

## Optimizing Teaching and Learning Space Operationalisation in Higher Education: A Quantitative Analysis using Timetable Data

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### ABSTRACT

*According to the International Facility Management Association, facilities management is a profession that involves the convergence of operations from various disciplines to ensure the efficiency of the environment by incorporating staff, places, procedures and technologies. Space management is one of the keys to facilities management because space-related spending incurs the second-largest cost after staff wages in higher education institutions. Despite the significant financial investment in educational infrastructure, inefficient space operationalisation remains a persistent challenge. Inadequate monitoring and evaluation of teaching and learning space utilization can lead to underutilized resource, impacting institutional sustainability and operational effectiveness. Therefore, this study, aims to evaluate of the operationalisation of teaching and learning space in the School of Geomatics Science and Natural Resources, UiTM Shah Alam based on one of the selected semesters. The objective of this study is to examine the performance of space-based capacity and timetable information. Data was gathered from the School of Geomatics Science and Natural Resources, UiTM Shah Alam and the timetable was extracted from the Integrated Course Registration and Scheduling System (ICReSS) through Jupyter Notebook (Phyton). This data was used to determine the trend of the space utilisation rate (SUR) using Microsoft Excel for data entry and SPSS software to analyse the data. In addition to statistical analyses, qualitative data were gathered through semi-structured interviews with administrative staff to contextualize scheduling practices and identify operational challenges. The results from the analysis show that the space utilisation rate for 19 selected teaching and learning rooms varies from 10.96% to 88.37%.*

*Keywords: Facilities management; frequency index; space management; space frequency; spatial planning*

## INTRODUCTION

Higher Education Institutions (HEIs) rely on well-structured space management strategies to optimize academic and operational efficiency. Space is one of the most valuable assets within an institution, serving as a critical component for teaching, learning, and research activities (Sidik et al. 2024). However, the effectiveness of space management is not solely determined by the availability of physical space but also by how efficiently it is allocated and utilized to meet institutional demands. The ability to assign space to a particular function whether for individual use, departmental requirements, or multi-functional purposes is fundamental to ensuring optimal resource utilization (Peng et al. 2022). Effective space management extends beyond occupancy assessment, it also involves scheduling, administrative coordination, and strategic planning to ensure that institutional space is used efficiently. This includes determining the number of occupants per room, assessing usage frequency, and ensuring an optimal distribution of available resources (Peng et al. 2022). The primary objective of space management is to maximize resource availability in both short and long-term institutional planning while minimizing inefficiencies (Tagliaro et al. 2020). Institutions that lack a structured approach to space utilization risk underutilization, operational inefficiencies, and increased facility management costs.

Efficient space management plays a critical role in shaping institutional performance and sustainability. HEIs must balance increasing student enrolments with limited physical infrastructure. Poor space management can lead to several inefficiencies, including underutilized spaces, overcrowding, and ineffective scheduling, which negatively impact both student learning experiences and administrative decision-making (Papaioannou et al. 2023). To address these issues, many universities worldwide have adopted advanced facilities management tools, integrating spatial analytics and automated scheduling systems to enhance operational efficiency (Peng et al. 2022). These tools enable institutions to analyze space utilization patterns, improve classroom scheduling, and optimize teaching and learning environments. However, despite these advancements, many institutions still struggle with inefficient space utilization due to limited awareness, ineffective planning, or rigid scheduling frameworks (Diallo and Tudose 2024). In many cases, classrooms remain underutilized due to poor alignment between scheduling systems and actual space requirements.

Although space management is a fundamental component of HEI operations, several challenges hinder its effective implementation. One of the primary issues is

the difficulty in accurately measuring and analyzing space utilization rates due to limitations in data collection and analytical techniques. Many universities still rely on manual assessments, which lack precision, while inconsistent scheduling policies lead to inefficient room allocations. In many institutions, classroom space allocation is not systematically monitored, resulting in disparities in room occupancy. Some classrooms remain underutilized, while others experience overcrowding, creating imbalances that affect teaching and learning quality and overall institutional efficiency (Sidik et al. 2024). Poorly managed teaching and learning spaces, such as overcrowded classrooms or misallocated rooms, can compromise instructional quality, reduce student engagement, and diminish overall learning outcomes. Additionally, unlike HEIs in developed countries, Malaysian universities still face challenges in implementing data-driven space management strategies. Many institutions lack integrated digital systems capable of tracking space usage in real time and providing actionable insights (Rawia et al. 2023). Studies in the United Kingdom and the United States have demonstrated that HEIs that adopt smart space management technologies such as real-time occupancy sensors and automated scheduling systems achieve significantly higher space utilization efficiency (Cavus et al. 2022; Monero Flores & Häne 2022). These technological approaches help institutions optimize classroom space by aligning student demand with available capacity.

Recognizing the challenges associated with inefficient space utilization in HEIs, this study aims to assess the effectiveness of teaching and learning space allocation by analysing real-time scheduling and capacity data from the School of Geomatics Science and Natural Resources, UiTM Shah Alam. The study is motivated by the need to bridge the gap between institutional space availability and actual usage to develop data-driven policies for optimized space allocation. This research evaluates how efficiently teaching and learning rooms are utilized based on actual timetable data. By leveraging data analytics, the study seeks to provide insights into improving space management strategies to enhance overall institutional efficiency. Moreover, underutilized spaces contribute to unnecessary energy consumption, such as lighting and air-conditioning in unused rooms, which contradicts institutional goals for environmental sustainability.

