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Study on the Design Quality Indicators for Building Evaluation of Taiwan Campus

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Abstract

Campus buildings play a crucial role in education. Designing campus buildings in Taiwan to meet high-quality standards is crucial due to the frequent seismic activity and the evolving requirements of modern education. Architects often rely on past experiences and regulations, which may only partially meet user needs, leading to suboptimal designs. This study examines the application of the Design Quality Indicator (DQI) framework to evaluate and enhance the design quality of campus buildings. We reviewed literature and cases to compile suitable DQI metrics, and then conducted the survey to assess various dimensions, including functionality, build quality, and impact. We also collaborated with property management experts to evaluate 60 campus buildings. The results indicate that teaching and dormitory buildings generally achieve higher levels of user satisfaction and operational efficiency. Conversely, administrative buildings show deficiencies in accessibility and innovation. Key issues identified include inadequate indoor environmental quality and insufficient adaptability to future needs. Recommendations for improvement focus on addressing these low-scoring areas through better design integration, flexible layouts, and sustainable technologies. This study highlights the need for continuous evaluation and adaptation in the design of campus buildings to meet the evolving requirements of the educational sector and ensure safety in earthquake-prone regions. Future research could explore the performance of buildings post-occupancy evaluation to assess the potential of incorporating DQI early in the design process, providing valuable insights for the field.

Keywords: Campus Buildings, Design Quality Indicator (DQI), Building Evaluation, Taiwan, Quantitative Method

■1.0 INTRODUCTION

Campus buildings are essential in the educational system, serving as crucial environments where students learn and develop. The planning and design of campus facilities involve various factors, including the rationality of spatial layout, assurance of comfort, completeness of functional facilities, and environmental harmony (Fisher and Dovey, 2016; Uduku, 2010). For example, appropriate lighting and ventilation can enhance students' attention and concentration, while comfortable temperatures and climate control can improve their overall comfort and learning efficiency (Maxwell, 2018). Therefore, the quality of campus buildings directly impacts teaching quality and students' comprehensive development. Different types of buildings serve varied functions and user needs, which require specific design standards. Classifying campus buildings allows for a more precise evaluation and targeted design improvements.

For example, teaching buildings, dormitories, administrative offices, libraries, and sports facilities have unique requirements. Teaching buildings need flexible classroom layouts to support diverse teaching methods, while dormitories emphasize comfort and privacy. Administrative offices require efficient workspace design and good visitor reception areas. Libraries need quiet study environments and ample storage for resources, while sports facilities must consider large open spaces and ventilation. Classifying campus buildings enhances design and evaluation accuracy and aids in developing targeted improvements (Fisher and Dovey, 2016; Uduku, 2010).

According to the Ministry of Education in Taiwan, the 1999 Chi-Chi earthquake (also known as the 921 earthquake) caused significant damage to 1546 campus buildings, with 293 needing complete reconstruction and 8600 requiring seismic reinforcement. The estimated total loss was approximately USD 14.66 million (Center for Disaster Philanthropy). More recently, the Hualien earthquake affected 380 campuses, causing an estimated $250.3 million NTD in damage. These incidents underscore the urgent need for regular inspections, reinforcements, and adherence to strict building codes to ensure student safety and educational continuity.

To address the impact of these earthquakes, the Taiwanese government plans to demolish unsafe buildings and construct new ones that meet modern seismic standards to mitigate future earthquake risks. Therefore, selecting campus buildings within 10 to 20 years old for this study, along with adhering to applicable local regulations, is crucial for developing a suitable evaluation framework.

Architects face several challenges during the design process of campus buildings (Sanni-Anibire and Hassanain, 2016). They often rely on traditional design methods influenced by past experiences and local regulations, limiting their ability to innovate and fully address end-users' needs. This can result in a disconnect between architectural design and practical usage, impacting the effectiveness of campus buildings (Catalina and Iordache, 2012). Additionally, designing campus buildings involves catering to stakeholders' diverse requirements and expectations, including teachers, students, parents, administrators, and others, necessitating designers to balance various needs while maintaining design integrity (Deppeler and Aikens, 2020).

Furthermore, evolving society and rapid technological advancements present new challenges to campus building function and usage, requiring designers to adapt and incorporate these changes promptly to ensure the relevance and advancement of their designs (Turunen et al., 2014). The design issues often lead to practical usage problems, which vary across different types of buildings. Identifying and addressing these specific problems through comprehensive evaluation is essential, and this is precisely the significance of our study.

In recent years, campus buildings in Taiwan have faced several challenges. Campus buildings, predominantly public and of strategic social significance, are a prime example that must uphold high standards (Noro and Zilio, 2022). Despite a dramatic increase in the number of campus buildings over the past two decades of previous educational policies, the overall planning, design, and construction quality remain relatively weak, resulting in buildings with structural or functional deficiencies (Wang et al., 2020). Many existing campus buildings suffer from significant structural issues such as cracks in walls, foundation subsidence, and overall deterioration of building materials. These problems often stem from inadequate initial construction quality and insufficient maintenance over the years. For instance, the 1999 Chi-Chi earthquake revealed that numerous campus buildings lacked the necessary seismic resilience, leading to widespread damage and highlighting the urgent need for retrofitting and reinforcement. These measures are essential for ensuring the buildings can endure the frequent seismic activity in Taiwan and safeguard the lives of students and staff. Additionally, many buildings were constructed with budget constraints that limited the amount of reinforcement used, such as the quantity of rebar, which needs to be increased to improve structural integrity and withstand natural disasters better. As Taiwan continues its educational reforms, flexible use of space has become more important, yet functional deficiencies are widespread. Many buildings fail to meet modern educational requirements, lacking adequate facilities for technology integration, flexible learning spaces, and energy-efficient systems. These inadequacies not only compromise the safety and functionality of the buildings but also affect the learning environment, making it less conducive to contemporary educational practices (Mitchell and Sickney, 2019). Many campus buildings have exceeded their legal lifespan, necessitating consolidation or transformation due to declining birth rates and an aging population.

