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Architectural Design of Universities for Green Campus in Guangdong-Hong Kong-Macao Greater Bay Area and Singapore: A Comparative Aspect

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Abstract. College campuses need the most attention to build. This article is relevant, as the design of green campus buildings is one of the essential forms of the good ecological development concept that can best reflect the sustainable development of university campuses. The total energy consumption of school buildings is second only to that of all kinds of office buildings and accounts for a considerable proportion of the total. The purpose of this study is to investigate the typical campus buildings in Singapore with mature development of green campus buildings to provide a reference for the study of architectural development in the Guangdong-Hong Kong-Macao Greater Bay Area with similar climate adaptability. This paper uses Ladybug Tools to conduct quantitative analysis and compares the Greater Bay Area with Singapore, which has similar conditions, to try to summarize the universal design strategies and models suitable for it. It was found that the university campuses in the Greater Bay Area have a better development in the greening of building courtyards and building roofs, while in the greening of building platforms and building walls, it still needs to carry out more technical practice. It was established that among all kinds of designs on the green campus of the Singapore universities, the energy-saving-oriented design has the highest proportion. It was concluded that only by absorbing more mature design experience and strategies can the development of green campus buildings in the Greater Bay Area go further. The findings of the paper will further provide more powerful data support for the development of the Greater Bay Area and Singapore, and simply put forward feasible and universal design patterns and strategies to a certain extent

Keywords: green building, visualization, Grasshopper, Ladybug, campus building, quantitative relationship



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INTRODUCTION

The development of the Greater Bay Area (GBA) is inseparable from the construction of universities and personnel training. In 2008, the Ministry of Education and the Ministry of Housing and Urban-Rural Development jointly launched the “Opinions on Further Strengthening the Work of Energy-Saving and Water-Saving in Colleges and Universities to Promote the Construction of Energy-Saving Campuses” and the “Guidelines for the Management and Technology of Conservative Campus Construction in Colleges and Universities (Trial)” (Guangdong-Hong Kong-Macao Greater..., 2019). Since then, major colleges and universities across the country have extensively carried out the construction of green universities, campuses, and energy-saving campuses. With the continuous advancement of urbanization, the upsurge in building university towns in China continues to rise (Liu & Wang, 2022).

However, the extensive university development, planning and construction in recent years have not been environmentally friendly and have also brought a series of problems, such as waste of land resources and large energy consumption. According to Q. Lijuan (2018) and Ya. Ibrahim et al. (2021), faced with these problems, the development of university campuses has taken a new direction. The construction of university campuses is increasingly inclined to adapt to local conditions and to the intensive development mode guided by the inner needs of college students. Therefore, utilization of land resources and the construction of energy-saving, and green campuses have become major trends in the current planning and construction of colleges and universities (Abdelkhalik & Azmy, 2022; Kelly & Iqbal, 2021).

According to the opinion of W. Jianhua et al. (2018), the three-dimensional greening of buildings at the university campus of the Greater Bay Area is still restricted by realistic conditions to a considerable extent. For example, due to the high degree of urbanization and the shortage of land, Hong Kong and Macao have always been inclined to vertical greening in the development of green campus buildings and are relatively mature in terms of building roof greening and sky garden greening. However, T. Chen (2021) considers that the green campus buildings in Guangzhou and Shenzhen are inclined to ground and courtyard greening, but there is a lack of architectural three-dimensional greening designs with high greening efficiency. Overall, the greening rate of three-dimensional greening in the campus buildings of the Greater Bay Area is not high, and the green area is small.

Singapore has a small land area, most of which is hills and plains (Jing & Tuo, 2019). The overall climate is hot and humid year-round, with rain and typhoons (Gholami et al., 2020). According to B. Zhu et al. (2020), the green building evaluation system guides the entire process of green campus construction during the development of university campuses in Singapore. Therefore,

in the preliminary design of campus buildings, more consideration is given to the green building design strategy and the introduction of green space, which can help achieve the coordination and unity of the green space from the whole to parts. Unlike Singapore, which has limited development space, the Guangdong-Hong Kong-Macao Greater Bay Area has a vast land area. X. Linji (2018) believed that these large-area resources are still undeveloped, suggesting considerable development space. Therefore, there is still a considerable gap between greening in the campus buildings of the Greater Bay Area and that in Singapore, another research object of this paper. So, it is necessary to carry out visual quantitative relationship analysis on climate characteristics, energy consumption, solar radiation, and other aspects to deeply investigate the universal strategy for greening design of campus buildings.

The purpose of this paper is to study the campus architecture with mature development of green campus buildings in the Guangdong-Hong Kong-Macao Greater Bay Area and Singapore.