Despite its contributions, this study acknowledges several limitations. The research is based on one academic semester (Semester 1, Academic Session 2019/2020) and examines only 19 teaching and learning rooms within the institution. While this approach provides valuable insights into space utilization trends, future research should extend the analysis to multiple semesters and a broader range of academic buildings to obtain more generalizable

conclusions. Additionally, external factors such as curriculum changes, enrolment fluctuations, and institutional policies that may affect space utilization were not included in the scope of this study. This study employs a quantitative approach to evaluate teaching and learning space utilization, focusing on statistical analysis of timetable data to identify usage patterns and operational efficiency. The primary objectives of this study are: (1) to assess space utilization rates (SUR) in UiTM's teaching and learning rooms based on actual timetable data; (2) to evaluate the efficiency of space allocation by analysing the relationship between scheduled usage and actual room occupancy; and (3) to provide recommendations for improving space utilization efficiency using statistical and benchmarking techniques. The remainder of this paper is structured as follows: Section 2 presents a literature review of space management theories and methodologies, Section 3 details the research methodology, including data extraction and analysis techniques, Section 4 discusses the study's findings and their implications, and Section 5 concludes with recommendations for HEIs to enhance space utilization efficiency.

## LITERATURE REVIEW

Effective space management is a critical aspect of facilities management in HEIs, ensuring that teaching and learning environments are utilized efficiently to optimize available resources. Space allocation directly impacts institutional costs, operational efficiency, and academic performance, making it essential for universities to implement data-driven space management strategies. Without effective space utilization, institutions may experience underutilization of classrooms, scheduling inefficiencies, and unnecessary infrastructure expansions, leading to increased operational costs (Saaidina et al. 2023). As universities grow in student population and academic programs, strategic space management is essential for ensuring that facilities are used efficiently, equitably, and in alignment with institutional goals. This section provides a comprehensive review of space management principles, key performance indicators, challenges in space utilization, and global best practices in HEI space planning.

### CONCEPT OF SPACE MANAGEMENT IN HIGHER EDUCATION INSTITUTIONS

Space management in HEIs involves the strategic planning, allocation, and monitoring of physical spaces to maximize efficiency while meeting institutional needs. It extends

beyond mere occupancy assessment, incorporating elements such as timetabling coordination, administrative scheduling efficiency, and dynamic space utilization frameworks (Sidik et al. 2024). According to Peng et al. (2022), the primary objective of space management is to ensure that teaching and learning facilities are effectively utilized while minimizing operational costs and maintaining academic flexibility. Universities that fail to implement structured space management strategies often face resource wastage, scheduling conflicts, and infrastructure inefficiencies, making it increasingly necessary to develop intelligent space allocation models. This study is guided by User-Centered Space Planning Theory, which posits that spatial planning in higher education should align with user needs and behaviors to ensure optimal resource allocation and satisfaction.

Several factors influence space management in HEIs, including student enrolment trends, academic scheduling policies, technological advancements, and institutional priorities. An effective space management framework requires a systematic approach integrating real-time data analytics, predictive modelling, and adaptive scheduling mechanisms to ensure that spaces are used optimally. As universities continue to expand, the demand for flexible learning spaces has increased, necessitating the adoption of smart campus initiatives that leverage Internet of Things (IoT) sensors, artificial intelligence (AI), and cloud-based management systems. These technologies help track classroom usage, optimize scheduling, and enhance learning experiences. According to Tagliaro et al. (2020), universities that integrate AI-driven space planning models have reported higher classroom efficiency and improved institutional sustainability.

### METRICS AND MODELS FOR SPACE UTILIZATION ANALYSIS

Several key performance indicators (KPIs) are widely used in HEIs to assess space efficiency and identify areas for improvement. The Space Utilization Rate (SUR), Frequency Rate (FR), and Occupancy Rate (OR) are fundamental metrics that help institutions analyse classroom allocation trends (Yang et al. 2021). The FR measures how often a room is used relative to its total availability. A high FR indicates efficient scheduling, whereas a low FR suggests underutilized spaces or inflexible timetabling policies. The FR is the percentage of total hours of usage in a week (HU) over the total hours of maximum usage allocated in a week (HA). For example, the total hours of room usage in a week might be 17 and the total hours of room usage allocated in a week might be

43. Hence, the FR is  $(17/43 \times 100) = 39.5\%$ . The equation used for FR is given as Eq. 1. The OR assesses whether the number of students occupying a room matches its seating capacity. Overcrowding ( $OR > 100\%$ ) suggests misallocation, while low OR values indicate wasted resources. OR is the percentage of total space occupancy (TSU) compared to the total room capacity (TRC) and the total hours of use within a week (HU). For example, the total occupancy for a week might be 1600 occupants. The per-hour space capacity might be 30 occupants. The total hours of maximum usage allocated for a week might be 43. Therefore, the OR is  $1600 / (30 \times 43) \times 100 = 124\%$ . The equation used for OR is given as Eq. 2.

$$Frequency\ Rate\ (FR) = \left( \frac{HU}{HA} \right) \times 100 \quad (1)$$

$$Occupancy\ Rate\ (OR) = \left( \frac{TSU}{TRC \times HU} \right) \times 100 \quad (2)$$

