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# On the comparison of occupancy in relation to energy consumption and indoor environmental quality: a case study

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**Abstract**

The present work focusses on the investigation of the correlation between occupancy, energy performance of the building as well as the quality of the indoor environment in terms of the thermal and air quality aspects. In this respect 3 different types of rooms (use and occupancy), situated in a building of the National University of Singapore campus, were selected. The building is equipped with an advanced BMS system capable of assessing the energy performance, the thermal behaviour and the air quality of all sections, thus providing guidelines towards a zero energy performance maintaining an acceptable indoor environment.

The results indicate that strong correlation between energy consumption and occupancy is identified while the levels of illuminance do not seem to be strongly influenced by the amount of people. The indoor concentration of $CO_2$ which is related to human exhalation, found to be high especially during the class hours. This is attributed to the insufficient performance of the mechanical ventilation central system which cannot be adjusted accordingly.



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## 1. Introduction

The energy performance of all dwellings and the quality of the indoor environment, has been the topic of research of many groups all over the world. This is of importance for many countries with tropical climatic conditions , where buildings account for over 36 % of the total electricity sales in the recent years and is expected to grow in the future [1]. The present research focuses on the case study of a typical building which operates in the campus of the National University of Singapore (hence forth NUS). Singapore Island experiences a warm and moist climate with rainfall rate averaging 2381 mm per annum. The diurnal variation of temperature is little and ranges by about 7 $^0$C. At the same time the mean annual relative humidity is about 84% with typical daily maxima approaching saturation in the cooler early mornings [2]. This type of climate may have an adverse impact on occupant comfort [3]. Similarly, the occupants number alongside their environmental adaptation and activity in the building, their comfort and the energy consumption, is still subject of research. Recent research work has reported results on lighting, ventilation and air conditioning energy consumption in different climatic and cultural areas [4]. Both theoretical and experimental work indicates that for the Quebec and Rome climates, manual versus constant lighting control reduced lighting consumption by about 80% and that the cooling and primary energy loads are significantly reduced by 42% 57% ,60% and 43% respectively [5]. However the main source of energy consumption of a building is due to the spread of the HVAC (Heating Ventilation and Air Conditioning) installations which is further increased by the growing demand for better thermal comfort. In fact in developed countries HVAC is the main energy consumption system of a typical dwelling since it is responsible for almost half of the total energy consumption especially for the non-domestic cases, [6]. As far as the indoor environment is concerned, the increasing numbers of people in the building, results to higher levels of carbon dioxide ($CO_2$) produced mainly by human exhalation [7]. It is well understood that $CO_2$ concentrations can be used as a tracer gas for the evaluation of the ventilation system performance, [8 & 9].

The aim of this paper is to present the results of an experimental campaign that took place in an educational building of the National University of Singapore (NUS). The results refer to the energy consumption and air quality of three rooms, each one with different usage and occupancy. The impact of different occupancy patterns on the energy demands, the illuminance of the building, as well as the internal levels of temperature, relative humidity and $CO_2$, are examined. The study of these parameters, constitute an innovative contribution to the limited literature on energy consumption measurements within educational buildings of countries with hot and humid climate.

### *1.1. Methodology*

The experimental campaign took place in 3 different types of rooms in terms of occupancy (an executive room, a computer room and a lecture theater) which were carefully selected from the block of buildings of the campus of the NUS. The main objective of the research was to investigate the impact of human presence to the change of energy consumption and indoor air quality within the building. In this respect, measurements were taken in situ on a continuous 24hour basis for a period of 4 months. During the experiment, the daily uses of every room (lectures, meetings, presentations etc.) and the operational details were also recorded. It is noted that the rooms are located in different floors and that the building is situated in the city center area.

Energy consumption (kWh), illuminance (lux), temperature ($^0$C), relative humidity (%) and $CO_2$ concentration (ppm) constitute the main measured parameters. Firstly, a raw database is created and analyzed qualitatively and quantitatively by statistical software tools. In order to achieve a high quality data acquisition, Tukey's Two Sided test [10] was implemented to remove unwanted outliers and replace them with missing values. Subsequently, with the aid of K- Nearest Neighbor (KNN) imputation technique [11] the missing data have been replaced by a weighted average of k nearest values. Thus, a smoother group of time series is achieved and unwanted measurements that could influence the final results are neglected.

The results should initially give a general view of the three rooms background for each measured parameter during the entire experimental period. Depending on this overview, the analysis focuses on specific days of interest where particularly high levels of specific parameters will be further analyzed so that the causes and conditions of this behaviour will be investigated. Moreover, the study of any potential correlation between variables will be facilitated