is usable for further quantitative analysis included hypothesis testing. To achieve this objective, based on a questionnaire survey new sample of data collected on facility management factors, sites ($n=76$) and buildings on the sites ($n=207$) from the range of Hungarian Corporate Real Estates were participated. Data mining techniques included Descriptive Statistics, Correlation Analysis, one-way ANOVA and Box Plot was used to identify significant relationships to determine differences in annual O&M costs by age, number of users and heritage. This study presents new results where negative correlation between maintenance costs and age of the facilities was found. ANOVA was obtained ($p < 0.05$), the number of users of buildings has a significant positive effect and explain almost 60% of annual utility costs of facilities. Identical to the hypothesized nearly 100% higher mean annual maintenance cost per m^2 was measured between heritage and non heritage facilities.

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1. Introduction

The aim of this paper is threefold: to describe a benchmark survey that investigated prototype for the integration of benchmark project in Computer-Aided Facility Management (CAFM) information system, to outline case study for this procedure, and to report the new results of the benchmarking. The research determined the formalisms needed to achieve this integration during the development of benchmark database. During the last decade, considerable effort has been undertaken in both academic and industrial environments to improve the costly and time-consuming design cycle in the development of digital integrated applications in the field of facility management. As a result, several different information

technology components have been developed [6,9,22]. In today's information-driven age, it is recommended that the facility managers are able to capture performance data, utilizing a process through the application of software solutions namely CAFM or Building Information Modelling (BIM) [1,2,13,18] or Geographic Information System (GIS) [22] or Computerized Maintenance Management Systems (CMMS) [12]. Real-time data is a key tool in the facilities manager's toolkit, enabling early decision making and prompt action where necessary. In addition, it is also recommended that the organization can access the performance data in order that they too are able to benchmark issues [15]. Operation and maintenance cost information has a stronger impact on customer decision than physical qualities. Planning future O&M costs of facilities is a critical issue to the annually facilities sustainment budget. Another study indicated that O&M costs are the most important determinant in the life cycle cost of the building [19].

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Table 1

Comparison of previous benchmark surveys.

	No	Cost and currency	Measurement
Tatari and Kucukvar [20] US	74 (LEED-NC v2.2) certified green buildings	Construction cost (\$)	Artificial Neural Network (ANN) and regression model for cost premium prediction
Lai and Yik [11] Asia	10 luxury hotels in Hong Kong	Operation and maintenance (O&M) costs (HK\$)	Energy cost dominated the O&M expenditure of hotels. The cost for maintaining lifts and escalators constituted the major part of maintenance costs.
De Marco et al. [5] EU	100 Italian distribution warehouses	Maintenance cost (€)	Tukey Linear regression analysis
Róka-Madarász [16] EU	54 Hungarian corporate facilities	Operation and maintenance (O&M) costs (HUF)	The study categorised environmental, health, cleaning, maintenance and utility cost by age, main functions and industry of the buildings.
König and De Cristoforo [10] EU	residential buildings in Germany	Life Cycle Cost BNB/DGNB benchmarks (€)	Life Cycle Costing (LCC) Life Cycle Assessment (LCA)
Szónyi [19] EU	100 Hungarian public facilities (16 hospitals, 69 schools, 8 cultural, 7 authority)	Life Cycle Cost (LCC) Investment cost, Replacement cost, Resale value, Annually and non annually operating, maintenance and repair cost, Energy cost (HUF)	Life Cycle Cost Analysis (LCCA) Total cost of owning and operating in a given period of time. Measurement based on the three factors: costs (LCC), time and discount rate.
Tu and Huang [21] Asia	65 Taiwan condominium properties	Operation and maintenance (O&M) costs (NTD)	Artificial Neural Network (ANN) Model

2. Objective of the study

The objective of this study is to create benchmark database that is available for further quantitative analysis.

1. Literature review and comparison of previous benchmark surveys by both academics and professional organizations.
2. Design and explain the feasibility flowchart for the benchmarking project.
3. Modelling the data exchange from different CAFM system components and create benchmark database from CAFM database.
4. Using classical data mining techniques such as computing descriptive statistics or more sophisticated techniques like correlation and ANOVA.

For quantitative analysis facility features are measured that influence cost effective operation and maintenance in the commercial real estate sector.

These are being: 'Number of users' of the buildings – the number of people using the building. 'Annual utility consumption' – it represents the yearly utility consumption of facility including Energy, Gas, Water, Wastewater and District heating consumptions. 'Annual cost of operation' – it represents the yearly operation cost of the facility including the Energy, Gas, Water, Wastewater, District heating, Environmental, Health and safety, Building tax, Authority fees, Disaster recovery, Property insurance, Property protection, Cleaning costs. 'Annual cost of maintenance' – it represents the yearly maintenance cost of facility including the Architectural, Mechanical, Electrical, Outdoor and Other maintenance costs, expressed as gross square meter costs. 'Age of the facility' and Heritage facility.

Specifically, this study seeks:

- A) To investigate the relationship between Annual maintenance cost and Number of users of the facilities towards facilities in Hungary.

The hypothesis to assess this objective is presented below:

H1. There is a positive correlation between 'Annual Maintenance cost' of the facilities and 'Number of users' of the buildings towards facilities in Hungary.

- B) To Investigate the Relationship between Number of users of the facilities and Annual Utility Cost towards facilities in Hungary.

The hypothesis to assess this objective is presented below:

H2. There is a significant relationship between 'Number of users' of the buildings and the 'Annual utility cost' towards facilities in Hungary.

- C) To Investigate the Relationship between Heritage and non Heritage buildings and their Annual Maintenance cost.

The hypothesis to assess this objective is presented below:

H3. Heritage buildings have 100% higher mean 'Annual maintenance cost' than the Non Heritage buildings.

3. Gaps in the previous benchmark projects

Many sources are available for analyzing facility management benchmarks [3,7]. The issue of benchmarking in facilities management costs has been a subject of discussion by both academics and professional bodies for over one decade in continental European countries, in the USA, in Asian countries for example De Marco et al. [5] in Italy, König et al. [10] in Germany, Lai and Yik [11] in Hong Kong, Róka-Madarász [15–17] and Szónyi [19] in Hungary, Tatari et al. [20] in the US and Tu et al. [21] in Taiwan. The Table 1 shows the comparison of academic staff research in a field of benchmarking.

3.1. Rating systems

Within the real estate profession there have been different efforts to develop a method to certify environmental performance. In the United Kingdom, the most significant method defining and assessing environmental building performance is BREEAM, the *BRE Environmental Assessment Method*. BREEAM uses a consensus based weighting system to aggregate performance into one overall score for a building, which is then rated on a scale ranging from pass, good, very good to excellent. The main methodology used in the United States is LEED the *Leadership in Energy and Environmental Design* Scheme by the US Green Building Council. This is a point-based system, similar to BREEAM, but resulting in buildings being awarded bronze, silver, gold or platinum status. Similarly DGNB *Deutsche Gesellschaft für Nachhaltiges Bauen*, the German building certification system uses bronze, silver, gold or platinum certificates. The cited previous studies describe both certified LEED

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