Integration of Principles for Energy-efficient Architecture and Sustainable Facilities Management

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ABSTRACT: Building use and operation account for 40% of the total energy consumption in Europe. Energy efficiency is not only an architectural issue. How a building is used and operated will have a high impact on total energy consumption. The objective of this paper is to integrate principles for energy-efficient architecture and sustainable facilities management. The integrative approach targets the cooperation of architects and facilities managers towards improvements to buildings’ energy-efficiency. In addition, it contributes to the changing focus of FM from cost reduction towards adding quality and value. The theoretical background to the research presented here is founded on the theory of post-occupancy evaluation and building performance evaluation. The theory and its exemplary applications are discussed regarding energy-efficiency improvements to architectural design and facilities management. Findings are structured regarding how architects and facilities managers can benefit from an integrative approach. It is concluded that there is a general need to systematically study how buildings are used and operated in order to maximize their full potential for effective and efficient energy consumption.

Keywords: building performance evaluation, energy-efficient architecture, energy efficiency, performance criteria, post-occupancy evaluation, sustainable facilities management, sustainability

BACKGROUND AND OBJECTIVE
From a European perspective, the use and operation of buildings accounts for 40% of total energy consumption. The majority of buildings’ energy demands are covered by non-renewable resources. The overall objective of the European Union is to reduce the level of energy consumption [19]. How can buildings consume less energy and at the same time ensure usability, functionality, and esthetical quality? Research in the field of sustainable real estate development and facilities management combines long-term and medium-term strategies for the development of energy-efficient buildings together with the day-to-day decisions in energy-efficient management. The overall vision is to increase the participation of facilities management (FM) in the entire building life cycle. Cooperation between architects and facilities managers can link experience from building operation and use in the development of new building projects. The integration of principles for energy-efficient architecture and sustainable facilities management (SFM) targets the advancement of expert knowledge of “energy-efficient buildings” and “energy-efficient management” and the integration of such knowledge in sustainable development and lifecycle management. In this regard, the objective is to integrate the design principles of energy-efficient architecture and the practice criteria of SFM for purpose of evaluations of and improvements to non-residential buildings.

Our research focuses on non-residential buildings in Norway. Non-residential buildings encompass eleven main building types: kindergartens, office buildings, school buildings, universities and university colleges, hospitals, nursing homes, hotel buildings, sports buildings, commercial buildings, cultural buildings, and light industry buildings and workshops [1]. Most of these building types are also used as public buildings, and thus are an important part of public infrastructure and contribute to the benefit of society. Public buildings have a high level of usage and high requirements in terms of their accessibility. Typically, public building stocks are characterized by having historical development, with different construction types, building ages, and building conditions. The challenges to the operation of such buildings are to adapt them to changing user demands and to make them accessible mainly to the public and hence to anonymous users. The greatest potential for estimated annual energy savings is recognized as being in commercial buildings, followed by office buildings, light industrial buildings and workshops, and school buildings [1].

PRINCIPLES FOR ENERGY-EFFICIENT ARCHITECTURE AND SUSTAINABLE FACILITIES MANAGEMENT
Principles for Energy-efficient Architecture

Existing principles for energy-efficient architecture are structured into four categories or stages related to the building lifecycle. The starting point is the location of the building and considerations of climate and site conditions. The second step is the building design, which refers to the building’s shape, orientation, and materialization. Thereafter, the third step involves detailed planning for the building construction. The fourth and final step is the planning the technical systems. Sustainable architectural design and construction management applies the following principles:

- The location for a new building requires considerations of climate and site conditions and the appropriate positioning and orientation of the building. The main inputs are possibilities for natural lighting, the use of sunlight, the effects of shade, windbreaks, planting areas, and the design of open spaces.
- Energy-efficient building design is in general characterized by the shape and compactness of the building as well as the thermal quality of its shell. Other key factors are the orientation, window arrangement, and subdivision of the various zones of the ground plan, buffer zones, and materialization of the construction type.
- Key elements of energy-efficient building construction are high thermal protection, air tightness, solar energy use, and heat-storage systems. In addition, the environmental compatibility of the building materials and the disposal or reuse of the construction materials should be taken into consideration.
- Efficient energy use is essential for a building’s technical systems, as the source of energy used will have a high impact on the environmental efficiency of the systems. A building’s heating system will encompass the production, distribution, and transfer of heat. In addition, the coordination of a heating system and a building’s utilization will have an impact on the building’s energy consumption [2].