The SUR is a composite metric derived from FR and OR, providing a holistic measure of space efficiency. Higher SUR values indicate optimal space usage, while lower values suggest the need for redistribution or reallocation strategies (Hamdan et al. 2022). The SUR refers to the percentage of the FR multiplied by the percentage of the OR. For example, the FR is 44.7 % and the OR is 54.4 %. Hence, the percentage of space utilisation rate (SUR) is  $(44.7 \times 54.4/100) = 24.32\%$ . The equation used for SUR is given as Eq. 3. The Frequency Index (FI) is another widely adopted approach for analyzing classroom efficiency. It classifies room utilization into four categories based on usage levels, ranging from Minimal Usage (0-50%) to Critical Usage (>101%). According to Tertiary Education Facilities Management Association (TEFMA) guidelines (2009) and Ani et al. (2012), an optimal FI falls within 51–75%, ensuring effective space allocation without overburdening classrooms (Lok et al. 2021). Universities with FI values below 50% risk financial inefficiencies and resource underutilization, while those exceeding 100% experience overcrowding, affecting learning quality and institutional sustainability. The equation used for FI is given as Eq. 4, while the calculated FI rate is usually represented by a value score and a colour key, as shown in Table 1.

$$Space\ Utilization\ Rate\ (SUR) = \frac{FR \times OR}{100} \quad (3)$$

$$Frequency\ Index\ (FI) = \frac{FR}{HA} \quad (4)$$

TABLE 1. Indicators of learning space frequency index

Index	Indicator	Interval Percentage	Description
0-1	Minimal Usage	0-50%	The low level used frequency
1-2	Optimal Usage	51-75%	The best level used frequency
2-3	Maximal Usage	76- 100%	The high level used frequency
3-4	Critical Usage	>101%	The crucial stage used frequency

Source: Ani et al. (2012)

### CHALLENGES IN SPACE UTILIZATION AND SCHEDULING

One of the most persistent challenges in HEI space management is underutilization, where available classrooms remain vacant for a significant portion of the academic week. Valks et al. (2021) found that many Saudi Arabian universities operate with SUR values below 50%, leading to significant financial inefficiencies and unnecessary infrastructure expansion costs. Similarly, studies in Malaysian HEIs reveal that low FR and OR values often result from inflexible scheduling frameworks (Hamdan et al. 2022). Factors contributing to underutilization include rigid class scheduling policies that do not adjust to real-time enrollment trends, departmental silos preventing cross-faculty room sharing, and faculty and student preferences for specific rooms, leading to an imbalanced allocation of resources.

While some rooms remain underutilized, others suffer from overcrowding, leading to suboptimal learning conditions and reduced student engagement. Zhou et al. (2019) highlight that in UK HEIs, institutions face financial penalties if space utilization falls below a specified threshold, motivating universities to optimize scheduling to prevent room shortages and overcrowding (Monero Flores & Häne 2022). Mismatched room assignments are particularly problematic in universities where timetabling is conducted manually or where departmental scheduling autonomy prevents a centralized approach to space allocation. Overcrowding is often a result of last-minute student enrollment fluctuations, poor forecasting of class sizes when scheduling courses, and a lack of dynamic, real-time adjustments in space assignments. Addressing these challenges requires automated scheduling tools that dynamically allocate classrooms based on fluctuating enrollment data.

## GLOBAL BEST PRACTICES IN HEI SPACE MANAGEMENT

Several universities worldwide have adopted AI-driven scheduling models to dynamically allocate rooms based on historical usage patterns, predicted student enrollments, and course demand. In Australian HEIs, the use of cloud-based space management software has significantly improved classroom efficiency by reducing room mismatches and preventing scheduling conflicts (Cavus et al. 2022). AI-based systems enable real-time monitoring of classroom occupancy, automated room reallocation based on demand shifts, and more equitable distribution of spaces across faculties.

Another best practice is the implementation of real-time space utilization dashboards, which enable faculty members, course schedulers, and institutional administrators to track room occupancy trends dynamically. These dashboards use IoT sensors and cloud computing to provide live updates on space availability, allowing adaptive scheduling and improved decision-making. A study by Jutaim et al. (2023) in UiTM Sarawak found that integrating automated space monitoring tools helped reduce classroom idle time by 30%, demonstrating the effectiveness of real-time analytics in enhancing space efficiency. These global practices provide a framework for improving space utilization strategies in HEIs, particularly in universities facing space constraints and scheduling inefficiencies.

The literature highlights the critical role of structured space management in HEIs, emphasizing the importance of dynamic scheduling, real-time monitoring, and strategic allocation frameworks. Key challenges such as underutilization, rigid scheduling policies, and overcrowding persist in many institutions, necessitating innovative solutions such as AI-driven scheduling models and real-time space dashboards. Universities that integrate automated, data-driven space optimization techniques can significantly enhance space efficiency, reduce operational costs, and create better learning environments for students. As HEIs continue to expand, adopting intelligent space management solutions will be crucial for achieving long-term sustainability, efficiency, and academic excellence.