MATERIALS AND METHODS

Singapore and the Greater Bay Area share hot and humid climates. Singapore has always attached foremost importance to the exploration and development of green buildings as a major strategy to relieve domestic resource shortages and environmental pressure. Universities in Singapore use Green Mark, a green building evaluation system (Green Mark Certification Scheme, 2021), to guide the construction of the Green campus, which provides inspiration and reference for the update and revision of the “Green Campus Evaluation Standard” (2019) in China in terms of evaluation objects, evaluation grading, category setting and provision integration.

The Green Mark evaluation standard system is based on the core concepts of environmental friendliness and sustainable development in the whole life cycle of buildings and is positioned as “a green certification system for evaluating the environmental impact and performance of tropical and subtropical buildings”. This standard fully reflects the characteristics of a hot and humid climate, thus being widely used in Singapore and has been promoted internationally. Singapore is located in a tropical coastal area with a typical tropical climate of high temperature and humidity. The Green Mark evaluation standard starts from the innovative perspective of climate adaptation, considering indoor and outdoor light and heat, environmental comfort, etc., and comprehensively considers coping strategies from scales of single buildings, blocks and cities. Furthermore, this system covers the comprehensive utilization of water resources, materials, and waste and accounts for a large proportion of the entire evaluation system. In terms of indoor environmental quality, it establishes a more systematic and effective feedback

mechanism through intelligent technology to achieve precise indoor environmental control to carry out the concept of healthy buildings.

To fulfil the main purpose of this study, the following scientific methods were used:

– Visual quantitative analysis: Visual quantitative analysis is based on the plug-in Ladybug Tool of grasshopper, a commonly used analysis software. It provides a multidimensional comparative quantitative analysis based on meteorological data, including a comparative analysis of sunshine time, annual monthly average temperature, wind direction, wind speed, the relationship between solar trajectory and thermal radiation, etc., between the Guangdong-Hong Kong-Macao Greater Bay Area and Singapore. It establishes a quantitative relationship of a single variable, thereby conducting research through reliable quantitative data support.

– Literature research: First, the issues and papers on current green buildings were selected through CITE Space software. Then, by reading many studies, the authors conducted in-depth research and analysis of the relevant theories. The literature relevant to the subject

under study was selected according to the criteria of originality and relevance to the green building design of university campuses.

– Comparative study: The comparative study was based on the high degree of similarity between the green buildings of Singapore University campuses and those in the Guangdong-Hong Kong-Macao Greater Bay Area in terms of geography and climate.

RESULTS AND DISCUSSION

A quantitative analysis and comparison of climatic factors between the Greater Bay Area and Singapore

The most representative universities in Singapore have high greening rates overall, rich, and diverse ways of building greening, and a general multilevel building greening space (Fig. 1). These typical campuses have the common feature that they all make full use of indoor and outdoor green space to form a unique architectural form. In addition, the platform green space is the main green space of these buildings, dominated by the building veranda and the semi-outdoor space on the ground floor.

