

Available online at www.sciencedirect.com**SciVerse ScienceDirect**

Procedia Engineering 21 (2011) 922 – 928

**Procedia
Engineering**www.elsevier.com/locate/procedia

2011 International Conference on Green Buildings and Sustainable Cities

The sustainable approach to the green space layout in high-density urban environment: a case study of Macau peninsula

Li Min^a, Gong Fangying^{a*}, Fu Jiawei^a, She Meixuan^a, Zhu He^a^a College of Forestry, South China Agricultural University, Guangzhou 510642, China

Abstract

Based on a case study of Macau peninsula, this paper explores a sound approach to the urban green space development in high-density urban environment that could enhance the sustainability of the city.

© 2011 Published by Elsevier Ltd. Open access under [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/).

Selection and/or peer-review under responsibility of APAAS

Keywords: high density; urban environment; green space outlay; sustainable approach; Macau peninsula

1. Introduction

1.1. Background

High-density city has become a distinct characteristic of urban development, since the latter half of the 20th century witnessed the fiercest urbanization. Besides, the global population is growing by 1.8% a year and it will reach 5.1 billion, of which over 56 per cent of people in developing countries will live in cities by 2030, whereas in developed countries it may well exceed 84 per cent by then [1].

A series of urban environmental problems has been brought in high-density urban environment, such as lack of public open space, population overload, traffic jam, deterioration of ecological environment, etc. Furthermore, the lack of urban green space, low accessibility of parks and the deficit of their eco-efficiency, all these have been influencing the quality of human living environment. Especially, protection and expansion of green eco-space have become one of the mainly restraining factors for urban development in high-density cities, of which population density are higher than 50,000 per km².

* Corresponding author. Tel.: +86-137-6074-0871; fax: +86-20-8528-599.

E-mail addresses: fannyc.kung@gmail.com gdlimin@hotmail.com

1.2. Study Area

In order to find an appropriate approach to extend green space in high-density urban environment and encourage its social and economic sustainable development, Macau peninsula, which is known as one of the highest-density area in the world, is chosen for case study. Its green space layout will be investigated detailed and analyzed and deeply in this paper.

Macau, of which population density is 18,400/km², is known as one of the highest-density city in the world. Its 29.5km² being home to an impressive 542,400 people, base on the statistics in 2010. Nowadays, more than 85.5% of residents living in Macau peninsula, which is merely 9.3km². According to the field research in August 2010, the ratio of urban green space is 26.9%, and the per capita green area and per capita area of green space for leisure and recreation is 5.4m² and 2.7m² separately in Macau peninsula. What is also worth to mention is the population density is higher than 100,000/km² in the P₁,P₂,P₃,P₄ and P₅ of Macau peninsula.



Fig.1. (a) Old compact district in Macau; (b) Map of population density distribution in Macau peninsula

2. The green space layout in Macau peninsula

It is of great significance to study the green space layout in Macau peninsula, considering it is very helpful for exploring a sound approach for the urban green space development in high-density urban environment. This paper tends to explore the inherent law of the green space layout in high-density area of Macau. As a result, the fragmentation of green space patch, evenness of green space arrangement, effective serving distance of city parks and accessibility of city parks in Macau peninsula have been studied in this paper, according review on relative literatures. In these approaches, information technology (IT) and geographic information system (GIS) support are indispensable [2-3].

2.1. Fragmentation of green space patch

There are 608 green patches in Macau peninsula, including 539 green patches which are smaller than 5,000m² (Fig2). And the density of green space patch is 62/km² in Macau peninsula, compare with those

in Yuexiu district of Guangzhou and Futian district of Shenzhen, with 27/km² and 23/km² respectively. Overall, the degree of fragmentation and green space patch density are high in Macau peninsula, and the distribution pattern of green space is mainly characterized by small and scattered. In some high-density area, the size of the green patch is usually small and lack of connection.

