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A Study on Spiral Organization of Space Syntax in Shanghai Natural History Museum

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Abstract

Space syntax is a set of techniques to analyse the spatial layouts and users' activity patterns in a building. This paper evaluates a study on the building typology of a museum or public institution. The main objective of this paper is to identify the permeability and wayfinding of the spatial structures of the selected museum, which influences the way users utilise the spatial organisation. The chosen case study is the Shanghai Natural History Museum (SNHM). This study uses the existing layout plans to observe the museum spaces. The study also explores the wayfinding and the level of permeability of the museum using the justified graph as the measurable tool. The result demonstrates that the overall building spaces have a straightforward and complex spatial configuration with balanced public and private spaces of the selected floor plans. Furthermore, the layout spaces interpret the level of wayfinding of each area has a good separation of accessibility. This study illustrates that space syntax is a practical tool for architects to comprehend the function of the spaces since it visualises the building's spatial configurations and quantifies the main building typology trait.

Discipline: Architectural Engineering.

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1 Introduction

Building typology is one of the influencing factors of architectural spatial layout, meaning different building typologies will reflect different architectural compositions. A building circulation

is essential to have an organised mechanism layout and communication space (Natapov et al., 2015; 2020), especially in museums. Good circulation in a museum is crucial. It connects the visitor with the interior areas full of exhibit items, allowing them to have a leisurely educational museum experience. It is a distinctive informal education constructed through movement in space, which encourages the visitor to travel along a clear linear path, spiral path, radial path, grid path, network path (Elottol & Bahauddin, 2011; Wineman & Peponis, 2010), or more freely weaving a self-directed course. The accessibility or spatial development pattern should reflect users, and the overall spatial organisation includes private, semi-public, and public areas (Sarzali et al., 2024). This paper discusses the spatial structure of space syntax in the Shanghai Natural History Museum (SNHM). For this case study building, the SHNM was designed by Perkins and Will and completed its construction in 2015. It is known as one of the largest museums in China, connected to the urban sculpture park to become an integral of the more extensive parkland and exhibit more than 10,000 artifacts from all seven continents (Blitz, 2015; Ricci, 2016; Aguilar, 2021).

The SNHM museum has won several awards, including the 2015 AIA Chicago Devine Detail, making it a suitable building to study. In addition, the museum managed to achieve high sustainable ambitions and was certified with LEED Gold certification due to its multiple energy-saving techniques.

This study focuses on the spatial organisation of building typology designed to act as a cultural institution or a place of assembly. It aims to understand the spatial arrangement of the unique spiral organisation of SHNM. This research will identify the permeability and wayfinding of the spatial structures in SHNM by using space syntax study.

2 Literature Review

Based on Hassan et al. (2019) and Dursun (2007), space syntax is a tool for investigating the connection between space, spatial structures, and human behaviour. In addition, space syntax techniques give some tools for exploring the mechanics of architectural spaces and interpreting the spaces as social formations reflected in architectural appearances. Usually, space syntax is analysed by a thorough examination of permeability and wayfinding qualities.

According to Hassan et al. (2019), permeability is described as the level of people's or vehicles' ability to travel in a specific direction inside and outside a particular space of a building. For example, the permeability level includes public, semi-public, semi-private, and private areas. As for the wayfinding definition, it is a method that guides individuals through their physical surroundings, enriching their experience and awareness of the setting.

SHNM is categorised under the building typology type of cultural institutions, mainly as museums (Blagojevic, 1997). The museum includes a wide range of activities such as exhibitions, education for youth, laboratory exploration, and administration. According to Hillier et al. (2006), due to its spatial arrangement, a museum is usually used to convey and promote an educational goal of some type and form a pattern of visiting. Not only for leisure educational programs but other spaces support typologies such as café, restaurants, research laboratories, offices, etc., the

space can be categorised into private, semi-public, semi-private, and public. Those categories represent the level of permeability (Ong et al., 2024). Based on the floor plan observation starting from the parkland area, 70-80% of the overall size is meant for public and semi-public usage. The rest are private and semi-private.

