

## Study on space utilization rate of teaching building

### Scoping study

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**Abstract:** The influx of international students has led to a huge increase in demand for university space in the UK, while the government has limited investment. Therefore, it has become necessary to improve the utilization rate of space. This study analyzes occupancy data collected over a period of one and a half years in spaces and student support spaces, in two buildings at the University of Southampton. The results show that in the Buildings, where academics are the main users, the space utilization rate from the booking system is lower than the monitored space utilization rate, and the error range is varied from 1% ~ 20%. The overall space utilization rate is generally low. In the Building, where students are the main users, the space utilization rate is about 50%. At the end of the semesters, the space utilization rate even reached 100%, which was at a relatively high level. Building on these results, monitored occupancy data is essential to review the utilization of space. Students support spaces had much greater utilization than academic spaces.

**Keywords:** building occupancy, space utilization, energy consumption, cost, Sensor analysis

### 1. Introduction

The utilization of space in colleges and universities is a problem that attracts much attention. On the demand side, the UK is faced with a large influx of international students and an increasing demand for teaching space. However, the British government's investment in university higher education is limited. Faced with the ever-expanding number of students, it has become necessary to optimize the use of existing facilities in order to minimize cost and investment in new buildings but also reduce energy demand.

According to many studies (Rozilah et al. 2012), the utilization of space in Universities is often below their design goals; this includes spaces such as teaching spaces, academic offices, studios/laboratories and support offices. The benchmark for space utilization as defined as follows (NAO, 1996); <25% poor; 25%-25% satisfactory; >35% good. For example, one of the teaching buildings at Tun Husonn University in Malaysia (Jutaim et al. 2023) has an occupancy rate varying from 17% to 54% and a utilization rate varying from 8% to 45%, with 9 of the 13 teaching spaces monitored below the 25% threshold utilization rate. This low utilization rate was attributed to the number of students per classroom, with larger classrooms being less occupied compared to smaller classrooms. Another study at the Delft University of Technology study showed that the actual utilization of lecture halls is less than 60% of the planned utilization (Valks, et al. 2021).

This study mainly focuses on the space utilization rate in higher education places, by reviewing space calendar booking, monitoring the number of people in the room and comparing the results to benchmark. The aim of this study is to provide recommendations for

higher education institutions, to improve space utilization, with implication on estate costs, energy demand, and students satisfaction.

## 2. Literature review

### 2.1 Definitions

Space utilization rate (U %) is defined a percentage from the frequency rate (F %) and the occupancy rate (O %) divided by 100, formula as follows:

$$U\% = \frac{F\% \times O\%}{100} \quad (1)$$

The frequency rate (F %) is the percentage of **hours used** by maximum hours allocated for a defined period of time (t), formula as follows:

$$F\% = \frac{\text{total hours used}(t)}{\text{total maximum hours}(t)} \quad (2)$$

The occupancy rate (O %) is the percentage of **actual number of occupants** by the maximum number of occupants (space capacity) for a defined period of time (t), formula as follows:

$$O\% = \frac{\text{total capacity used}(t)}{\text{total maximum capacity}(t)} \quad (3)$$

In some relevant studies, the questionnaire was initially used to investigate satisfaction with the use of space, mainly among students, teachers and administrators in some universities. The contents of the questionnaire mainly include whether the teaching needs are met, some meeting rooms and their use, and the use of equipment. Regardless of the method used, the results differ to some extent from the intended capacity of the designed room, and actual usage is often lower than the room booking data. For example, a Delft University of Technology study showed that the actual utilization of lecture halls is less than 60% of the planned utilization. In another article on the use of office space, it was mentioned that small offices are highly used and large offices are less efficient than it. All of this suggests that the preferences of research users can affect space utilization.

### 2.2 Data collection methods

Often, questionnaires are initially used to investigate satisfaction with the use of space, mainly among students, academics, and administrators (Rahman, et al, 2015). The contents of the questionnaire mainly include whether the teaching needs are met, the provision of meeting rooms and their use, and the use of equipment.

Many studies use manual counts to estimate the occupancy, and calendar or booking system to estimate the frequency of use (Valks, et al. 2021). More recent studies used sensing methods to offer a more accurate and complete estimation of space utilization (Valks, et al. 2019).

## 3. Research aim and objective

This project aims to review the space utilization rate by estimating the utilization time and number of users of the teaching spaces at the University of Southampton.

This paper has the following objectives:

1. Analyze existing university building data and assess whether the estimated utilization rates meet the higher benchmark.

2. Review the limitations of the building usage and design, and propose improvement

## 4. Methodology

### 4.1 Case study buildings

The study includes two case study buildings: Building 178 and Building 60. Building 178 was completed in 2019; it is a five-storey mixed-use building that includes engineering laboratories and academic offices. Research meeting rooms are on three floors; three on the 3<sup>rd</sup> floor (3023, 3067, 3069), one on the 4<sup>th</sup> floor (4023) and one on the 5<sup>th</sup> floor (5023). Each meeting room can accommodate up to 6 people (see Fig.1). Building 60 was refurbished in 2023; it is a two-storey mixed-use building that includes open study areas, quiet study areas, discussion areas, small meeting rooms for two people and larger meeting rooms for up to six people.