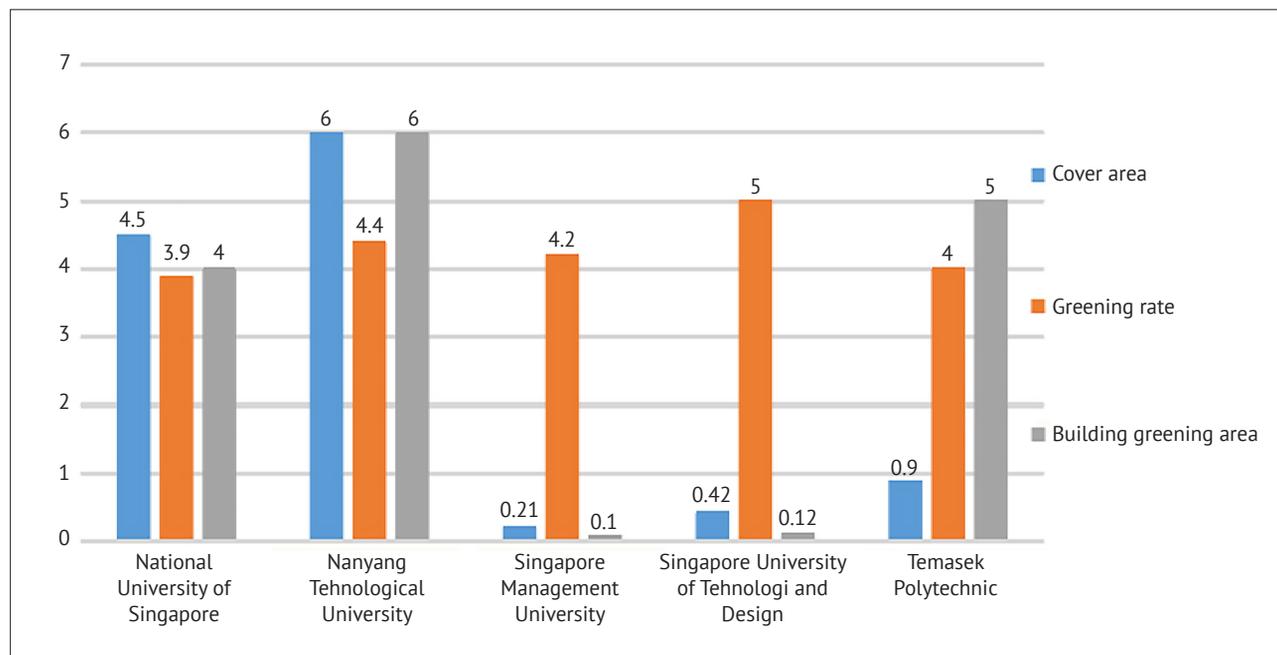


Figure 1. Horizontal comparison table of greening data of typical universities of green buildings in Singapore

Figure 2 is completed by Ladybug Tool sun Path and sunlight Analysis. Based on the meteorological data of the four representative areas of Guangdong-Hong Kong-Macao Greater Bay Area and Singapore, according to the single variable method, the solar trajectory, wind

speed and annual sunshine time from 9:00-15:00 of June 15th every year of the same building area are analysed and then made into quantitative visualization charts. The authors chose this time, because it was necessary to investigate the level of illumination, specifically in daylight.

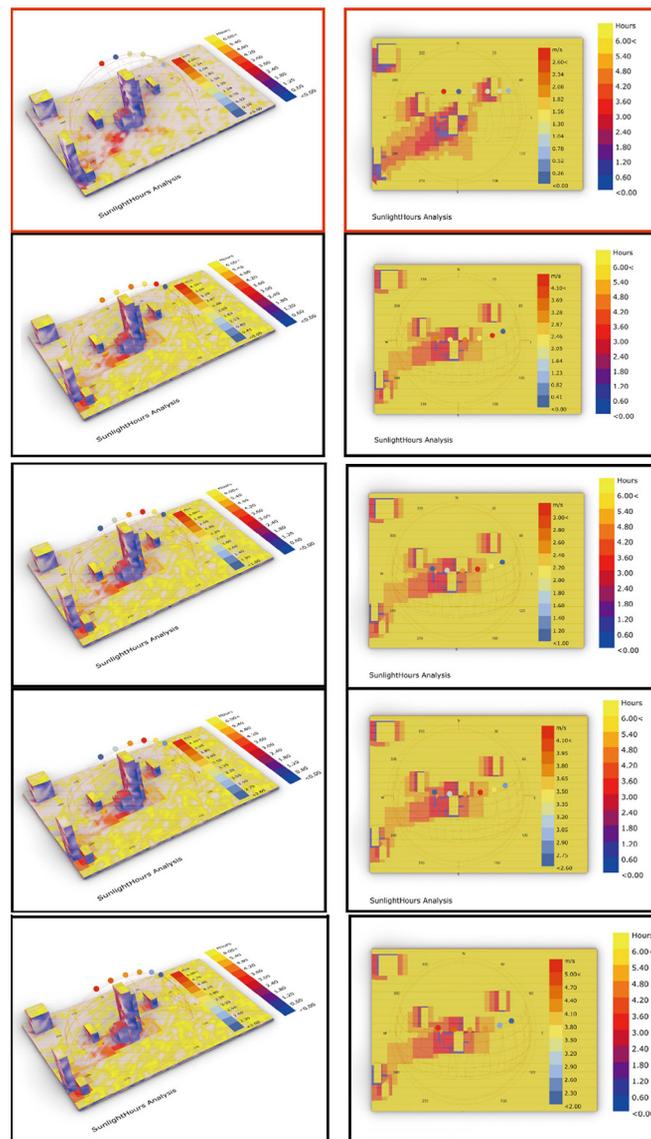


Figure 2. Comparison charts of solar trajectory and wind speed and thermal radiation and sunshine time in Singapore and the Guangdong-Hong Kong-Macao Greater Bay Area

There are slight differences in the annual sunshine duration in Shenzhen, Guangzhou, Macao, Hong Kong, and Singapore, but they are all within the range of 1.2 h–6 h, and the annual average sunshine duration of these five places is higher than the average level of other regions in China. The differences in wind speed variation in 6 hours of the same day in these five places were also slight, and the maximum wind speeds were all in the range of 5.00 m/s–<1.00 m/s. However, with the movement of the solar track, there were significant differences in wind speed in these five places at the same time. The solar radiation range of the same building area in these five places is the same.

