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Bridging the gap between energy consumption and the indoor environmental quality of a 1960s educational building

Xi Wen Leong[a], Emmanuel A. Essah[a]*

[a]*School of Built Environment, University of Reading, Reading, RG6 6AW, UK*

Abstract

The fundamental purpose of a building has evolved from merely providing protection from external environmental climate to more emphasis on integrating building services through building regulations to provide the synergy of comfort, efficiency and safety to the indoor environment. This research recognizes the rising demand and increasing quality of indoor environmental quality (IEQ) in the modern society compared to the acceptable level of previous traditional buildings. Generally due to its varied operations, educational buildings, in this case University libraries have its own set of challenges and barriers such as minimizing damages and decay of books and maintaining indoor conditions with an oversight of providing good IEQ to occupants. This paper presents a detailed evaluation of a 1960s-educational library with 24-hour access at the University of Reading. Through *in-situ* measurements, modelling and simulations of the building's energy consumption, IEQ parameters and occupancy patterns, investigations have been performed. Varied scenarios using the Integrated Environmental Solution (IES) software were also investigated. The findings illustrate that due to mixed façade configuration (i.e. sandstone and bricks) there is the unflinching need to balance aesthetics of the facade and functionality of a building to reduce excessive energy use via heating, without compromising on occupant comfort and well-being Although it is envisaged that refurbishing the library building will provide energy savings of up to 40%, this is farfetched and can only be achieved at the detriment of occupant comfort levels as evident in the simulation results, where these savings could not be realised. This paper further discusses the methods, scenarios, and results of ensuring good IEQ, comfort and energy efficiency are not been seen as mutually exclusive. This study forms part of ongoing research into the impact of educational buildings.

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Keywords: University Library; Energy; Indoor Environmental Quality; Modelling

* Corresponding author. Tel.: +44-0-118-378-8563
E-mail address: e.a.essah@reading.ac.uk

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1. Introduction

It is well documented now that over the years the building sector has accounted for 40% of the annual global energy consumption and 30% of greenhouse gases emissions [1]. Notably, in the UK aside domestic buildings, the non-domestic sector (industrial, commercial and public buildings) which consists of over 2 million buildings accounts for about 17% of total UK energy consumption. Commercial and public buildings (including educational buildings) contribute to 13% of the non-domestic energy consumption with continuously growing figures [2] due to an estimated 44% growth of student enrolment over the past 10 years across 200 universities [3]. More than 75% of these existing non-domestic buildings are dated pre-1980s where energy efficient strategy was not paramount [4]. It is estimated that by 2050, most of these buildings will remain in existence [5]. In addition, with a continual shift towards energy efficient buildings, the uptake of building regulations continues to be an essential requirement [6]. Therefore, the need to consider potential measures to maintain the structure of the building and attain efficient energy conservation has increasingly become important. Achieving this not only reduces costs but minimize the environmental impact by reducing emissions of carbon dioxide (CO_2) and other gases associated with global warming [7]. To date many studies have discussed energy saving methods for buildings most of which have ‘fixed time’ usage (say 8am-6pm) whereas there is very little on 24-hour access buildings [8]. In this paper, various issues of refurbishment, energy consumption and how it impacts on the indoor environment (IE) of a 24-hour access educational building is discussed.

1.1. Educational Buildings: Challenges in bridging the performance gap

The provision of suitable indoor environmental conditions are requirements for comfort and health of human beings, especially since human beings spend on average, 87% of their time in a building [6]. The impact of poor indoor environmental quality (IEQ) as a result of high indoor pollution, very low or high indoor temperatures, lack of daylight, excess noise, indoor air quality and thermal comfort [9] has detrimental effects on occupants. However, in todays’ building designs, emphasis is placed on achieving energy savings when constructed, with less emphasis on the IEQ factors. This is observed to have a negative consequence on indoor conditions hence in the technical guide of CIBSE -TM54, it has been suggested that comfort and energy efficiency should not be seen as mutually exclusive [10]. In the context of Universities, nowadays regarded as ‘small cities’ because of its size, population and varied activities within the campuses, there is always a fine line between optimizing IEQ and/or energy savings. Nevertheless, the composition of such institutions results in high energy consumption amidst ensuring sustainability is still a priority. In a recent study, it has been noticed that changes to building regulations have influenced energy use in public buildings including Universities, with about 40% reduction. Although it is still uncertain to what extent adequate IEQ is achieved. This more so because educational buildings are characterised with a range of continually changing users, varied activities, and population density. With this post design uncertainty, it becomes more complex if such educational buildings (i.e. university libraries) are open for 24 hours a day, all week due to daily dynamic changes.

The operation of university libraries (UL) requires increasing energy use, maintenance, acceptable levels of IEQ while ensuring low energy cost and low emissions [11]. The design of such facilities with energy conservation in mind does have an impact on how IEQ is optimized. The fact that existing information is insufficient and lacks consistency, makes it difficult to understand the underlying changes that affect the influencing parameters [12]. As a result, despite the fact that understanding occupancy patterns and use of ULs is complex, it is worth studying with the integration of building simulation software. This is for modelling and prediction to inform the initial stage of the buildings design. The fact that the main parameters influencing ULs is unclear, understanding the complex relationship between design, energy demand/consumption, occupancy behaviour and coupled with 24-hour access, without compromising the quality of the IE is essential. To bridge this gap, *in-situ* measurements and building simulation modelling are two major methods used and discussed in this paper.

2. Methodology

This research focuses on the University Library (UL) located at the Whiteknights Campus of University of Reading (UoR) in the South-East of England. The 5-storey building is constructed with a combination of masonry-brick and sandstone wall, single-glazed windows and a total floor area of 9,774 m^2. Built in the 1960s, the building has a district heating system, with 24-hour access. Two main methods were considered for this study; experimental methods and