## RESEARCH METHODOLOGY

This study employs a quantitative approach to evaluate space utilization in teaching and learning rooms within the School of Geomatics Science and Natural Resources, UiTM Shah Alam. The methodology consists of two main phases: data acquisition and data analysis, designed to systematically extract, process, and interpret space utilization trends. The study utilizes timetable data

extracted from the ICRess, with statistical computations conducted using SPSS software to assess FRs, ORs, and SURs. This methodological framework ensures that the research findings are both empirically robust and applicable to institutional decision-making. To enhance the credibility and validity of the findings, data triangulation was employed. This involved cross-referencing three complementary data sources, which are institutional timetable records from ICRess, classroom physical capacity data, and student enrolment figures. This comprehensive quantitative approach enabled cross-validation of results and provided a well-founded understanding of space utilization challenges and opportunities.

## DATA ACQUISITION

For the data acquisition phase, the timetable was extracted from the ICRess. The ICRess is an online timetabling system used by UiTM. Data for this study was gathered from the School of Geomatics Science and Natural Resources, UiTM Shah Alam, for Semester 1 of the Academic Session 2019/2020. The teaching and learning room timetable were used to observe how learning space had been allocated compared to actual use. The information was extracted using Jupyter Notebook (Python) from the ICRess and saved in an IPYNB file. The IPYNB file is a notebook document used by Jupyter Notebook to help scientists work with the Python language and their data in an immersive analytical environment. The extraction process used is shown in Fig. 1.

Ethical considerations were observed throughout the study. Although no sensitive or personally identifiable information was collected, permission to access the ICRess timetable data and to conduct informal consultations with faculty members was formally granted by the School of Geomatics Science and Natural Resources, UiTM Shah Alam. All consulted individuals were briefed on the objectives of the study and gave verbal consent prior to participation. Since the study did not involve formal interviews or survey instruments, ethics committee approval was not required under institutional policy.

A total of 19 undergraduate teaching and learning rooms were identified. A list of the total number of students per subject was compiled to achieve the goal and Microsoft Excel was used for data entry when evaluating the data using the Statistical Package for the Social Sciences (SPSS) programme. The sample consisted of all 19 available teaching and learning rooms in the faculty, ensuring a comprehensive representation of spatial usage during the selected academic semester. Prior to statistical analysis, all datasets were screened for completeness and accuracy. Data cleaning involved validating classroom time slots, checking for missing values, and correcting discrepancies

in occupancy calculations. These steps ensured the reliability of the computed metrics, particularly FR, OR, and SUR.

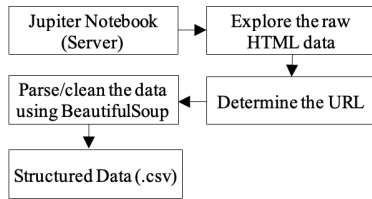


FIGURE 1. Timetable extraction process using Jupyter Notebook

### DATA ANALYSIS

For the data analysis phase, all the information extracted from ICRess was analysed. Four main aspects were calculated based on the 19 teaching and learning rooms:

1. Total hours usage in a week (HU)
2. Total hours of maximum usage allocated in a week (HA)
3. Total space occupancy (TSU)
4. Total room capacity (TRC)

After that, the SUR was calculated to identify the space utilisation rate for each room. An example of how the SUR was determined for a room is given in Table 2. The room was G-A315, with a capacity of 50 people per hour. As Table 2 shows, the room was only used for 26 hours per week out of a total of 43 hours per week. Therefore, the space utilisation FR can be derived by adopting the formulas given in Eq. 1 - 3.

1.  $FR: (26/43) \times 100 = 60.47\%$
2.  $OR: 1600 / (50 \times 26) \times 100 = 123.08\%$
3.  $SUR: (60.47\% \times 123.08\%) / 100 = 28.19\%$

TABLE 2. Space utilization rate calculations of room G-A315

Room Capacity: 50 Hours Used: 26											
Time/Day	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	Total Student
Monday		(1)90	(2)90	(3)90				(4)20	(5)20	(6)20	330
Tuesday	(7)60	(8)60	(9)60	(10)60							240
Wednesday	(11)60	(12)60	(13)30				(14)60	(15)60			270
Thursday			(16)90	(17)90			(18)5	(19)5			190
Friday	(20)90	(21)90	(22)90	(23)30				(24)90	(25)90	(26)90	570
Total											1600

### RESEARCH METHODOLOGY

This section presents a detailed analysis of the space utilization findings for 19 teaching and learning rooms in the School of Geomatics Science and Natural Resources, UiTM Shah Alam, during Semester 1 of the Academic Session 2019/2020. The results are interpreted based on three key metrics, FR, OR, and SUR. These indicators are essential in understanding how efficiently the available teaching spaces are being used and whether the current allocation strategies align with institutional needs. A further analysis of trends in space utilization is provided to identify

underlying inefficiencies, followed by recommendations for improving space allocation and scheduling strategies.

### SPACE UTILIZATION METRICS ANALYSIS

To assess the effectiveness of space utilization, the study computed FR, OR, and SUR for all 19 selected rooms as shown in Table 3. The results indicate a wide range of utilization levels, with some rooms being used at near-optimal levels while others are significantly underutilized. This variation suggests inconsistencies in the allocation of teaching spaces, highlighting the need for a more structured and data-driven approach to room scheduling.