State of the Art in Facilities Management with a Focus on Energy Efficiency

Sustainability is at the top of the European FM research agenda [3]. In the European context, FM is defined as: “The integration of processes within an organization to maintain and develop the agreed services which support and improve its primary activities” [4]. According to the European FM norm, there are two sets of FM services and these respectively relate to the categories “space and infrastructure” and “people and organization” [4].

FM services in the category “space and infrastructure” support the real-estate related core processes of companies and, depending on the needs of the contractors, are structured into: (1) accommodation, (2) workplace, (3) technical infrastructure, (4) cleaning, and (5) other spaces or infrastructure. Services that have a direct impact on the built environment are: strategic space planning and management, conception and briefing of a room- and space-management program, design and building construction, lease and usage-management, building management and maintenance, and refurbishment and/or reconstruction. The following services in the area of technical infrastructure have an impact on the energy requirements and ecological quality of the built environment: energy- and energy-source management, sustainable environmental management, managing and maintaining the technical infrastructure, managing and maintaining the building’s control system, maintenance of equipment, and disposal management.

FM services in the category “people and organization” support the organizational core processes of companies and include services in the following areas: (1) health, (2) safety at work, (3) security and environmental issues, (4) hospitality, (5) information and communication, and (6) logistic and other supporting services. As services provided in this category influence the quality of the workplace and result in specific demands for ecological products, they impact the interdependency between the company and the built environment.

FM contributes directly to sustainable development of the built environment within the three major areas of responsibility: support and improvement of the “main activities,” and preservation and development of supply of services in the areas of both “space and infrastructure” and “people and organization”. Furthermore, FM contributes indirectly to the three overall target areas of sustainability: “the ecosystem, society and the economy” [5]. Junghans points out that a comprehensive SFM assessment tool is not available. However, existing systems can be used in some cases [5]. For example, the US Green Building Council (USGBC) has published a guideline which is suitable for the assessment of existing buildings’ operations and maintenance [6].

Discussion of Changes in Facilities Management with a Focus on Energy Efficiency

According to Atkin and Brooks the whole lifecycle perspective on buildings has been adopted through the enforcement of legislation [7]. With regard to sustainability and environmental issues, they cite the Energy Performance of Buildings Directive (EPBD) as example [7]. However, Barret and Baldry consider also facilities managers in the position of conducting post-occupancy evaluations (POEs), but not to apply expert-based building evaluation systems: “As this book is directed towards good practice in facilities management, only POE methods are described in this section, as these can be carried out by the facilities management
In this respect, Cotts et al. describe FM already as participating in the plan and design process of buildings [10]. With regard to the need for sustainability and green building guidelines, good working knowledge is needed to achieve optimum building projects, “because user input, through the facility manager, is an absolute requirement in good project planning” [10]. In this respect, Cotts et al. statement is relevant to the overall vision of the present paper: the participation of facilities managers in the entire building lifecycle represents a link between experience gained from the operation and use of buildings and the development of new projects. This idea has also been mentioned in the context of building performance evaluation (BPE). Preiser and Schramm assume that facilities management can take over a leading role in the application of BPE: “Going forward, the application of the ‘integrative framework of BPE’ may increasingly be led by Facilities Management” [11]. The theoretical framework for BPE and its development regarding earlier studies of POE is described in the next section.

Further, Booty refers as well to new development in environmental law that will have consequences for the role of facilities managers [9].

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T HEORY OF POST-OCCUPANCY AND BUILDING PERFORMANCE EVALUATION

Wolfgang Preiser et al. developed a theoretical framework for post-occupancy evaluation and building performance evaluation [12]. POE is designed to explore in a systematic way how far existing buildings fulfill the objectives of architectural design in reality, i.e., once they are occupied. The methodology is based on comparison between the targeted to-be status and the as-is status of the building in the use and operation phase. Since the 1980s POE has become an internationally respected research methodology. When it was first implemented, only residential environments and housing design were studied; however, “POEs have since targeted hospitals, prisons, and other public buildings, as well as offices and commercial buildings” [13]. The purpose of POE is to collect information and develop knowledge on the impact that building design and construction decisions have in a long-term perspective. Such knowledge can be utilized for further improvements in the building industry. However, the building industry has only a small impact on existing buildings, and therefore Preiser and Vischer developed the evaluation methodology further and integrated POE as one of six processes in a BPE process model [13]. BPE is described as the “process of systematically comparing the actual performance of buildings, places and systems to explicitly documented criteria for their expected performance” [13]. BPE encompasses the whole building lifecycle with six main phases: (1) planning, (2) programming, (3) design, (4) construction, (5) occupancy, and (6) facility management. The lifecycle allows feedback in every project phase and therefore impacts ongoing building development. BPE is targeted to improve the building industry and provide knowledge on built environments and their impacts in general. BPE is aimed to develop a common understanding and the respect of all participants in the building’s lifecycle, such as building owners, architects, and facilities managers.