In Shenzhen, Guangzhou, Macao, and Hong Kong, the sunshine duration of the same building in the same area is the same. In comparison, the sunshine duration in Singapore is longer, exceeding the average duration of the above four places by approximately 0.6–1 h. In Shenzhen, Guangzhou, Macao and Hong Kong, the wind speed

in one day reaches the maximum value at noon, and in the morning and afternoon it shows a gradually decreasing trend, while the trend of wind speed in Singapore in one day gradually increases from morning to night.

The Greater Bay Area and Singapore enjoy sufficient average sunshine duration and light conditions, with abundant solar energy being available, which is one of the important conditions for the green campus buildings. Although the Greater Bay Area and Singapore have some differences in daily wind speed and direction, they both have sufficient wind energy to be considered as a means of developing energy efficient design. The Greater Bay Area and Singapore share the same annual sunshine duration and radiation range. Therefore, for the green campus buildings in the Greater Bay Area, the energy-saving (solar, wind energy) design models and strategies of Singapore's buildings can be a good reference. This induction produces design patterns and

strategies of general applicability. On this basis, general design patterns and strategies can be inducted and summarized.

Figure 3 is done by Ladybug Windrose. Based on the meteorological data of the four representative regions of Guangdong-Hong Kong-Macao Greater Bay Area and Singapore, the paper employs a single variable, that is, wind speed and direction in the abovementioned five places from January 1st 1:00 to December 31st 24:00 during the full year to conduct analysis and then make a quantitative visualization chart.

The differences in wind direction among the five places are slight: north winds prevail in Singapore and Guangzhou, while northeast winds prevail in Shenzhen and Macao, and east winds prevail in Hong Kong. These five places all belong to a typical subtropical climate.

Among them, the Guangdong-Hong Kong-Macao Greater Bay Area shows more features of the subtropical monsoon maritime climate, with warm winters and hot summers. Its wind speed in summer is smaller than that in winter, with unstable wind directions in spring and autumn. Among the areas, the wind speed in Hong Kong is lower than that in the other three places, which is related to its unique urban density. Wind speed in Singapore varies within a small range. Therefore, its wind energy is more stable than that in the Greater Bay Area and is thus easier to use. Nevertheless, changes in wind direction and speed in the Greater Bay Area are complicated and related to urban buildings, so the use of wind energy is not as convenient as that in Singapore. Therefore, the use of wind energy should be considered according to local conditions.