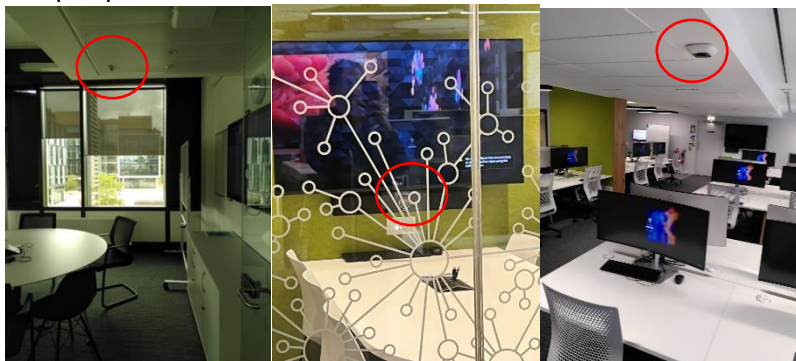


Figure. 1 Building 178 meeting room (left) & Building 60 open learning zone (right) sensors shown in red circle

### 4.2 Data collection

The study used three data collection methods. In Building 178, a booking room calendar was collected and PIR sensors (HOBO UX90-006) were installed for a period of 19 months; from the 1<sup>st</sup> of January 2023 to the 31<sup>st</sup> of July 2024. The sensors are installed on the ceiling of the five meeting rooms, above the central meeting table. This method can monitor the frequency of use but not the occupancy. In Building 60, PIR cameras were installed for a period of 6 months; from the 1<sup>st</sup> of January 2024 to the 30<sup>th</sup> of June 2024. The sensors are in all spaces in the building, installed on the ceiling, usually covering 2 to 6 seats (see Figure 1). This method can monitor the frequency of use and occupancy rate, as the number of users at a specific time and location are monitored.

### 4.3 Data analysis

Using the monitoring data and assumptions, the utilization rate will be estimated. For Building 178, the booking room calendar data are processed first. This data shows the time and duration of the room used. From the PIR sensors data, the average frequency of use was estimated. Finally, the space utilization rate of each meeting room in Building 178 was estimated and compared for both methods. For Building 60, the average occupancy and space usage for each time period, day and week, were estimated. This enabled the comparison of space utilization between different learning areas.

## 5.Results

### 5.1 Building 178

From the booking room calendar and the PIR sensor data, the meeting room date and duration of use was collected. But there was no data on the actual number of people using the rooms, for this study it was assumed that 4 people will be in the meeting. According to formula (3) above, the applied formula can be written as followed:

$$O\% = \frac{\text{duration hours} \times 4(\text{people})}{\text{available hours} \times \text{Maximum room capacity}} \quad (4)$$

The results are as follows are summarized in table 1. Estimated space utilization rate ranged from booking room calendar ranged from 0.87% to 3.61%, while estimated space utilization rate from PIR sensors ranged from 4.14 to 21.52%. This demonstrates that the space utilization rate estimated from booking room calendar is a significant underestimation of the actual space utilization rate. The difference between the two estimates ranged between 1.08% and 20.23%. From the review of the difference, there are two groups, two meeting rooms (3067 and 3069) have errors of ~1-2%; while three meeting rooms (3023, 4023, 5023) have errors of ~15-20%. The first group of meeting rooms are located along a corridor and can be accessed by students and academic staff; while the second group of meeting rooms are at the end of a corridor, mostly accessed by academic staff. This distinction in the shared nature of the space, may be the reason for the difference in utilization rate. Meeting rooms that are perceived as shared-user space are booked in advanced, while meeting rooms with one user group are used but not booked. In summary, the estimation of utilization rate from booking room calendar may be underestimated and may not be reliable for university estate management.

Table.1 Building 178 space utilization rate

Room number	Hours used	Frequency rate%(outlook)	Occupancy rate%(outlook)	Utilization rate%(outlook)	Utilization rate%(PIR)	Difference (%)
3023	656.10	17.61	8.66	1.29	16.69	15.40
3067	600.40	19.23	13.32	2.56	4.14	1.58
3069	950.70	25.51	14.17	3.61	4.69	1.08
4023	664.90	17.85	7.72	1.29	21.52	20.23
5023	287.20	7.71	12.21	0.87	16.68	15.81

Over a week, each room in Building 178 is used differently. Rooms 3023, 3067, 3069, 4023 and 5023 all have the highest frequency of use on Thursdays, while the lowest frequency is not the same.