With regard to the focus of this paper, it is the overall scope encompassing an architectural design focus, i.e., the third main lifecycle phase, “design,” and the facilities management focus, i.e., the sixth main lifecycle phase “facility management,” why BPE is considered as an appropriate theoretical framework for the integration of energy efficiency principles in architecture and facilities management. The challenge is to identify and further develop the most important criteria regarding the energy efficiency focus related to heating as the main energy-consumption driver of buildings. However, thermal comfort is also an important part of user comfort.

DISCUSSION OF CRITERIA FOR INTEGRATED ARCHITECTURE AND FM EVALUATION

The main POE and BPE categories and exemplary criteria are discussed regarding common structures and definitions in architecture and FM. According to Preiser and Schramm, the evaluation criteria are structured in three main categories and a fourth, overarching context, category [11]:

1) Built environment: workstations, rooms, buildings, and entire complexes of buildings or facilities
2) Providers and users: individuals, groups, and entire organizations
3) Performance levels and criteria: based on client goals and user needs; this hierarchy of performance levels includes technical (health, safety, security), functional (functionality, efficiency, work flow), behavioral (social, psychological, cultural), and aesthetic performance criteria
Technical elements in the field of architecture are typically structured regarding the building process. For example, within the German building code DIN 276, there are seven categories for the allocation of building process costs: costs related to (1) the property, (2) preparation of the building site, (3) building construction, (4) technical infrastructure, (5) outside facilities and gardening, (6) user equipment and artwork, and (7) ancillary expenses. This structure addresses experts such as architects and engineers and was developed for cost calculations of building processes. However, in Germany it is also used for the assessment of existing buildings and for cost estimations regarding the optimization of architectural design during the planning process.

The German building code DIN 18960 provides a structure for FM-related costs in four categories: (1) capital costs, (2) administration costs, (3) operational costs, and (4) maintenance costs. Subcategories of operational costs (3) refer to the technical and functional elements of building performance, e.g., energy supply and waste disposal, cleaning, and operation of technical systems. Architects know the functional elements of building performance evaluation referring to their basic knowledge of buildings’ dimensions and functional layout planning. Key figures and background information about different building types are needed in order to understand and transform user needs into appropriate building design. A well-known architectural guide is the book Architects’ Data [14], which has been published in Germany since 1936 and has been included in most architectural education study programs. Behavioral elements refer to common FM definitions, e.g., the European standards for energy efficiency [4], which focus on service integration (see the section headed ‘Principles for energy-efficient architecture and sustainable facilities management’ for further details on the categorization of FM services).

In summary, the performance levels and criteria in POE and BPE are close connected to architectural design and FM practice regarding the mentioned technical and functional building elements, but the focus differs, particularly regarding user perspectives of POE and BPE. In addition, behavioural elements have not been a main part of architectural and FM studies to date. However, the categories of POE, BPE, architecture, and FM criteria are similar enough to be comparable or transferrable, and they are different enough that the involved actors can learn from each other. From the discussion on the state of the art in FM (in the section headed ‘Discussion of changes in facilities management with focus on energy efficiency’), it is apparent that there are different opinions about FM’s qualifications to lead the application of BPE and to integrate the energy efficiency focus. However, future education in FM will have to deal with new challenges. Facilities managers will need knowledge that enables them to understand both the user perspective and the architecture perspective.