To face these challenges, the quality of campus buildings should be assessed periodically. The UK Construction Industry Council (Gann et al., 2003) developed an evaluation method through the Design Quality Indicators (DQI), a comprehensive assessment of building quality across three evaluative dimensions and ten indicators, including functionality, suitability, aesthetics, and sustainability. By integrating DQI into the design process, architects can better address end-user needs in the early stages of development, thereby improving overall efficiency and social impact. The DQI framework facilitates stakeholder engagement through structured workshops and online tools, allowing for comprehensive feedback and learning for future projects. This process ensures a sense of ownership among users and helps identify the strengths and weaknesses of a design. Moreover, the DQI helps create more sustainable buildings by focusing the design and construction team on the specific needs of the end users, ultimately enhancing the functionality and social relevance of the buildings (Tyagi et al., 2024).

This research explores the application of DQI to enhance construction quality in campus buildings in Taiwan. Through an extensive literature review and evaluation by professionals, we will identify DQI indicators suitable for Taiwanese campus buildings and conduct a detailed analysis of design quality across different campus buildings. By doing so, we seek to provide theoretical support and practical insights for future campus building design, emphasizing the importance of considering user needs. And architectural quality during renovation and refurbishment. And also, architectural quality during renovation and refurbishment. Furthermore, the findings of this research will contribute to the broader application of DQI, thereby enhancing the overall quality of learning environments and deepening architects' understanding of user needs. This research endeavors to advance practice and methodology in campus building design, driving the development and progress of campus buildings. Additionally, this study addresses a significant research gap by applying the DQI framework specifically to Taiwanese campus buildings, which has yet to be extensively covered in existing literature.

Before applying DQI, it is essential to discuss general campus building assessments and available evaluation methods. Campus building assessments typically involve evaluating various aspects such as functionality, safety, sustainability, and user satisfaction. Common evaluation methods include post-occupancy evaluations, the Building Research Establishment Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), and the Facility Performance Evaluation (FPE). These methods help determine the effectiveness of the building design, its impact on users, and areas for improvement. Integrating these evaluation techniques can provide a comprehensive understanding of a building's performance and guide enhancements in design quality (Deppeler and Aikens, 2020; Turunen et al., 2014).

This research explores the application of DQI to enhance construction quality in campus buildings in Taiwan. Through an extensive literature review and evaluation by professionals, we will identify DQI indicators suitable for Taiwanese campus buildings and conduct a detailed analysis of design quality across different campus buildings. By doing so, we seek to provide theoretical support and practical insights for future campus building design, emphasizing the importance of considering user needs and architectural quality during renovation and refurbishment. Furthermore, the findings of this research will contribute to the broader application of DQI, thereby enhancing the overall quality of learning environments and deepening architects' understanding of user needs. This research endeavors to advance practice and methodology in campus building design, driving the development and progress of campus buildings. Additionally, this study addresses a significant research gap by applying the DQI framework specifically to Taiwanese campus buildings, which has yet to be extensively covered in existing literature (Catalina and Iordache, 2012; Sanni-Anibire and Hassanain, 2016).

The remainder of the paper is organized as follows. In Section 1, we systematically analyze the issues and challenges in campus building design through an in-depth study of relevant literature and field investigations. In Section 2, we elaborate on the theoretical foundation of Design Quality Indicators and their potential application in campus building design. In Section 3, we present our research methodology, including the sample size, selection criteria, and data collection methods. In Section 4, we discuss the results and findings from our study, providing detailed recommendations for improving the design quality of campus buildings. Finally, in Section 5, we conclude with a summary of our contributions, limitations, and suggestions for future research.

■2.0 LITERATURE REVIEW

Our literature review primarily focuses on the organization of DQI indicators applicable to campus buildings in Taiwan. DQI (Design Quality Indicator) is widely regarded as a professional tool for assessing the quality of architectural design. It was developed by the UK Construction Industry Council in 1999 to quantify and improve the quality level of architectural design (Whyte and Gann, 2003). Initially used in the design process of new construction projects, the application scope of DQI has expanded to post-occupancy evaluation and renovation planning, achieving outstanding results in various fields. Research by Zemke and Pullman (2008) explored the correlation between DQI factors and real estate performance, finding that DQI scores are closely related to the satisfaction of guests and employees after building use. This highlights the critical role of DQI as a comprehensive indicator for assessing building performance and enhancing user experience and satisfaction. The study by Lu and Juan (2023) further demonstrated applying the Kano model and Quality Function Deployment (QFD) based on DQI in designing visitor centers in national parks. Their results show that design strategies incorporating DQI help better meet public expectations and satisfaction, indicating the value of DQI in the early stages of projects. In campus architecture, Hwang and Kim (2011) developed DQI indicators for promoting green renovation of campus buildings based on user participation design methods. By holding green renovation design workshops, they verified the practical application of DQI in environmental protection and sustainability, emphasizing its practicality in architectural design.

Gann and Whyte (2003) applied the DQI framework to evaluate campus buildings in the UK. Their research showed that involving users through structured workshops and feedback mechanisms led to significant improvements in building design. The DQI process allowed for the identification of critical design issues early in the development stage, ensuring that the final buildings better met the needs of students and staff (Gann and Whyte, 2003). Research by Hassanain and Iftikhar (2015) used the DQI framework to assess the design quality of campus buildings in Malaysia. The study highlighted how DQI helped identify deficiencies in spatial arrangements, environmental quality, and overall functionality. The findings were used to guide the refurbishment and upgrading of existing campus facilities to meet modern educational needs (Sanni-Anibire and Hassanain, 2016). These examples illustrate the versatility and effectiveness of the DQI framework in improving the design quality of educational facilities. By focusing on user needs and involving stakeholders in the design process, DQI helps create buildings that are not only functional and safe but also conducive to learning and development.