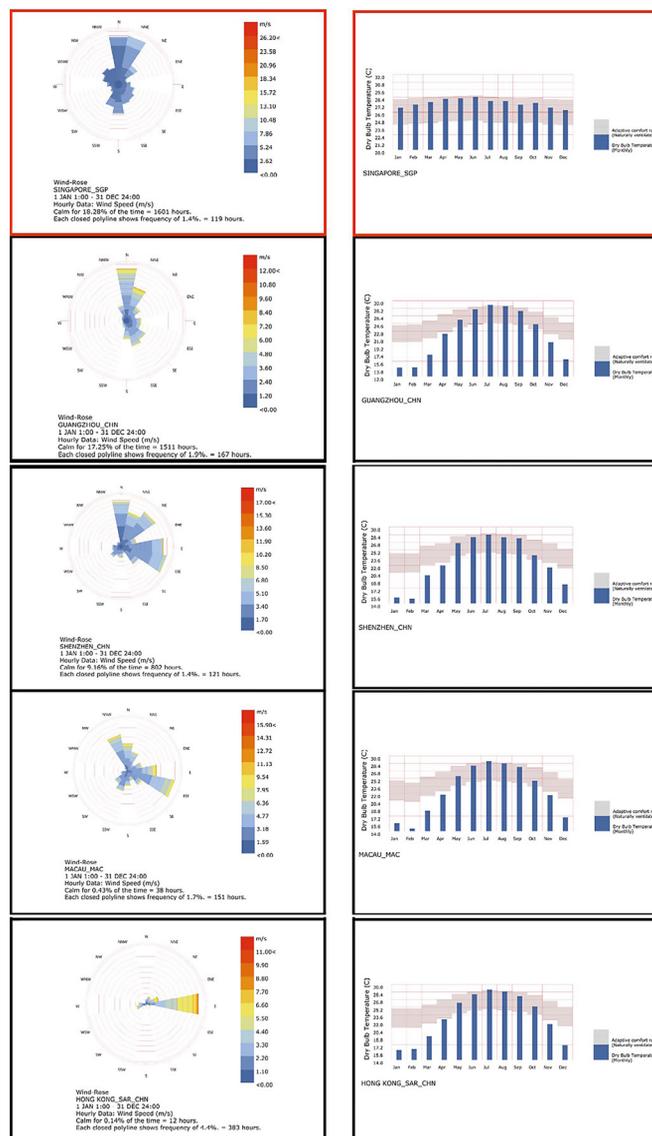


Figure 3. Comparison charts of the wind roses and the annual monthly average dry bulb temperature and annual thermal comfort temperature

Figure 3 is partially completed with the help of the Ladybug Monthly Bar Chart. According to the meteorological data of four representative regions of the Greater Bay Area and Singapore, the monthly average dry bulb temperature and comfort temperature of the five regions based on the single variable, thermal comfort of level 2 (naturally ventilated), are analysed in this paper and further embodied in a quantitative visualization chart. The highest temperature in the five places is the same, approximately 28.4°C, and their highest temperature month is July every year (that is, the summer season). The five places are warm throughout the year, and their lowest temperatures are >13.8°C. It can be clearly seen from the annual monthly average temperature changes that the Greater Bay Area has four distinct seasons throughout the year, with significant seasonal temperature changes and a maximum temperature difference of approximately 12°C between summer and winter, while Singapore experiences little change in temperature throughout the year, with a maximum temperature difference of approximately 4°C between summer and winter.

The temperatures of the five places are the same throughout the year, and they all belong to a typical subtropical climate. The climate of Singapore is hotter than that of the Greater Bay Area, which is affected by factors such as wind direction and wind speed. Under the same thermal comfort level, the suitable temperature ranges of the five places are similar. Therefore, the indoor and outdoor energy saving design modes and strategies of Singapore are a good reference for the Greater Bay Area.

Quantitative analysis of energy consumption data in the Guangdong-Hong Kong-Macao Greater Bay Area

According to the analysis of online data from 2000 to 2017, the total energy consumption of public buildings

and diverse types of energy consumption in four major cities in the Greater Bay Area is shown in terms of energy consumption. As early as 2000, the total energy consumption of Hong Kong was as high as 3.5 Mtce, which is much higher than the other three cities in the Greater Bay Area, while the energy consumption of Macao, which is sparsely populated, is less than 0.5 Mtce year-round, ranking last in the Greater Bay Area.

South China University of Technology International Campus is the third campus of South China University of Technology in Guangzhou. The first two are the old Wushan campus and the new campus of Guangzhou Panyu University Town. The International Campus is also located in Panyu District, Guangzhou, facing the University Campus across the bank. Adhering to the construction concept of integrating Chinese and Western education concepts, tradition and modernity, the International Campus adopts high standard planning and stands at a high starting point. It is committed to creating an innovative green campus. The community building takes the green space in the centre of the campus as the core of the landscape, thus extending to the north and south, and then forms the multifunctional campus space through important spatial nodes.

In terms of campus planning and zoning, it adopts a horizontal and vertical pattern, with 7 sequences of horizontal A-G and vertical 1-7, dividing the campus into different blocks. Moreover, each block uses the same label and then sets a/b/c/d and other sublevel labels for buildings. The C2-C3 group architectures (Table 1) are connected by outdoor corridors on the second floor, and vertical stairwells are used to organize space nodes. The design of the platform corridor on the second floor also adopts various forms with a sense of design.

Table 1. The C2-C3 building cluster analysis table of South China University of Technology international campus

Basic building information	Gross floor area	61300 m	Green rate	26
	Land area	15200 m	Building green rate	3952
	Floor area ratio	4.0	Building stories	6F

Cooling requirements for building spaces are kept low through the design of campus building orientations, shading between blocks and corridors. In addition, the balance between daylight quality and shading is achieved using solar analysis and daylight simulation tools to maximally reduce window heat gain (Fig. 4). In the water management section, Stormwater Management encourages

the treatment of stormwater before it enters public drains, while the campus design incorporates protections against stormwater runoff. Landscape water saving requires "drought-resistant plants to be selected in the design to reduce water demand. Therefore, in landscape design, local landscape species with low water consumption are universally used (Fig. 5).