Table.1. Statistics for the green patches in different scale of Macau peninsula

Number of green patch / Percentage						Green patch density (per km ²)
I : >50,000m ²	II : 10,000-50,000m ²	III: 5,000-10,000m ²	IV: 1,000-5,000m ²	V : 100-1,000m ²	Total	
7	29	33	174	365	608	62
1.2%	4.8%	5.4%	28.6%	60.0%	100.0%	-----

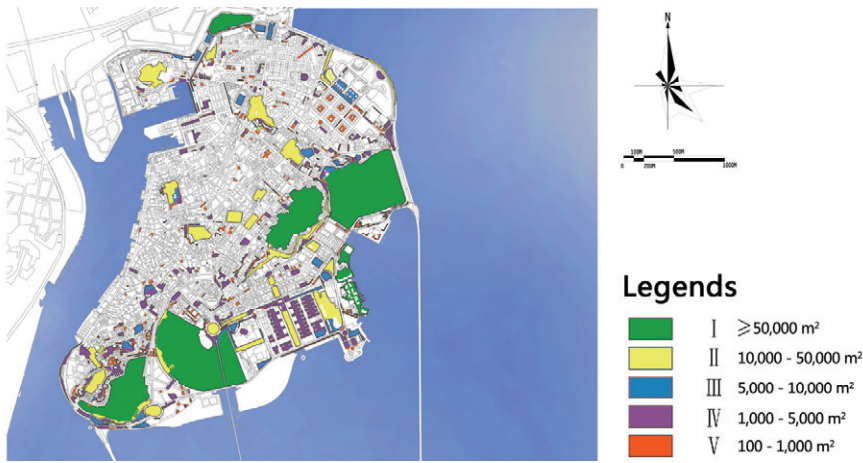


Fig.2. Analysis chart of the urban green space of different scale in Macau peninsula

2.2. Evenness of green space arrangement

To analyze the Evenness of green space distribution, Macau peninsula was divided into 8 quadrates (1,000m x1,000m), which consist of 16 small quadrates (250m x 250m) (Fig 3). The result showed that the average of green ratio and its difference in these 8 quadrates is 22.9% and 11.7%. The average green ratio in the highest dense area is less than 15% while the green ratio and its difference in some low-density areas are high.

As for the city parks, the average of its ratio and its difference in those 8 areas are 11.4% and 8.4%. Furthermore, there are some service blind areas of city parks distribution in some high-density area and new development area.

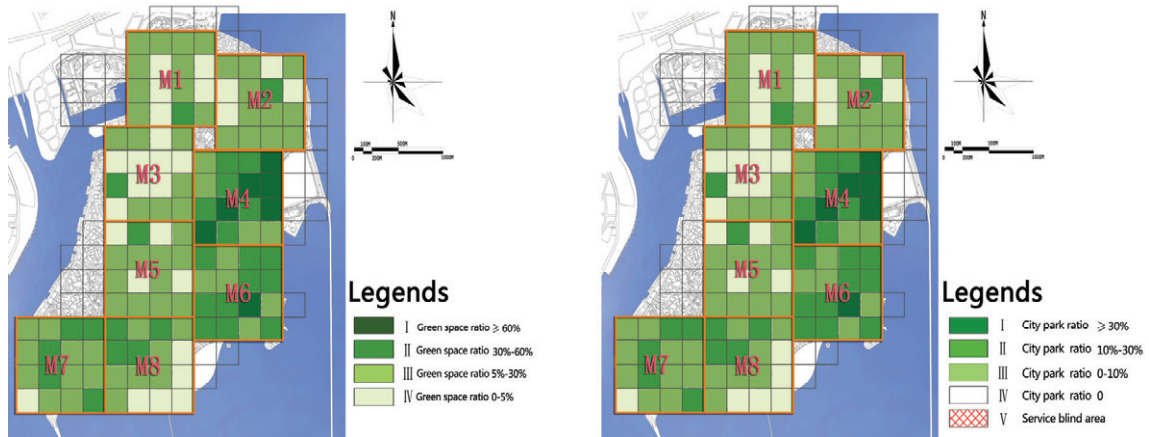


Fig.3. (a) Evenness analysis of urban green space in Macau peninsula; (b) Evenness analysis of City parks in Macau peninsula

2.3. Effective serving distance of city parks

In Macau peninsula, the ratio of city parks is 12.0%. When the effective serving distance of city parks is 100m, it can service 7.1 km², which accounts for 76.6% of Macao Peninsula area. If the serving distance is 200m, the service area can reach 9.0km², which is the 97.0% of Macao Peninsula area. And the city parks can service the whole urban area of Macau peninsula, except for several areas (Fig 4). That is to say, all residents of Macau peninsula can reach the city parks within 200m out of their house. This phenomenon is quite rare in high-density cities.