FINDINGS FROM POE AND BPE CASE STUDIES REGARDING INTEGRATION OF PRINCIPLES FOR ENERGY-EFFICIENT ARCHITECTURE AND FM

Evaluate the Building as an Entire System

Existing principles for energy-efficient architecture are structured into four successional phases regarding the building process. The architectural planning process starts with considerations of climate and site conditions. This is followed by the design of the building with respect to shape, orientation, and materialization. Thereafter, detailed planning of the building construction is carried out, and finally the technical systems are planned. All of these process phases are based on basic technical and environmental knowledge, without consideration of user perception. As mentioned with
reference to the structure of the German building code DIN 276, typical architectural thinking concentrates on how to produce the building with focus on the building process phases. This indicates that evaluation of user perceptions has not been taken into account in energy-efficient architectural design to date. Findings from POE case studies underline that it is important to consider the building as an entire system. Preiser et al. claim that it is “another drawback of existing procedures that most testing and evaluation take place in laboratory settings rather than in the field” [12]. The argumentation is based on the different interactions of materials under actual-use conditions. An example can be found regarding the acoustic quality evaluation of school buildings. Within the diagnostic POE of elementary school buildings in Columbia, the buildings were evaluated as an entire system regarding acoustical quality. “Listening to the spaces in the buildings as well as examining their volume and materials provided a preliminary list of spaces to be tested for reverberation” [12].

Evaluate Different Times
Key elements of an energy-efficient building construction include high thermal protection and airtightness. High thermal protection and airtightness are typical characteristics regarding the definition of passive houses: “Passive Houses are buildings in which a comfortable temperature can be achieved year-round with minimal energy inputs. Passive Houses must meet very stringent requirements regarding both their design and construction” [15]. In addition, certification criteria for passive houses are, for example, related to a specific space heating demand, namely ≤ 15 kWh/(m²yr), and air changes (pressure test result), namely ≤ 0.6/h [15]. Passive houses are therefore less flexible regarding changing user needs, which should be considered in the decision processes of the architectural design phase. Within the diagnostic POE of elementary school buildings in Columbia, the buildings were evaluated considering potential changes in activities due to time of the year and weather conditions: “The extended observation period helped capture potential changes in activities due to better spring weather conditions” [12].

Define Research Questions for As-Is and To-Be State Comparison
The exact definition of as-is and to-be status is a key element of POE and BPE methodologies. Walden responded to this requirement by surveying user satisfaction as-is compared with importance of the same criteria of user satisfaction for the future, and found that the building performance evaluation of a German office building revealed overall building efficiency, natural lightning, and user well-being as most important environmental elements for the future [16]. In addition, Walden assumed that in Germany employees prefer to control environmental conditions such as lightning, cooling, and heating, and use building technology as though it is fully-automatic central air conditioning [16]. Preiser et al. identified indoor air quality as important area for post-occupancy evaluation. Their argumentation is based on problems experienced with reduced levels of ventilation due to the energy crisis in combination with improved airtightness of buildings [12].

Evaluate Users as Individuals, Groups, and Organizations with Different Needs
Energy consumption is invisible to users and for this reason it is difficult to influence user behaviour. Olsson et al. addressed the question “Who is the user” and one of their findings was that “It is sometimes more or less implicitly assumed that there is only one homogenous group of users” [17]. A good example of user orientation can be found in POE surveys. Sheila Ornstein et al. included questions about users’ comfort experience in summer and winter in their building performance evaluation questionnaire [18]. The objective of their study was to refine and improve the quality of office buildings. The main categories for analyzing the comfort of the work environment were: temperature, humidity, air quality, ventilation, odors, and lighting quality. Ornstein et al. report that the respondents of the survey were differentiated regarding several categories, such as gender, education, family income, age, time spent working in the company (years), activity carried out most frequently in the office, and smoker/non-smoker [18].

CONCLUSION
The integration of principles for energy-efficient architecture and sustainable facilities management is designed to reduce energy consumption in the operation and use of buildings and to ensure usability, functionality, and esthetic quality. There is a general need to improve the energy efficiency of non-residential buildings. In Norway, the highest annual energy saving potential is recognized in commercial buildings, office buildings, light industry buildings, workshops, and school buildings.

Existing principles for energy-efficient architecture and the practice in facilities management use different perspectives and background knowledge. The architectural perspective focuses on the building process and the project phases, whereas facilities management considers the building as an entire system and has the necessary knowledge for understanding the user perspective.

Post-occupancy evaluation (POE) and building performance evaluation (BPE) provide the theoretical basis for an integrative framework. The identification of the most important criteria and the application to energy efficiency require further research. However, the existing
methodology can be used to develop an integrated Architectural design and Facilities Management Evaluation framework on Energy Efficiency (AFMEE).

Case studies of POE can be utilized to increase cooperation between architects and facilities managers and in particular to support the development of a common understanding of how buildings are used and operated in the course of time. Further case studies on energy efficiency are required in order to close the gap in our understanding of how experiences of building use and operation can support the development of improved principles for energy-efficient architecture.

REFERENCES