Figure 4. Planning Zoning Map of International Campus of South China University of Technology (Image source: South China University of Technology)

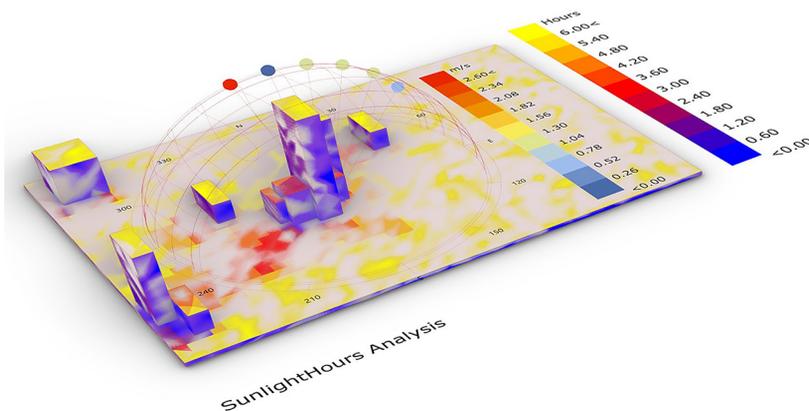


Figure 5. Singapore Sunlight Hours Analysis

Green Building encourages the use of green building practices in the design, construction, and renovation of buildings in the area. This campus consists of several enclosed buildings designed with natural ventilation principles, cooling technology, covered walkways, louvered curtain walls, open spaces, indoor sunlight, and water treatment equipment. Its buildings have obtained platinum-ranking certification from the Singapore Green Label. Green mobility requires compact and walkable zoning patterns in the master plan with walking distances within 500 m of the main building entrance and with shelters and connections. The campus buildings are completely open and highly connected. In addition,

the introduction of diagonal viewing corridors and various vertical and horizontal connections can help create an open campus walkway. The geometry of the building allows for a perfect ventilation path for outdoor gathering spaces such as the inner courtyard. Shaded sidewalks also serve as external circulation routes, helping to create a walkable, low-carbon campus.

In Singapore, the development of green campuses has always employed the green building evaluation system as the guideline during the entire construction process. Therefore, in the preliminary design of campus buildings, more consideration is given to the green building design strategy and the introduction of green

space, which can help achieve the coordination and unity of the green space from the whole to parts (Table 2).

Since the popularization of higher education in Singapore in the 1990s, the construction of university campuses in Singapore has paid increasing attention to campus green space. They all enjoy a higher average greening rate and larger average greening area than universities in the Guangdong-Hong Kong-Macao Greater Bay Area in China. In the design process of green space, universities in Singapore focus on the integration of buildings and the overall environment of the campus and integrate the design of green space into the cultural spirit of the campus to achieve a campus cultural atmosphere that is free and natural. The specific campus building greening space design is not limited to the traditional ground type and integrated greening landscape design but a combination of various greening space design methods, which is conducive to improving the overall

greening environment of the campus and creating better learning and communication space for students. All of these have constructed a pleasant university campus for students to study and travel and truly achieved the reinforcement of a pleasant environment and academic governance, which is worth learning from.

Furthermore, it shows the comprehensive application of the latest building greening technology on the campus of Singapore University, especially the application and practice of building platform greening and building wall greening technology, which is an excellent example for our reference. The Greater Bay Area needs to give full play to the unique advantages of the university's combination of production, education, and research, pay attention to the trial and use of green innovative technologies first on campus, and provide comprehensive feedback on the application and effects, thus laying a solid foundation for the promotion of the whole society.

Table 2. Comparison of green building indicators for green campus buildings in Singapore and the Guangdong-Hong Kong-Macao Greater Bay Area

Project	Singapore	Nine cities of Guangdong	Hong Kong and Macao
Land area(km ²)	719.1	54954	1137
Population (10000 people)	564	6150.6	814.8
GDP (trillion yuan)	239	8.10	2.88
GDP per capita (ten thousand yuan)	42.3	13.2	35.3
Number of universities	56	139	31
University density (university/km ²)	0.078	0.0025	0.027
Number of universities per 10,000 people	0.099	0.023	0.038
Average university greening rate	62%	25%	51%
Average green area of university buildings (university/10 km ²)	0.0858	0.0018	0.728
Representative universities	National University of Singapore, Singapore University of Technology and Design, Nanyang Technological University	Sun Yat-sen University, South China Normal University, Jinan University, Shenzhen University, Southern University of Science and Technology	Chinese University of Hong Kong, Hong Kong University of Science and Technology, Hong Kong Polytechnic University, University of Macao, Macao University of Science and Technology, Macao Polytechnic Institute, City University of Macao

According to H. Jun et al. (2020), the microclimate optimization in the environmental planning section calls for validation of the optimized design through simulation of major climate data and field measurements before and after development to improve microclimate, for example, the use of natural planting and water optimization. M.A. Alim et al. (2022) convinced that small plants on the campus can be planted along corridors, hanging gardens

and green roofs from the external area to the building space to regulate the microclimate. J. Ren et al. (2022) considered that the overall campus design integrates with natural environment through facade plantings, green roof terraces and hanging gardens, as well as extensive planting of small native trees and flower-watching plants.