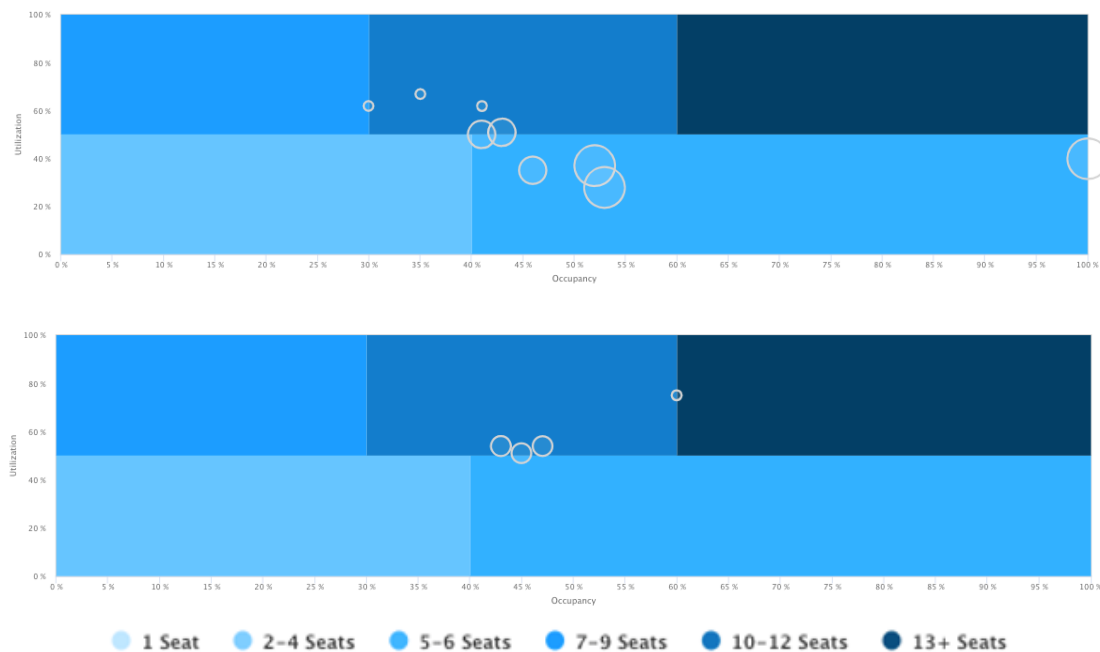
### Analysis of space utilization rate of teaching building 60

Building 60 is highly occupied on both floors every month except during holidays such as Christmas and Easter. Building 60 is open from 8 a.m. to 10 p.m. The rooms on the first floor are mainly learning areas with (a) desks and monitors, (b) informal meeting and learning spaces with soft furniture and (c) meeting rooms. There are three types of capacity: spaces (a) with 2-4 seats(43% of the space), spaces (b) with 7-9 seats (29% of the space) and spaces (c) with more than 13 seats (28% of the spaces). The second floor is dominated by meeting rooms (2-4 seats, occupying 25% of the escape) and open learning areas (5-6 seats,

occupying 75% of the escape). On the first floor, students prefer a one-seat area, while there are more people using 5-6 seats on the second floor. This shows that in normal use, students who study alone prefer to study on the first floor, while those who study in groups prefer to study on the second floor. Overall, the occupancy rate and utilization rate of the two floors is high, see Figure 2 and Table 2).

**Table 2.** Building 60 space utilization rate

	Room type	Occupancy rate%	Peak Occupancy%	Utilization rate%
Level 1	All type of space	46	100	20-50
	Meeting room	40-55	100	
	Open and quiet space	48	100	
Level 2	All type of space	47	100	45-50
	Meeting room	40-50	100	
	Open and quiet space	44	100	



**Table 2.** Building 60 occupancy vs.space utilization rate (each spaces are shown as circles)

In Building 60, 46 % of the space is occupied on the first floor and 47 % on the second floor. During peak hours, the occupancy rate of all types of Spaces on both floors reached 100%, indicating that the utilization rate of Building 60 was full. From the perspective of space utilization, the overall level of the second floor is much higher. This shows that students prefer to study and do activities on the second floor.

If you look at the semester, the occupancy rate in the semester usually fluctuates around 50%, and sometimes even reaches 70%. But there is a sudden drop during the holidays.

## 6. Conclusions

The study reviews the occupancy, frequency and utilization rate of two buildings using three methods. The results show that estimating the utilization rate from the booking room calendar may be underestimated and unreliable for university estate management.

Overall, the utilization rate between the types of spaces varied, with the shared academic/student spaces showing the lowest rate (~4-5%), while the spaces used by academics only had also 'poor' rates (~16-22%) lower than the 25% benchmark, but the spaces used by students had 'good' rate (~20-50%) greater than the 35% benchmark (NAO, 1996).

The limitations of this study are mainly in the small sample of space studies. Also, data accuracy may be compromised as only a single sensor was deployed. The booking data for Building 178 is based on estimates of capacity, so the results are biased. Improvements to research should include expanding data sources, incorporating more sensors into analysis, and identifying a number of occupants. A questionnaire survey should be conducted on the user group to investigate space satisfaction and the existing challenges.

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Through the analysis of the results, it points out the existing problems of higher education places and the ways to optimize and improve them. However, there are certain limitations in the research process, and the selected samples may not be representative.

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