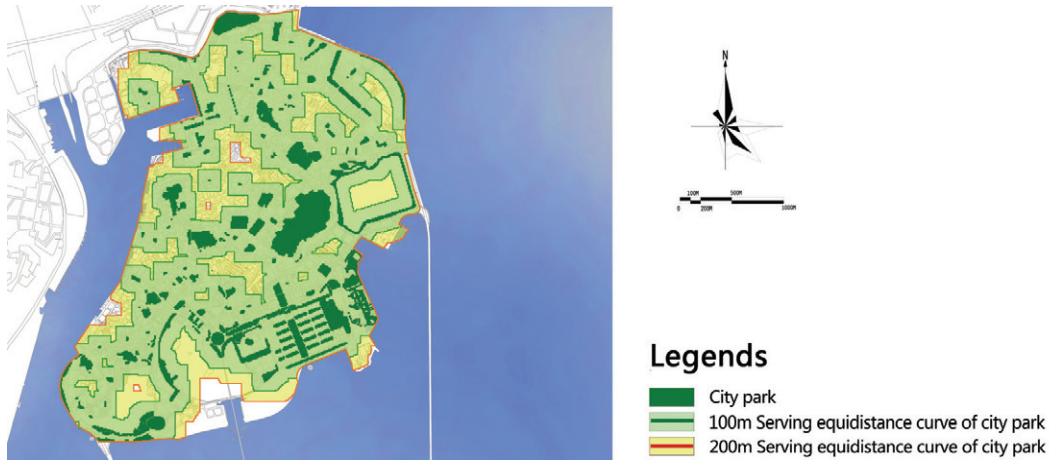


Fig.4. Service equidistance curve of city parks in Macau peninsula

2.4. Accessibility of city parks

The accessibility of city parks in Macau peninsula has been analyzed in this thesis basing on the rule of minimum transport costs and walking speed of a normal adult. The result showed that people can walk to the nearest city parks within 15min as well as the walking distance will not exceed 750m. Among them, walking distance 50-150m(1-3min), 150-250m(3-5min), 250-500m (5-10min) and 500-750m (10-15min), their service area can cover 24.8%,18.3%,10.1% and 3.7% of the whole urban area respectively.

In some areas, where per capita area of city parks are relative large, the accessibility of city parks is high, vice versa. Overall, people could walk to the nearest city parks in 15min, not exceed 750m walking distance, when they departure from any point of Macau peninsula.

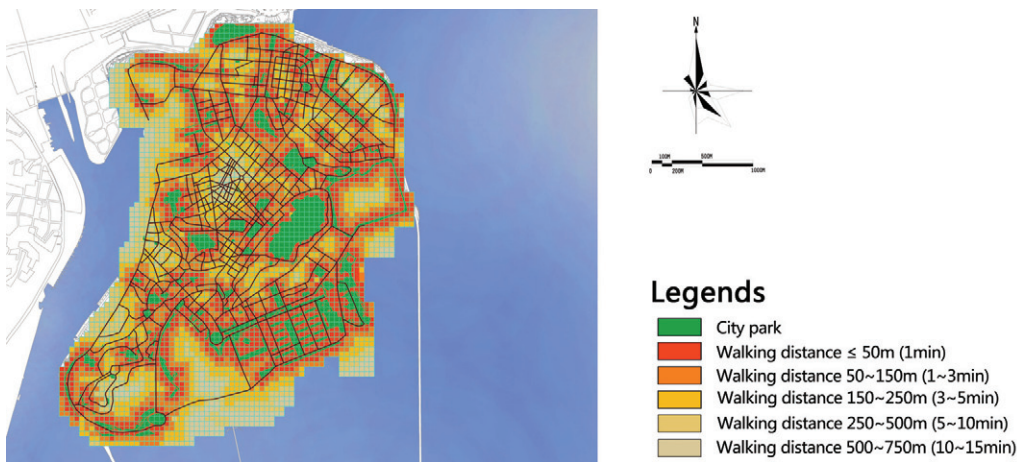


Fig.5. Analysis of accessibility of city parks in Macau peninsula

3. The appropriate approach to distribute green space in high-density urban environment

3.1. Dotted distribution combined with network system

In Macau peninsula, the area of most of the green space is less than 1000m² and presents a dotted distribution. From urban area to suburb area, with population density and building density decreasing, the number of green space is increasing. Despite the challenge of competing land uses for economic development, much has been done to ensure that parks, open spaces and nature areas are set aside to counter the effects of high density urban living [4-5]. To improve the connectivity and reduce the fragmentation of green space, the construction of green belt is suggested. Simultaneously, green belt can connect green space into a green network system, which can enhance the accessibility between city parks. Reasonable public facilities combined with high accessibility of open green space can play a significant role in improving urban environmental quality and increasing the living standards of residents in recreation.