Site planning and building orientation calls for minimizing heat gain or loss using passive solar strategies

to reduce energy demand (Bakhshoodeh et al., 2022). According to J.A. Puppim de Oliveira et al. (2022), cooling requirements for building spaces are kept low through the design of campus building orientations, shading between blocks and corridors. In addition, the balance between daylight quality and shading is achieved using solar analysis and daylight simulation tools to maximize the reduction window heat gain. This statement is consistent with the results of our study.

In the water management section, Stormwater Management encourages the treatment of stormwater before it enters public drains, while the campus design incorporates protections against stormwater runoff (Bin & Zhongkai, 2017). According to these researchers, landscape water saving requires drought-resistant plants to be selected in the design to reduce water demand. We agree with this opinion, because also discovered that in landscape design, local landscape species with low water consumption are universally used.

According to N. Fezzioui & M. Benaichata (2021), the microclimate optimization in the environmental planning section calls for validation of the optimized design through simulation of major climate data and field measurements before and after development to improve the microclimate, for example, the use of natural planting and water optimization. Small plants on the campus can be planted along corridors, hanging gardens and green roofs from the external area to the building space to regulate the microclimate. In this way, the overall campus design integrates with natural environment through facade plantings, green roof terraces and hanging gardens, as well as extensive planting of small native trees and flower-watching plants.

CONCLUSIONS

The findings of this paper revealed that the collaborative social architecture adopted by the campus makes connectivity, collaboration, and sociability the core elements of the new campus design. It was shown that green universities will play a role in cultivating talent, which is also called “environmental education”, including the role of microclimate regulation played by green campus landscapes and the advanced benchmarking role of eco-city construction. In addition, it was found that the university campuses in the Greater Bay Area have a better development in the greening of building courtyards and building roofs, while in the greening of building platforms and building walls, it still needs to carry out more technical practice.

Based on the analysis of the characteristics of campuses in Singapore, the recommendations for Chinese campuses were provided as follows: active response to the unique geographical climate of the Greater Bay Area; sustainability, which helps improve the entire life cycle of buildings and greening; full integration with the architectural form; integration with traffic space; combination with the shared communication space on campus; the maximized use of roof space; integration of indoor and outdoor campus landscape; and rational use of planting devices.

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REFERENCES

- [1] Abdelkhalik, H.F., & Azmy, H.H. (2022). The role of project management in the success of green building projects: Egypt as a case study. *Journal of Engineering and Applied Science*, 69(1), article number 61.
- [2] Alim, M.A., Rahman, A., Tao, Z., Garner, B., Griffith, R., & Liebman, M. (2022). Green roof as an effective tool for sustainable urban development: An Australian perspective in relation to stormwater and building energy management. *Journal of Cleaner Production*, 362, article number 132561. doi: 10.1016/j.jclepro.2022.132561.
- [3] Bakhshoodeh, R., Ocampo, C., & Oldham, C. (2022). Exploring the evapotranspirative cooling effect of a green façade. *Sustainable Cities and Society*, 81, article number 103822. doi: 10.1016/j.scs.2022.103822.
- [4] Bin, Zh., & Zhongkai, H. (2017). Investigation and enlightenment of green buildings in Singapore. *Construction Technology*, 8, 20-22.
- [5] Chen, T. (2021). Smart campus and innovative education based on wireless sensor. *Microprocessors and Microsystems*, 81, article number 103678. doi: 10.1016/j.micpro.2020.103678
- [6] Fezzioui, N., & Benaichata, M. (2021). Green roofs under hot and dry climate in south-west of Algeria: Study of the implementation conditions. *AZ ITU Journal of the Faculty of Architecture*, 18(2), 319-330. doi: 10.5505/itujfa.2021.04657.
- [7] Gholami, H., Bachok, M.F., Saman, M.Z.M., Streimikiene, D., Sharif, S., & Zakuan, N. (2020). An ISM approach for the barrier analysis in implementing green campus operations: Towards higher education sustainability. *Sustainability (Switzerland)*, 12(1), article number 363. doi: 10.3390/su12010363
- [8] Green Campus Evaluation Standard. (2019). Retrieved from <http://www.lngba.net/h-nd-502.html>
- [9] Green Mark Certification Scheme. (2021). Retrieved from <https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme>.
- [10] Guangdong-Hong Kong-Macao Greater Bay Area Development Plan. (2019). Retrieved from <http://stic.sz.gov.cn/bszn/201801.pdf>.
- [11] Ibrahim, Ya., Kershaw, T., & Shepherd, P. (2021). On the optimisation of urban form design, energy consumption and outdoor thermal comfort using a parametric workflow in a hot arid zone. *Energies*, 14(13), article number 4026.