The three dimensions of the DQI framework, functionality, quality, and impact (Gann and Whyte, 2003), provide multi-level assessment, aiding in a comprehensive understanding of architectural quality. The use of 92 statements and a 5-point Likert scale in the original DQI tool further enhances the precision of its evaluation. To adapt to the architectural characteristics and needs of the Taiwan region, we made localized adjustments. We developed a version of DQI indicators suitable for Taiwanese campus buildings based on DQI indicators. This version of DQI indicators includes ten dimensions and 71 indicators; the Design Quality Indicator (DQI) is a comprehensive framework encompassing three main facets: Building Quality, Functionality, and Impact. These facets delve into three evaluative dimensions: Use, Access, Space, Performance, Engineering, Construction, Urban and social integration, Internal environment, Form and Materials, and Character and Innovation. The adjustments ensure that DQI accurately reflects local architectural quality. It aids in design decisions, is accessible to stakeholders, measures design perspectives, enables analysis, and supports lifecycle assessment with a user-friendly interface. Overall, DQI, as a comprehensive and flexible tool, becomes a reference source for architectural professionals to assess and enhance architectural quality through its comprehensive dimensions and localized adjustments (Lee and Cho, 2012). The difference between this paper and previous studies is that this paper analyzes the DQI for various building types, whereas previous studies have focused on a single building. Since our goal is to analyze the applicability of DQI to different types of campus buildings, we classify campus buildings into five categories in the follow-up.

Table 1 DQI Indicators

Dimension: **Functionality**	Dimension: **Build quality**	Dimension: **Impact**
Uses	**Performance**	**City Urban and Social Integration**
1. Building meets various user needs.	1. Building has good facilities management.	1. Building height, volume, and skyline harmonize with the surrounding environment.
2. Building enhances organizational efficiency.	2. Building is easy to clean	2. Building contributes positively to the neighborhood.
3. Building fosters more creative user activities.	3. Building is easy to maintain	3. Surrounding spaces are pleasant.
4. Building ensures safe activities and work within.	4. Building materials and components are durable.	4. Building integrates well with existing neighborhood facilities.
5. Building is adaptable to future expansions or changes.	5. Building is weather-resistant.	5. Building design positively impacts regional urban landscapes.
6. Building interior spaces are flexible.	6. Building has good sound insulation.	
7. Building systems like HVAC and utilities are adjustable.	7. Building has good overall lighting condition and Artificial lighting control is appropriate.	
	8. Building can control the indoor climate and has adequate air quality	
	9. Indoor air conditions are suitable.	
	10. Building has low complaint levels	

Access

1. Building is easily accessible by public transportation.
2. Building provides sufficient parking.
3. Building is accessible for wheelchair users and those with physical disabilities.
4. Logistics and waste management routes are appropriate.
5. Outdoor spaces, pathways, and steps are well-lit and guided.
6. Fire evacuation routes are properly planned and facilitate emergency rescue.
7. Building entrances are clear and well-marked.

Engineering (technical features)

1. Building has energy and water-saving designs or devices.
2. Engineering systems operate smoothly and quietly.
3. Engineering systems are easy to maintain and replace.
4. Building design minimizes the need for mechanical ventilation and cooling.
5. Engineering systems are clearly arranged with defined collaborative relationships.
6. Fire safety strategies and evacuation plans are clear.
7. Building's seismic and structural design is safe.

Internal environment

1. Building interior spaces are relatively narrow and open.
2. Layout and public spaces are relaxing and enjoyable.
3. Overall lighting conditions are comfortable.
4. Indoor temperature is comfortable year-round.
5. Sound insulation is comfortable.
6. Indoor air quality is comfortable.
7. Access control for personnel is appropriate.
8. Building offers good views inside and outside.

Space

1. Building spaces and dimensions are appropriately planned.
2. Building layout and room relationships are suitable.
3. Building has good circulation
4. Building has an appropriate ratio of usable to total space.
5. Internal circulation distances are well-planned.
6. Space planning considers gender-friendly issues.
7. Building provides adequate storage spaces.

Construction

1. Materials used reflect the building's function and purpose.
2. Construction methods and materials are well-planned throughout the process.
3. Building construction is safe.
4. Building design considers future demolition and component recycling.
5. Layout, structure, and engineering systems are well-integrated.
6. Interior and exterior finishes are well-coordinated.
7. Building design anticipates future climate change impacts.

Form and Materials

1. Building’s exterior is pleasing and stress-free.
2. Building's orientation and layout are well-planned.
3. Exterior materials and details are of high quality.
4. Overall color and texture are appropriate and attractive.
5. Building's massing and composition are reasonable.

Character and Innovation

1. Building design has a meaningful concept.
2. Building looks interesting and encourages exploration.
3. Building completion connects to the organization's values or vision.
4. Building completion fosters greater unity among employees/users.
5. Building design and construction contribute significantly to new technologies.
6. Building serves as a model for future similar projects.

■3.0 METHODOLOGY

3.1 Campus buildings sample selection

The buildings investigated in this study are primarily located on public university campuses. The reason for choosing universities is that the construction projects of public universities are overseen by the Ministry of Education, which has more comprehensive project information and records, as well as dedicated maintenance and property management personnel. According to data from the Ministry of Education in Taiwan, there are 148 universities distributed in the northern (69, 47% of the total), central (30, 20% of the total), southern (43, 29% of the total), and eastern (6, 4% of the total) parts of Taiwan. To match the sampling proportion, we randomly selected 25 universities in the north, 12 in the center, 14 in the south, and 4 in the east of Taiwan, as shown in Figure 1, totaling 56 campuses. The types of campus buildings include teaching buildings, dormitories, administrative buildings, gymnasiums, and libraries. Therefore, to ensure fairness, this study established three sampling principles: 1) Priority is given to buildings with an age of 10 to 20 years, as building technology and seismic regulations have become relatively mature since 2000, and the quality of buildings is more consistent; 2) Priority is given to teaching or administrative buildings within the university, as these two types of buildings account for 60% of the campus buildings in universities; 3) Every university will have facilities such as gymnasiums, libraries, and student dormitories. If no teaching or administrative buildings within the campus meet the age condition, then gymnasiums, libraries, or dormitories are selected. The final sample of 56 buildings includes 17 teaching buildings, 15 administrative buildings, eight gymnasiums, nine libraries, and seven dormitories. This ensures that the number of each type of building corresponds to their distribution proportion.