TABLE 3. Analysis of space usage

No	Room	H <sub>U</sub>	T <sub>SU</sub>	Room Capacity	FR (%)	OR (%)	SUR (%)
1	G-STORE UKUR	27	1230	100	62.79	45.56	28.60
2	G-A503	20	600	30	46.51	100.00	46.51
3	G-B506	27	850	70	62.79	44.97	28.24
4	G-B508	37	1110	30	86.05	100.00	86.05
5	G-A315	26	1600	50	60.47	123.08	74.42

*continue ...*

...cont.

6	G-B513	21	840	70	48.84	57.14	27.91
7	G-MAKMAL GIS	14	370	30	32.56	88.10	28.68
8	G-M. U JURUTERA	18	490	30	41.86	90.74	37.98
9	G-A505	38	1140	30	88.37	100.00	88.37
10	G-MAKMAL RS	6	180	30	13.95	100.00	13.95
11	G-MAKMAL KARTO	16	480	30	37.21	100.00	37.21
12	G-MAKMAL PHOTO	12	360	30	27.91	100.00	27.91
13	G-B516	14	330	70	32.56	33.67	10.96
14	G-MAKMAL PHOTO 2	8	240	30	18.60	100.00	18.60
15	G-MAKMAL PC	22	660	30	51.16	100.00	51.16
16	G-DK1	11	255	30	25.58	77.27	19.77
17	G-DKB	17	1060	130	39.53	47.96	18.96
18	G-A509	38	1140	30	88.37	100.00	88.37
19	G-A508	38	1140	30	88.37	100.00	88.37

Table 3 shows three rooms, G-A508, G-A509, and G-A505 with the highest space utilization (SUR = 88.37%). These rooms are small (30 seats), used frequently, and fully occupied, showing efficient use. On the other hand, rooms like G-B516 (10.96%), G-MAKMAL RS (13.95%), and G-MAKMAL PHOTO 2 (18.60%) were underused, either due to low scheduling or low student numbers. One room, G-A315, was overcrowded (OR = 123.08%), which may affect comfort and safety. Overall, the data reveals three patterns: some rooms are well-used, some are underused, and a few are overcrowded. These trends highlight the need to balance scheduling and room assignments more effectively.

#### FREQUENCY RATE (FR) ANALYSIS

The FR represents the percentage of time a room is scheduled for use relative to its total available hours. A high FR value indicates that a room is frequently occupied, while a low FR suggests inefficient scheduling. The analysis revealed that rooms such as G-A508, G-A509, and G-A505 had the highest FR values, reaching 88.37%, demonstrating that these rooms were in consistent use throughout the semester. This high level of frequency utilization suggests that these rooms are in high demand, possibly due to their favourable location, availability of teaching facilities, or scheduling preferences by faculty members. This observation is supported by informal consultations with administrative staff during the data acquisition phase, who noted that rooms such as G-A508, G-A509, and G-A505 are frequently requested due to their proximity to departmental offices, consistent availability of teaching equipment, and established scheduling patterns. Although not formally quantified, these operational findings provide plausible explanations for the observed usage trends.

Conversely, several rooms showed significantly low FR values, indicating underutilization. For instance, room G-B516 recorded an FR of only 10.96%, suggesting that it was scheduled for use far less than its available capacity. Other underutilized rooms include G-MAKMAL RS (13.95%) and G-MAKMAL PHOTO 2 (18.60%), which were scheduled for use in less than one-fifth of their potential operational time. This finding raises concerns about the allocation efficiency of teaching spaces, as several classrooms remain idle for a substantial portion of the academic week.

One possible explanation for the disparity in FR values is the inflexibility of the scheduling system, where course timetabling does not fully consider room occupancy trends. Additionally, faculty preferences, lack of centralized scheduling, and misalignment between course needs and assigned rooms may contribute to these inefficiencies. This suggests that a more dynamic and automated scheduling system is required to balance space utilization and distribute classroom allocations more evenly.

#### OCCUPANCY RATE (OR) ANALYSIS

The OR evaluates how efficiently a room's seating capacity is utilized. A high OR indicates that the number of students assigned to a room closely matches the available capacity, whereas a low OR suggests either an excess of available space or poor room allocation. The results show that several rooms, such as G-A508, G-A509, and G-A505, had OR values of 100%, meaning that these spaces were fully occupied whenever they were scheduled. This indicates an effective match between the number of enrolled students and the room's seating capacity.

However, notable cases of overcrowding were observed, particularly in room G-A315, which recorded an OR of 123.08%. This means that the number of students

exceeded the room’s seating capacity, potentially leading to overcrowded learning environments, reduced student comfort, and hindered instructional effectiveness. Overcrowding can be attributed to last-minute enrolment fluctuations, miscalculations in scheduling, or an imbalance in the assignment of courses to room capacities. Such an issue highlights the need for real-time space management strategies that dynamically adjust room allocations based on enrolment data.

On the other hand, several rooms exhibited very low OR values, indicating substantial underutilization of available seating capacity. For instance, room G-B516 had an OR of only 33.67%, while G-B506 recorded an OR of 44.97%. This suggests that rooms with larger capacities may have been allocated to courses with smaller student enrolments, leading to a waste of space. Such mismatches often occur due to rigid scheduling policies that do not

account for fluctuating class sizes, underscoring the importance of more flexible and adaptive scheduling frameworks.