- [12] Jianhua, W., Zhen, L., & Lianfang, Sh. (2018). Analysis on the application of vertical greening in urban construction. *Sichuan Forestry Science and Technology*, 39(02), 116-119.
- [13] Jing, W., & Tuo, X. (2019). Coordination of beauty, health and comfort, and people-oriented: Study on the three-dimensional greening characteristics of green buildings in Singapore. *Architecture and Culture*, 5, 99-101.
- [14] Jun, H., Yufeng, L., & Yan, L. (2020). Research on green space design strategy of campus buildings in Singapore University. *Southern Architecture*, 2, 112-119.
- [15] Lijuan, Q. (2018). *Research and practice of green university campus energy efficiency management*. Hangzhou: Zhejiang University Press.
- [16] Linji, X. (2018). Singapore's vertical greening experience and related policies sharing. *Housing and Real Estate*, 32, 25-26.
- [17] Liu, Q., & Wang, Z. (2022). Green BIM-based study on the green performance of university buildings in northern China. *Energy, Sustainability and Society*, 12(1), article number 12.
- [18] Kelly, Z., & Iqbal A. (2021). Indigenous Housing Practices as Inspirations for Modern Green Buildings. *Lecture Notes in Civil Engineering*, 240, 149-158.
- [19] Puppim de Oliveira, J.A., Bellezoni, R.A., Shih, W., & Bayulken, B. (2022). Innovations in urban green and blue infrastructure: Tackling local and global challenges in cities. *Journal of Cleaner Production*, 362, article number 132355. doi: 10.1016/j.jclepro.2022.132355.
- [20] Ren, J., Tang, M., Zheng, X., Lin, X., Xu, Y., & Zhang, T. (2022). The passive cooling effect of window gardens on buildings: A case study in the subtropical climate. *Journal of Building Engineering*, 46, article number 103597. doi: 10.1016/j.job.2021.103597.
- [21] Zhu, B., Zhu, C., & Dewancker, B. (2020). A study of development mode in green campus to realize the sustainable development goals. *International Journal of Sustainability in Higher Education*, 21(4), 799-818. doi: 10.1108/IJSHE-01-2020-0021

Архітектурне проектування університетів для зеленого кампусу в районі Великої затоки Гуандун-Гонконг-Макао та Сінгапурі: порівняльний аспект

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Анотація. Студентські містечка потребують найбільшої уваги при будівництві. Дана стаття є актуальною, оскільки проектування зелених будівель кампусів є однією з основних форм концепції доброго екологічного розвитку, яка може найкращим чином відображати сталий розвиток університетських кампусів. Загальне енергоспоживання університетських будівель поступається лише енергоспоживанню всіх видів офісних будівель і становить значну частку від загального обсягу. Метою цього дослідження є вивчення типових будівель кампусу в Сінгапурі зі сформованим розвитком зелених будівель кампусу, щоб забезпечити основу для вивчення архітектурного розвитку в районі Великої затоки Гуандун-Гонконг-Макао зі схожою адаптивністю до клімату. У цій роботі використовуються інструменти Ladybug Tools для проведення кількісного аналізу та порівняння району Великої затоки з Сінгапуром, який має схожі умови, щоб спробувати узагальнити універсальні стратегії та моделі дизайну, які підходять для нього. Було виявлено, що університетські кампуси в районі Великої затоки мають кращий розвиток в озелененні внутрішніх дворів будівель та дахів будівель, тоді як в озелененні будівельних платформ та стін будівель все ще потрібно проводити більше технічної практики. Встановлено, що серед усіх видів дизайну зелених кампусів сінгапурських університетів найбільшу питому вагу має енергозберігаючий дизайн, орієнтований на енергозбереження. Зроблено висновок, що тільки шляхом засвоєння більш зрілого досвіду та стратегій проектування можна досягти подальшого розвитку будівель зелених кампусів у районі Великої затоки. Висновки статті надалі забезпечать більш ефективну інформаційну підтримку розвитку району Великої затоки та Сінгапуру, а також запропонують універсальні моделі та стратегії проектування

Ключові слова: зелена будівля, візуалізація, Grasshopper, Ladybug, будівля кампусу, кількісне співвідношення