As multifunctional spaces, campus buildings contain classrooms, laboratories, and multimedia rooms, which often require flexible layouts to support diverse teaching activities and provide students with a comfortable learning environment (Veloso and Marques, 2017). Administrative buildings primarily serve as office spaces, including office areas and reception areas, with professional offices, conference halls, and reception areas helping employees relax (Brown, 1998). Dormitories are student living areas that focus on bedroom design and provide more places for interaction and socializing. Some dormitories also have soundproofed study rooms. Gymnasiums offer spacious areas for students' daily physical education classes or professional competitions, with designs emphasizing aesthetics, practicality, and safety in the indoor physical environment. Libraries are usually resource-rich, serving as the primary reading places and essential places for students to study independently, with comfortable spaces affecting students' learning efficiency and discussion (Yusuf and Adigun, 2010). All types of campus buildings emphasize aesthetics, practicality, and functionality to enhance the overall educational environment. Categorizing campus buildings helps to discuss the specific improvement needs of different buildings, thereby better understanding their educational significance.

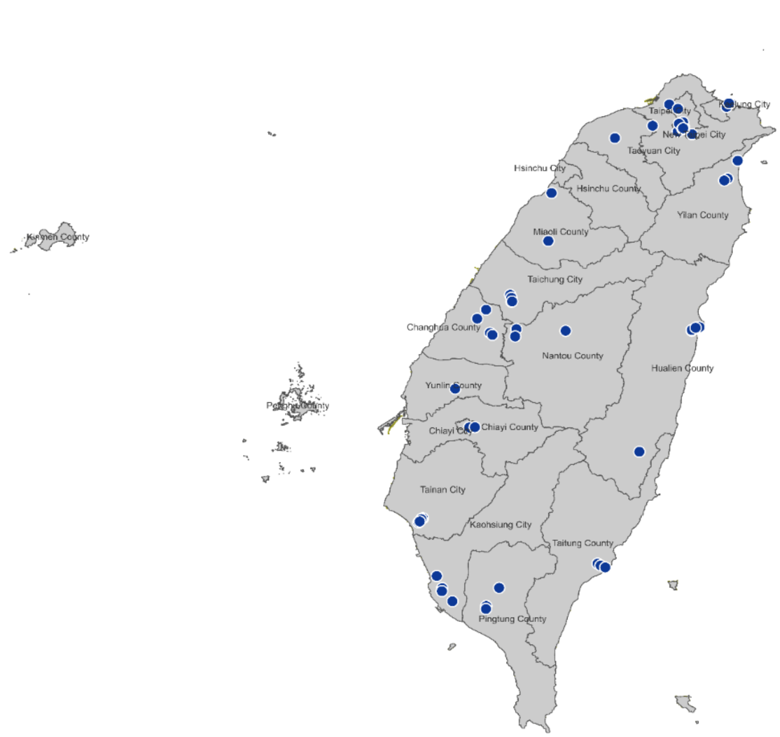

Figure 1 Campus buildings in Taiwan for evaluation

3.2 Questionnaire investigation

In Taiwan, the sector of property management participated from the design and management to the usage of the building. Therefore, they are the best source of information for our study. Additionally, they collect and organize feedback from users such as students and teachers, ensuring that their perspectives are also represented. We therefore invited them to fill out the DQI questionnaire due to their comprehensive knowledge and experience. These individuals have extensive experience in campus building project practices and are very familiar with all aspects of the building project process on campus. The composition of the DQI questionnaire is based on the indicators in Table 2. Each indicator has a corresponding score, ranging from 1 (strongly disagree) to 6 (strongly agree).

In this survey, a total of 60 questionnaires were distributed. After excluding various interferences and invalid questionnaires, 56 valid questionnaires were found. These valid questionnaires were used to analyze the design quality of campus buildings and propose corresponding improvement suggestions.

3.3 Questionnaire Analysis and Discussion

This study uses Cronbach's alpha coefficient to measure the reliability of the questionnaire. Cronbach's alpha coefficient was established in 1951 and is used to evaluate the internal consistency of a questionnaire (Tavakol and Dennick, 2011). The α coefficient ranges from 0 to 1, with higher values indicating higher reliability and better internal consistency of the questionnaire. In exploratory research, a reliability of 0.70 is acceptable, values between 0.70 and 0.98 indicate high reliability, and values below 0.35 are considered low reliability and should be rejected. The results of this study show that the overall α coefficient for the DQI questionnaire is 0.923, indicating that the questionnaire has very high reliability. This high reliability ensures that the data collected is consistent and dependable, forming a solid basis for the subsequent analysis and findings of the study.

■4.0 DISCUSSION

Following the overall analysis of DQI indicators, we now present the results for dormitories, teaching buildings, administrative buildings, libraries, and gymnasiums. The red segment indicates their average satisfaction levels, as shown in Figure 2. From Figure 2, it is apparent that student dormitories and teaching buildings have higher satisfaction levels compared to libraries. In the context of campus architecture, dormitories provide an environment for student residence, which is vital for developing social and interpersonal relationships. A good dormitory environment can enhance students' sense of belonging to the campus and affect their overall learning experience. Libraries, on the other hand, often score lower due to issues such as outdated facilities, lack of modern technology, insufficient resources, and inadequate maintenance. Teaching buildings are the central venues for academic activities, containing classrooms, laboratories, and offices. Teaching buildings directly support the campus's educational mission and serve as places for knowledge transmission and academic research; hence, they require considerable attention. Despite the importance of administrative buildings in providing administrative support and campus management, teaching buildings are often considered the campus's heart because the campus's primary mission is to provide high-quality education. Therefore, the significance of administrative buildings is just below that of teaching buildings. Libraries mainly focus on sharing academic resources and providing a quiet, long-term learning environment. Gymnasiums offer facilities for exercise, helping students maintain physical health and enhance academic performance.

Table 2 provides a statistical description of the overall data, with the first row showing the mean, the second row the standard deviation, the third row the minimum value, and the fourth row the maximum value. It is observed that the overall average score is 74.75.