### SPACE UTILIZATION RATE (SUR) ANALYSIS

The SUR combines both FR and OR to provide an overall assessment of space efficiency. High SUR values indicate that rooms are well utilized in terms of both scheduling frequency and student occupancy, whereas low SUR values suggest inefficiencies in either aspect. The results reveal significant variations in SUR across different rooms, with values ranging from 10.96% to 88.37%. Fig. 2 show the scatter plot illustrating how frequently used rooms (FR) correlate with their occupancy efficiency (OR). Each point represents a room, with labels identifying individual teaching spaces.

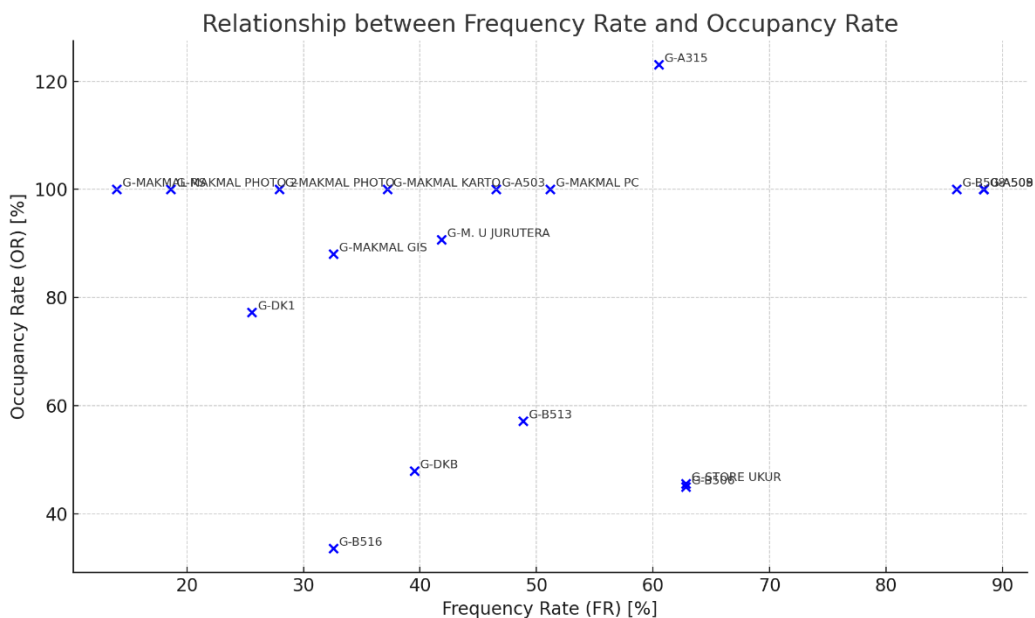


FIGURE 2. Relationship between Frequency Rate and Occupancy Rate

The highest SUR values were recorded for rooms G-A508, G-A509, and G-A505 (88.37%), demonstrating that these rooms were optimally used in terms of both scheduling and student occupancy. These findings suggest that these rooms were properly assigned to courses, with a balanced alignment between teaching schedules and class sizes. However, rooms such as G-B516 (10.96%) and G-MAKMAL RS (13.95%) had the lowest SUR values, indicating significant inefficiencies in their utilization. These rooms were not only scheduled infrequently but also had lower occupancy rates when they were in use, suggesting a misalignment in the space allocation process.

One of the key insights from the SUR analysis is the uneven distribution of space utilization across different rooms. While some rooms are at near-optimal levels of usage, others remain largely underutilized. This disparity indicates the need for a more data-driven space allocation strategy that ensures a more balanced use of available classroom resources.

### IDENTIFYING TRENDS IN SPACE UTILIZATION

The results from the space utilization analysis suggest that certain structural patterns and scheduling inefficiencies

contribute to the disparities in classroom usage. Fig. 2 shows the analysis of the FI classification, offering deeper

insights into space utilization trends and highlighting disparities in room usage efficiency.