In addition, abundant coastline can be used for seaside green belt trails by connecting and facilitating the new leisure walking space and the existing one. Hence, ecological landscape area in coastline would emerge after extending mangrove and creating green landscape for the protecting purpose. In Singapore, the 1991 Concept Plan adopted by the planning authority included the park connector network under its “Green & Blue Plan” [6]. Plans for the greenway network were reinforced in the Concept Plan Review in 2001 and more recently, in the Parks and Water Bodies Plan [7-8]. The smaller circuits serve local residential areas while the larger greenways can serve entire regions, or even the whole Macau Peninsula.

3.2. Horizontal distribution combined with three-dimensional greenery

The capacity of urban space is extremely limited in Macau because of its large population. In order to increase the utilization of urban green space, intensive land use, vertical greening and green roof are suggested.

As we know, “urban meteoropathy” phenomenon is common in high-density cities around the world. Developing multiple layers of greening for ground, wall and rooftop of buildings, such as green wall, green roof, is an important way to mitigate this issue, and emphasizing the diversity of building form, the building strewn at random and the cooperation of component building, is one of the most important approach for relieving the symptom of “urban meteoropathy”. Besides, it can improve the sensory effects of green landscape and promote the quality of the urban landscape. Simultaneously, for the sake of forming three-dimensional composite and efficient green network in high-densely populated city, green network could be combined with the measures mentioned above, transforming green roofs, green open space and sunken square into vertical green.

4. Conclusion

In 2031, there would be 829,000 people live in Macau, according to official projections. Therefore, high-density urban development model will be the future direction of urban development of Macao. In the mean while, the development of green space has been limited, because of land decreased. It is an urgent need to seek a sound approach for sustainable development in Macau, given that some problems have arisen, for example, high degree of fragmentation, urban green space decrease in some area, low accessibility of city parks, etc. The park connector network is therefore intended to be a multifunctional greenway, requiring planners “to seek a balance between the ecological, cultural, social and aesthetic goals” in their planning [9]. Network system integrating with three-dimensional greenery is advised to be

adopted in order to raise green looking ratio, improve the quality of green landscape and enhance the interaction between green space and building. Eventually, a sound approach to urban green space development in high-density urban environment could be emerged, ground on wise use of the green space.

The space between city parks is small, the distribution of green patch is even and green space has been integrated into the residential area in Macau peninsula, though the density of the city is extremely high. The conclusion of this paper, including the study of the urban green space outlay of Macau peninsula, the mode for distribution of urban green space in high-density city and the approach to expand green space, could provide reference for the construction of urban green space in similar high-density city. It is valuable in the field of urban sustainable development.

Acknowledgements

Gratitude is devoted to departments and agencies of Macao SAR government, who placed high value on this project and provided various forms of support for us.

References

- [1] Susan Roaf. The sustainability of high density. In: E. Ng , editor. *Designing high-density cities for social and environmental sustainability*, London: Earthscan; 2010, p. 27.
- [2] Ervin, Stephen, Carl Steinitz. Landscape visibility computation: necessary, but not sufficient. *Environment and Planning B: Planning and Design* 2003;**30**: 757-66.
- [3] Llobera, M. Extending GIS-based visual analysis: The concept of visualscapes. *International Journal of Geographical Information Science* 2003;**17**(1): 25-48.
- [4] Keung, J. Planning for sustainable urban development: the Singapore approach. In: Yuen B. editor. *Planning Singapore: From Plan to Implementation*, Singapore: Singapore Institute of Planners; 1998, p. 11-16.
- [5] Tan K.W. A greenway network for Singapore. *Landscape and Urban Planning* 2006;**76**: 45-60.
- [6] Urban Redevelopment Authority, Singapore. *Living The Next Lap: Towards a Tropical City of Excellence*.1991.
- [7] Urban Redevelopment Authority, Singapore. *Concept Plan 2001*.2001.
- [8] Urban Redevelopment Authority, Singapore. *Parks and Waterbodies Plan and Identity Plan, Subject Group report on Parks and Waterbodies Plan and Rustic Coast*.2002.
- [9] Ahern J. Greenways as a planning strategy. *Landscape Urban Plan* 1995;**33** (1-3): 131-155.