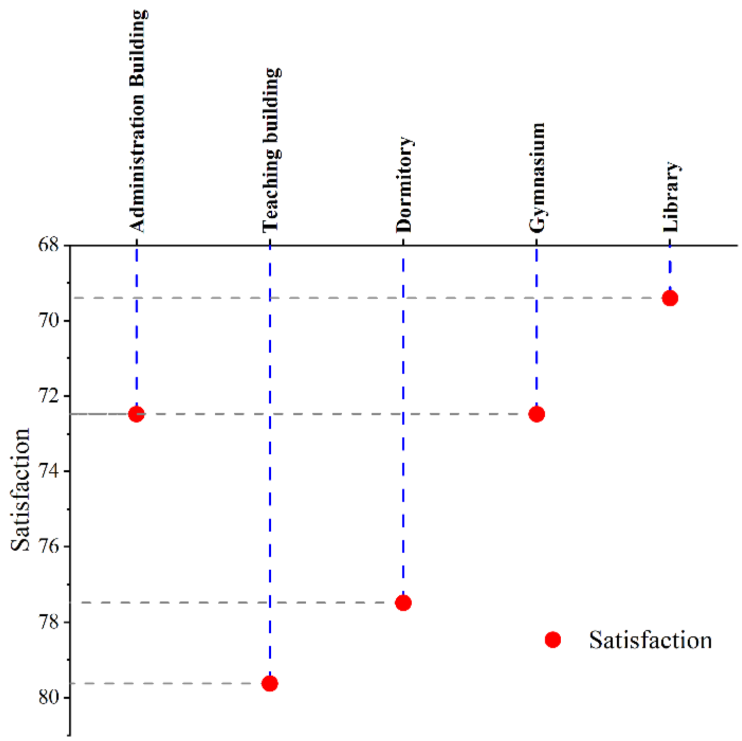

Figure 2 Average satisfaction of classification

Table 2 Questionnaire data

	Mean	Std	Min	Max
Satisfaction	74.75	11.12	49.06	94.05
Use	4.48	0.81	2.36	5.79
Access	4.61	0.72	2.00	5.67
Space	4.39	0.73	2.78	5.88
Performance	4.57	0.69	2.94	5.81
Engineering	4.64	0.7	3.13	5.88
Construction	4.50	0.92	2.57	6.00
Urban and social integration	4.56	1.03	2.17	6.00
Internal environment	4.6	0.82	2.64	5.88
Form and Materials	4.44	1.01	2.00	6.00
Character and Innovation	4.06	1.17	1.33	6.00

Based on the results in Table 2, each building type (dormitories, teaching buildings, libraries, etc.) has specific functional requirements. Meeting these requirements during design and construction affects user satisfaction and practicality, leading to different scores. Dormitories and teaching buildings generally score higher due to greater investment in materials, facilities, and maintenance. The mean satisfaction score across all building types is 74.75. Engineering (mean = 4.64) and internal environment (mean = 4.60) score relatively high, indicating that the buildings generally meet technical and environmental standards effectively. However, "Character and Innovation" has a lower mean score of 4.06, suggesting room for improvement in design innovation. The standard deviation for "Character and Innovation" (std = 1.17) indicates inconsistent performance across different buildings. The range of DQI scores highlights areas where some buildings perform exceptionally well (max = 6.00) while others fall short (min = 1.33).

Each type of building (such as dormitories, teaching buildings, libraries, etc.) has specific functional requirements. The degree to which these requirements are met during design and construction directly affects user satisfaction and the practicality of the building, thus leading to differences in scores across various aspects. The campus may vary in its investment in different buildings. Campuses that prioritize teaching and student living conditions might invest more resources in teaching buildings and dormitories, including better building materials, facilities, and maintenance, which could lead to higher DQI scores for these types of buildings. Different users' expectations and experiences with the building also affect DQI scoring. For example, students might have higher expectations for the comfort and privacy of dormitories, while they might focus more on functionality and the completeness of facilities in teaching buildings. Maintenance work and regular updates to a building also affect its DQI score. Buildings that need more effective maintenance might score lower in aspects such as the internal environment and construction quality. The degree of integration of the building with its surroundings, including whether it is conveniently accessible by public transport and interacts well with the community, also affects its score in "urban and social integration." Property management personnel, who are responsible for gathering and addressing feedback from various users, contribute to the DQI scoring process, ensuring that the scores reflect a comprehensive range of user experiences and expectations.

Significant differences exist in overall satisfaction with the DQI among the different types of campus buildings, indicating the need for targeted renovations for each building category moving forward.