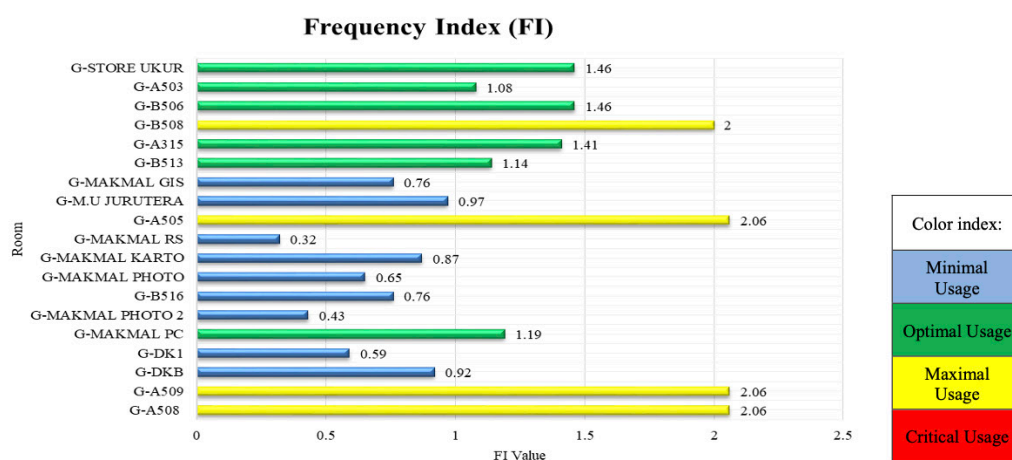


FIGURE 3. Overall frequency index of teaching and learning rooms

Several key observations emerged from the analysis of space utilization trends. Rooms categorized under Maximal Usage, such as G-B508, G-A505, and G-A509, demonstrated high efficiency, indicating that their space allocation is well-optimized and aligned with academic scheduling demands. In contrast, rooms classified under Minimal Usage, including G-B516, G-MAKMAL RS, and G-MAKMAL PHOTO 2, exhibited significant underutilization, with valuable teaching spaces remaining vacant for a substantial portion of the academic week. This inefficiency suggests a need for reallocation strategies and flexible scheduling mechanisms to optimize resource distribution. Additionally, no rooms were found to exceed the Critical Usage threshold (>101%), implying that widespread overcrowding is not a systemic issue. However, localized instances of overcrowding, particularly in G-A315, highlight the necessity for improved scheduling interventions to prevent excessive student density and enhance the overall learning environment. These findings emphasize the need for data-driven space management strategies to ensure equitable and efficient classroom allocation across the institution.

These findings indicate that current scheduling strategies do not optimize space utilization effectively. In the absence of an adaptive, data-driven allocation mechanism, certain rooms remain overburdened while others are underused, resulting in imbalanced resource distribution. Further analysis revealed that general purpose lecture rooms consistently exhibited higher SUR values than specialized laboratories, suggesting that scheduling practices prioritize spaces capable of supporting a wider range of academic activities, thereby ensuring more consistent utilization.

#### RECOMMENDATIONS FOR IMPROVING SPACE UTILIZATION

The findings from this study indicate that space utilization inefficiencies are largely caused by imbalanced room scheduling, mismatched class sizes, and rigid timetable structures that do not dynamically adjust to fluctuations in student enrolment. To address these challenges, institutions must adopt a more data-driven and flexible space management approach that ensures an even distribution of teaching spaces while optimizing resource utilization. This section outlines key recommendations to enhance space allocation strategies in HEIs, particularly in UiTM Shah Alam.

One of the most effective ways to improve space utilization is through the implementation of an AI-driven scheduling system. Current scheduling practices rely on manual input or static algorithms that fail to account for real-time room occupancy patterns and student enrolment shifts. By integrating machine learning algorithms, institutions can automate the scheduling process, dynamically assigning classrooms based on historical usage patterns, predicted student numbers, and optimal room size allocations. AI-driven scheduling models have been successfully implemented in several universities worldwide, showing a significant reduction in underutilized spaces while preventing overcrowding in high-demand classrooms. Additionally, an adaptive scheduling system would help in identifying and redistributing classroom resources more equitably, ensuring that no single room is overburdened while others remain underutilized.

Another critical recommendation is the redistribution of courses to underutilized rooms based on occupancy

trends. The study identified several rooms that were scheduled infrequently or had very low occupancy rates when used. This suggests that space allocation decisions are not systematically reviewed to ensure optimal use. Institutions should develop a centralized space management policy that prioritizes balanced room distribution across faculties and departments. By systematically analysing usage data, administrators can reassign courses from overcrowded rooms (such as G-A315, which exceeded its capacity) to underutilized rooms (such as G-B516 and G-MAKMAL RS, which recorded the lowest utilization rates). This redistribution strategy not only prevents wastage of institutional resources but also ensures that students are provided with an optimal learning environment.

Additionally, the introduction of a real-time space monitoring dashboard can significantly enhance decision-making regarding space allocation. A web-based or mobile-accessible system that visualizes space utilization in real-time would allow faculty members, course schedulers, and institutional administrators to track room occupancy trends more effectively. Such a dashboard could provide live updates on which rooms are being used, which remain vacant, and which are nearing capacity limits, allowing for dynamic adjustments when necessary. Similar real-time monitoring systems have been implemented in leading universities, helping reduce scheduling inefficiencies by ensuring that available spaces are utilized to their fullest potential. Furthermore, such a system could be expanded to include predictive analytics, forecasting future space requirements based on student enrolment trends, faculty needs, and evolving academic programs.

Beyond technology-driven solutions, it is also essential to periodically review and update space management policies to align with institutional changes and academic demands. Many inefficiencies in classroom utilization arise from outdated policies that do not accommodate shifts in student demographics, course structures, or teaching methodologies. To maintain an efficient and adaptive space management strategy, universities should establish a space utilization task force responsible for conducting annual or semesterly reviews of room allocation efficiency. This task force could work closely with academic departments, facilities management teams, and administrative units to ensure that scheduling policies remain aligned with institutional priorities. By establishing a structured framework for continuous assessment and policy refinement, HEIs can proactively address space inefficiencies before they become persistent challenges.

Although AI-driven scheduling systems and real-time space monitoring dashboards present valuable opportunities to enhance space utilization, their implementation at UiTM may face several practical constraints. These include initial investment costs, the need for staff training, limited

technical capacity, and integration challenges with existing systems such as ICRess. To ensure feasibility and minimize risk, a phased approach is recommended. The university could initiate a pilot project within a single faculty such as the School of Geomatics Science and Natural Resources to evaluate system performance, user adoption, and compatibility with institutional workflows. Insights from the pilot could inform broader deployment strategies. Furthermore, forming partnerships with technology providers or leveraging existing ICT infrastructure may reduce implementation costs and support a smoother transition toward data-driven space management.