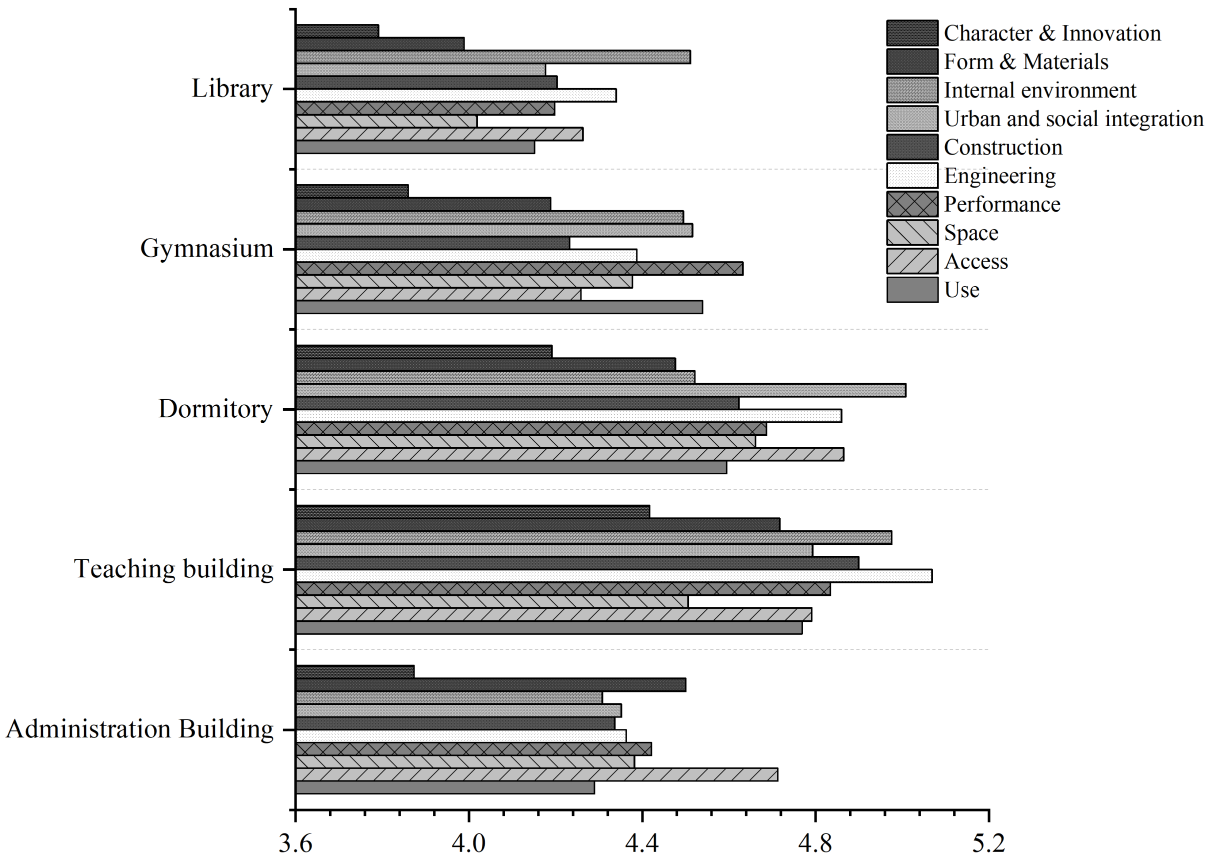

Figure 3 Mean values of DQI scores for different building types

Figure 3 illustrates the performance of various campus buildings under different evaluation criteria, with scores ranging from 1 to 6. The campus buildings evaluated include libraries, gymnasiums, dormitories, teaching, and administrative buildings. The criteria for evaluation encompass Use, Access, Space, Performance, Engineering, Construction, Urban and social integration, Internal environment, Form and Materials, and Character and Innovation. Among these, administrative buildings scored high across all criteria, particularly excelling in "Character and Innovation" and "Use," indicating their favorable perception. This high performance can be attributed to significant investments in quality materials and efficient space utilization, as well as their central role in supporting the administrative functions of the campus. Gymnasiums generally performed well on most criteria but scored lower in "Internal environment" and "Urban and social integration," suggesting areas for improvement in environmental comfort and community connectivity. Dormitories displayed lower scores in "Engineering" and "Performance" but fared better in "Use," highlighting their functional effectiveness in providing student accommodation. Teaching buildings exhibited relatively average scores without significant highs or lows, indicating a balanced performance. Libraries, however, had the lowest overall scores, remarkably lacking in "Character and Innovation" and "Form and Materials," indicating a need for enhancement in these areas. The scoring for each DQI indicator within each building type generally ranged between 3.8 and 4.8, providing a detailed overview of their performance.

Figure 4(a) presents the average scores for each DQI indicator, with "Character and Innovation" scoring relatively low (mean = 4.06, std = 1.17). This suggests that the challenges and constraints unique to educational buildings may contribute to the lower scores in this area. Traditional educational environments, budgetary and regulatory limitations, and a focus on educational needs often result in campus buildings adhering to long-standing design concepts, such as standardized classrooms and lecture halls, which may need to be more conducive to incorporating innovative elements. With limited funds, innovation is often seen as a luxury rather than a priority in resource allocation. The primary purpose of campus building design is to serve teaching and learning, leading to more emphasis on aspects like Use (mean = 4.48) and Space (mean = 4.39). At the same time, Character and Innovation may become secondary. Additionally, campus buildings must comply with stringent regulations, particularly regarding safety and accessibility, which can limit the scope for innovative design. These regulatory requirements ensure the buildings meet essential safety standards but can also restrict the flexibility needed to experiment with new design approaches.

Figure 4(b) further breaks down the scores by building type. Administrative buildings scored high across all criteria, particularly excelling in "Character and Innovation" and "Use," reflecting significant investments in quality materials and efficient space utilization. This high performance is due to their role in supporting administrative functions, requiring well-designed spaces. Gymnasiums generally performed well but scored lower in "Internal environment" and "Urban and social integration," suggesting areas for improvement in environmental comfort and community connectivity. Dormitories had lower scores in "Engineering" and "Performance" but fared better in "Use," highlighting their functional effectiveness in providing student accommodation. Teaching buildings exhibited average scores, indicating balanced performance. Libraries had the lowest overall scores, particularly in "Character and Innovation" and "Form and Materials," indicating a need for enhancement. The scoring for each DQI indicator generally ranged between 3.8 and 4.8, providing a detailed overview of their performance.

To improve the scores for Character and Innovation in campus buildings, it is recommended to foster greater involvement from teachers, staff, and students in the design process, ensuring that the buildings reflect the users' needs and innovative ideas. Allowing spaces to adapt as teaching methods and learning technologies evolve can enhance their functionality and relevance. Integrating the latest technology and sustainable design approaches can showcase innovation in both function and form. Collaboration with the arts, design, and technology sectors can introduce new perspectives and design concepts, enriching the educational environment. By embracing these suggestions, campus buildings can better serve learning and teaching and become exemplars of innovation and design excellence, fostering students' aesthetic literacy and inspiring creativity. Additionally, the design process should be analyzed, as using standard buildings (stock plans) will limit the character of a building and hinder innovation.

Furthermore, incorporating feedback mechanisms to assess the effectiveness of implemented innovations can provide valuable insights for continuous improvement. Engaging with the broader community, including local artists and designers, can bring fresh ideas and perspectives that enrich the educational experience. By prioritizing Character and Innovation alongside functional requirements, campus buildings can become dynamic spaces that inspire and support the holistic development of students.

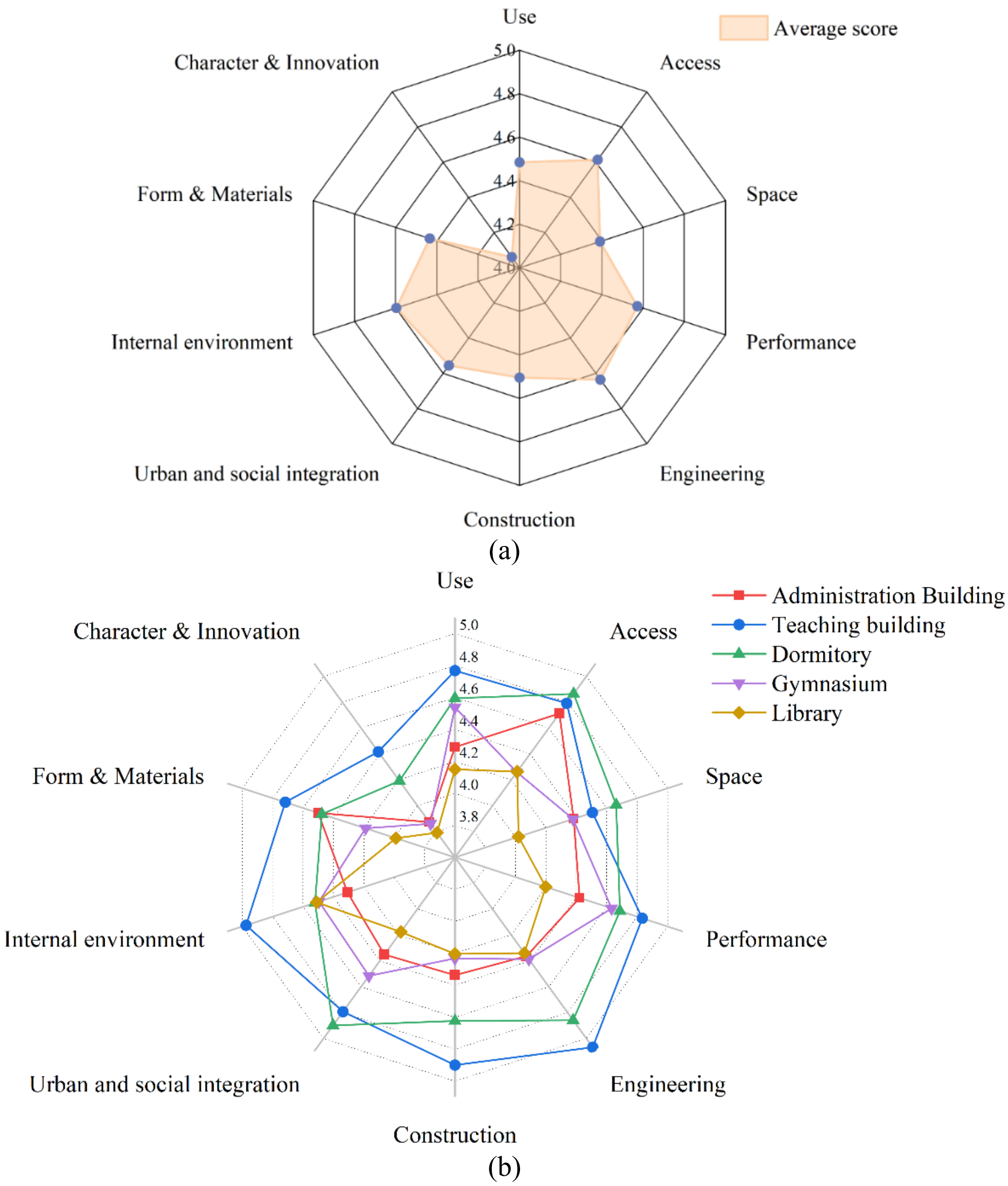

Figure 4 Overall building and various types of buildings DQI scores for each indicator.

Figure 5 presents the p-values from the analysis of variance (ANOVA) test regarding the DQI scores for different types of buildings. The results from Figure 5 indicate whether there are significant differences in the DQI scores between different building types. It is evident that the majority of p-values are less than 0.5, indicating that the differences in DQI scores caused by building types should be considered. Notably, the p-value for Engineering is less than 0.05, suggesting significant differences in the Engineering scores across different types of buildings. Libraries: Libraries must facilitate a quiet reading environment, making acoustic design particularly important. The storage of books also requires exceptional control over humidity and temperature, which may necessitate different demands for mechanical ventilation and air conditioning compared to other educational buildings. Additionally, lighting design must support extended reading periods and protect books from ultraviolet light damage. Gymnasiums: Gymnasiums typically require large column-free spaces to accommodate various sports activities, imposing special requirements on structural design. They also need robust ventilation systems to maintain good air quality and adjustable lighting systems to cater to the needs of different activities. Student Dormitories: Dormitories must provide students with a safe and healthy living environment, making good fire safety design and emergency evacuation plans crucial. Soundproofing in dormitories is also vital to ensure students can rest and study without disturbance. Teaching Buildings: Teaching buildings must accommodate diverse teaching methods, including traditional classroom teaching and modern interactive learning. Such buildings often require flexible interior space planning and advanced information and communication technology systems. Administrative Buildings: Administrative buildings support office and meeting activities, with their design emphasizing efficiency and a formal working environment. Security and privacy are also important considerations, especially in areas where sensitive information is handled. When scoring these different types of buildings, they are differentiated based on their respective design goals and usage requirements. For instance, a well-designed gymnasium might score higher in acoustics and ventilation systems, while a dormitory might perform better regarding safety and residential comfort. Architects need to balance these requirements, ensuring that the buildings not only meet current educational needs but are also adaptable to future changes and developments. Developments. The tabulate is displayed at the bottom of this paragraph.

Table 3 Building type and key requirements

Building Type	Key Requirements
Libraries	• Quiet reading environment (acoustic design). • Humidity and temperature control (mechanical ventilation, air conditioning). • Proper lighting to support reading and protect books from UV light.
Gymnasiums	• Large column-free spaces (structural design). • Robust ventilation systems (air quality). • Adjustable lighting systems for various activities.
Student Dormitories	• Safe and healthy living environment (fire safety, emergency evacuation). • Soundproofing for rest and study.
Teaching Buildings	• Accommodate diverse teaching methods (flexible interior space, advanced ICT systems).
Administrative Buildings	• Support office and meeting activities (efficiency, formal working environment). • Security and privacy (handling sensitive information).