In conclusion, enhancing space utilization in HEIs requires a holistic, data driven, and adaptive approach. Implementing AI-driven scheduling systems can automate and optimize classroom allocations, while redistributing courses to underutilized spaces ensures a more even distribution of academic resources. A real-time space monitoring dashboard can provide faculty and administrators with actionable insights, improving responsiveness to scheduling needs. Finally, regular policy reviews and institutional monitoring mechanisms are essential for ensuring that space utilization strategies remain effective in the long term. By adopting these recommendations, universities can achieve higher operational efficiency, reduced infrastructure costs, and a better learning environment for students.

## CONCLUSION

The management of teaching and learning spaces in HEIs plays a crucial role in ensuring the optimal utilization of available resources, operational efficiency, and a conducive learning environment. This study has systematically examined space utilization in 19 teaching and learning rooms at the School of Geomatics Science and Natural Resources, UiTM Shah Alam, during Semester 1 of the Academic Session 2019/2020. The findings provide valuable insights into the efficiency of space allocation, frequency of use, and student occupancy patterns, offering a data-driven approach to improving institutional space management strategies. The analysis revealed significant disparities in space utilization rates, with some rooms being highly occupied and frequently used, while others remained underutilized throughout the semester. The SUR ranged from 10.96% to 88.37%, demonstrating an imbalance in room allocation efficiency. Notably, rooms such as G-A508, G-A509, and G-A505 were among the most efficiently utilized, with high FR and OR, indicating a strong correlation between demand and scheduling

efficiency. In contrast, rooms such as G-B516 and G-MAKMAL RS exhibited low utilization rates, suggesting suboptimal scheduling and allocation practices. Additionally, instances of overcrowding were detected, particularly in room G-A315 (OR = 123.08%), emphasizing the need for real-time adjustments to prevent excessive student density in constrained spaces. These findings highlight an urgent need for enhanced scheduling policies that can dynamically adapt to changing student enrollments and academic requirements.

The study further underscores the limitations of current scheduling systems, which rely on static room assignment policies that do not consider real-time demand fluctuations or institutional capacity constraints. The disparities in utilization suggest that certain rooms are preferred over others due to location, amenities, or traditional scheduling patterns, while some classrooms remain idle due to inefficient allocation strategies. This imbalance not only leads to wasted institutional resources but also impacts the overall student learning experience, as poorly utilized spaces could be repurposed to meet growing academic needs. To address these challenges, the study proposes several strategic recommendations to optimize space utilization. The implementation of AI-driven scheduling models would allow institutions to dynamically allocate classrooms based on historical usage data, predicted student enrollments, and real-time room availability. Additionally, the redistribution of courses to underutilized spaces can alleviate pressure on overburdened rooms while ensuring a more equitable distribution of resources across faculties. The introduction of a real-time space monitoring system would provide faculty and administrators with actionable insights into classroom occupancy trends, enabling proactive adjustments to scheduling inefficiencies. Furthermore, regular policy reviews and periodic audits of space utilization should be institutionalized to ensure that allocations remain aligned with evolving academic needs and enrollment patterns.

Despite the valuable insights provided by this study, several limitations should be acknowledged. The analysis is confined to a single academic semester and a specific faculty, limiting its generalizability to broader institutional contexts. Future research should expand the scope by incorporating multiple semesters, additional faculties, and cross-institutional comparisons to develop a comprehensive framework for space optimization. Additionally, integrating advanced analytics techniques, such as predictive modeling and machine learning, could further refine scheduling efficiencies by forecasting future space demands and identifying underutilization patterns in real time. In conclusion, effective space management is essential for enhancing institutional efficiency and ensuring optimal resource utilization in HEIs. The findings of this study

highlight critical gaps in current scheduling practices, emphasizing the need for data-driven decision-making in classroom allocations. By adopting intelligent scheduling solutions, strategic room redistribution, and real-time space monitoring, institutions can significantly improve learning environments, reduce infrastructure inefficiencies, and create a more sustainable approach to space management. Moving forward, HEIs must prioritize adaptive and technology-driven space management strategies to meet the evolving demands of modern education, ensuring that facilities are used efficiently, equitably, and in alignment with institutional goals.

This study has demonstrated the importance of data-driven space utilization analysis in HEIs by evaluating frequency, occupancy, and utilization rates across 19 teaching and learning rooms. While the findings offer practical implications for improving space allocation at the faculty level, several limitations must be acknowledged. The analysis was confined to a single semester and focused only on one faculty, which limits the generalizability of the results.

Future research should expand the dataset to include longitudinal observations across multiple semesters, enabling the identification of usage trends over time. Inclusion of data from additional faculties would facilitate broader institutional assessment and interdepartmental comparisons. Furthermore, the deployment of real-time space usage sensors could enhance measurement accuracy by capturing actual occupancy patterns beyond scheduled allocations. These future directions would improve the robustness, scalability, and institutional relevance of the findings, supporting more equitable and efficient space management across the university.

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## DECLARATION OF COMPETING INTEREST

None.

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