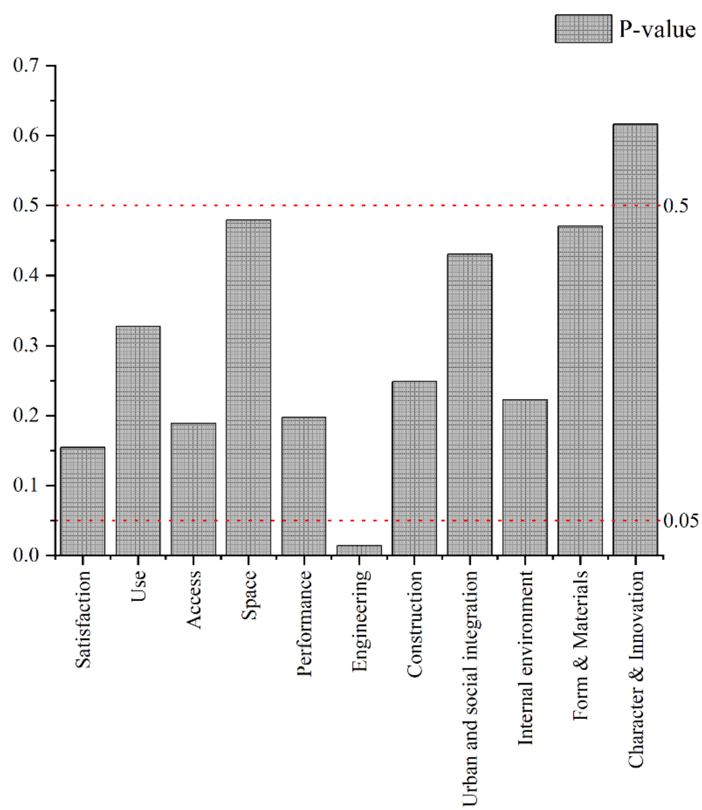

Figure 5 The P-values for the analysis of variance (ANOVA) of building types with overall satisfaction and scores for various dimensions.

5.0 CONCLUSION

The need to renovate and maintain campus buildings in Taiwan is becoming increasingly apparent. However, past experiences have revealed a disconnect between the initial design phase of these buildings and their effectiveness after construction. The design quality of campus buildings has a direct and profound impact on the learning outcomes of users, work efficiency, and overall health. Therefore, conducting an in-depth study on the applicability of Design Quality Indicators (DQI) for campus buildings in the Taiwan region is of great significance. To establish this connection, we referred to standard DQI indicators and reinterpreted the concept of DQI in campus buildings based on Taiwan's cultural and geographic characteristics. This involved streamlining and restructuring indicators while emphasizing the core goal of enhancing the overall quality of buildings. Through in-depth analysis, this study highlights the positive impact of improving DQI satisfaction on users. Our data indicate specific differences in DQI scores for different types of campus buildings, particularly in the Engineering score, which is significantly related to the building type. By analyzing our scoring data for DQI indicators, we can accurately identify the current pain points of campus buildings in Taiwan. Subsequent efforts can refer to the detailed scores of each DQI indicator for targeted renovations in each type of building.

The main contribution of this study lies in the in-depth analysis of the practical application of DQI in Taiwanese campus buildings, particularly highlighting the direct and positive impact of improving DQI satisfaction on users' learning, work efficiency, and overall health. However, it is essential to acknowledge certain limitations of this study. To ensure the generality of the method, we may have yet to consider the users' heterogeneity fully. Future research could explore the impact of improving DQI for campus buildings on operational costs, maintenance expenses, and long-term economic benefits to support sustainable architectural investment decisions. Additionally, comparing the research results from Taiwan with the application of DQI in campus buildings in other cultural contexts could shed light on the influence of different cultures on the perception of architectural design quality. Employing agent-based intelligent decision-making methods could help capture differences in users' perceptions of DQI indicators, leading to more personalized architectural design solutions.

It is important to note that the localized adjustments made to DQI indicators for Taiwanese campus buildings are a critical step towards ensuring that the assessment tool is relevant and practical locally. Including ten dimensions and 71 indicators covering a wide range of aspects, from Use and Access to Form and Materials and Character and Innovation, provides a comprehensive framework for evaluating the quality of campus buildings. To streamline the evaluation process and make it more efficient for evaluators, we combined certain indicators. For example, the indicators for "Indoor Air Quality" and "Ventilation" were merged to avoid redundancy and save time for respondents. Additionally, we increased the emphasis on sustainability by adding new indicators related to green building practices and environmental impact. Conversely, we eliminated indicators that were less relevant to the current context in Taiwan. For instance, indicators specific to outdated technological infrastructure, which are no longer applicable due to advancements in multimedia classroom technology, were removed. This level of detail allows for a more nuanced understanding of the strengths and weaknesses of each building, facilitating targeted improvements that can enhance the overall learning environment.

Moreover, the emphasis on user participation in developing DQI indicators, as seen in the example of green renovation design workshops, highlights the importance of involving stakeholders in the design process. This approach ensures that the final design not only meets technical and aesthetic standards but also aligns with the users' needs and preferences, ultimately leading to more satisfactory and effective educational spaces.

The study thoroughly examines and interprets Design Quality Indicators (DQI) for campus buildings in Taiwan, offering valuable insights for future architectural design and research endeavors. It underscores the significance of incorporating user needs and building quality into campus design, highlighting how DQI can enhance the learning environment. The customized DQI approach for Taiwanese campus buildings, emphasizing stakeholder engagement and a comprehensive assessment framework, establishes a robust basis for enhancing educational architecture quality in Taiwan. Through ongoing refinement and application of these indicators, architects and designers can play a crucial role in creating more supportive learning environments that foster holistic student development. Future research should address current limitations and delve deeper into the application and impact of DQI across various contexts, including post-occupancy building performance assessment, to explore the potential of integrating DQI early in the design phase. Such endeavors would yield valuable insights and contribute significantly to advancing educational architecture standards.

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