Specifically, the museum is accessible from Shanhaiguan Road, adjacent to Jing'an Sculpture Park. Users can also access Beijing West Road through Jing'an Sculpture Park. In addition, the Subway Station connects straight to the museum crossing the Shanhaiguan Road on the north.

According to Maglic (2012), biomimicry is a new field that investigates nature's most remarkable ideas and then mimics these designs and processes to address human issues. From the plan view, the museum is inspired by the nautilus shell, one of the purest geometric forms found in nature. Therefore, it is safe to say that the building styles of SHNM have visually resembled the element of nature, which is known as biomimicry design. Furthermore, the building style is enhanced by using natural ingredients in the facades representing a functional cellular structure of plants and animals. Both elements are integrated with local cultural references to represent the harmony between humans and nature.

3 Research Method

This research analyses and documents the study based on three processes: systematic observation, floor plan analysis, and quantitative analysis (Obeidat et al., 2017). According to Halim et al. (2019), the first step was to comprehend the concept of space syntax theory by conducting investigations of previous literature reviews on relevant themes, which were obtained mainly from books, journals, articles, websites, and references.

The Likert scale is one of the most reliable ways to measure opinions, perceptions, and behaviours. Based on Albaum (1997), the Likert scale directly evaluates the interaction and, indirectly, the immediate effects of direction and intensity. Similarly, in this case, study, the level of permeability and wayfinding can range from 0-6 scale interpreting from entry-level – to most private areas. The data then can be transformed and analysed into a vertical scale or Justified Graph with the depth level representing the permeability and wayfinding. The bigger the number, the greater the depth level and permeability and wayfinding.

The museum consists of six-story levels, and the system of numbering, shapes, and colouring will be applied to the floor plan. The building's primary ingress and egress are at the ground floor level. Ingress and exit will be indicated in blue colour. The lift and staircase will be displayed in brown and green colours. Specific colours characterise the permeability depth for each category. For example, the private area is red, the semi-public is magenta, and the public is yellow. All entries will be illustrated as E1, E2, E2, etc. In contrast, the space transition corridor will be described as C1, C2, C3, and so on, which may ease the understanding of the spatial configurations. The staircase and lift will be indicated as S1, S2, S3, and L1, L2, and L3, respectively.

The primary users of the SHNM are the visitors and staff. The depth of permeability and wayfinding is identified through the user's navigability level into each space from the number and

coloured indicator in the justified graph. The justified chart will have three classifications of depth level, which are private (red), semi-public (magenta), and public (yellow). A tabulation data is produced to show the relationship between the area, depth of space, level of permeability, and wayfinding.

- Level of permeability – public to private
- Level of wayfinding – easy to medium to hard

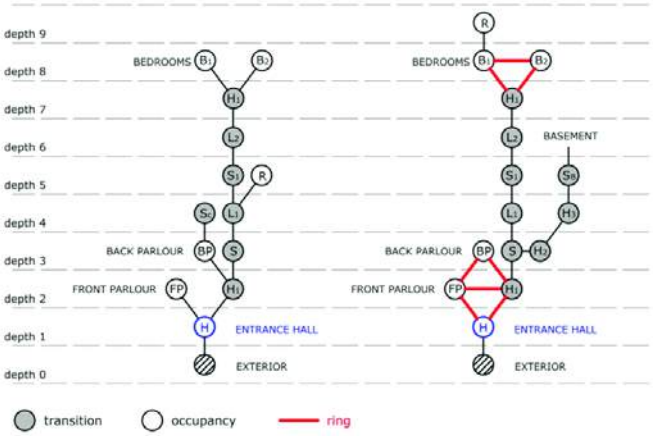

Figure 1: Example of measurable scale graph used for space syntax study.

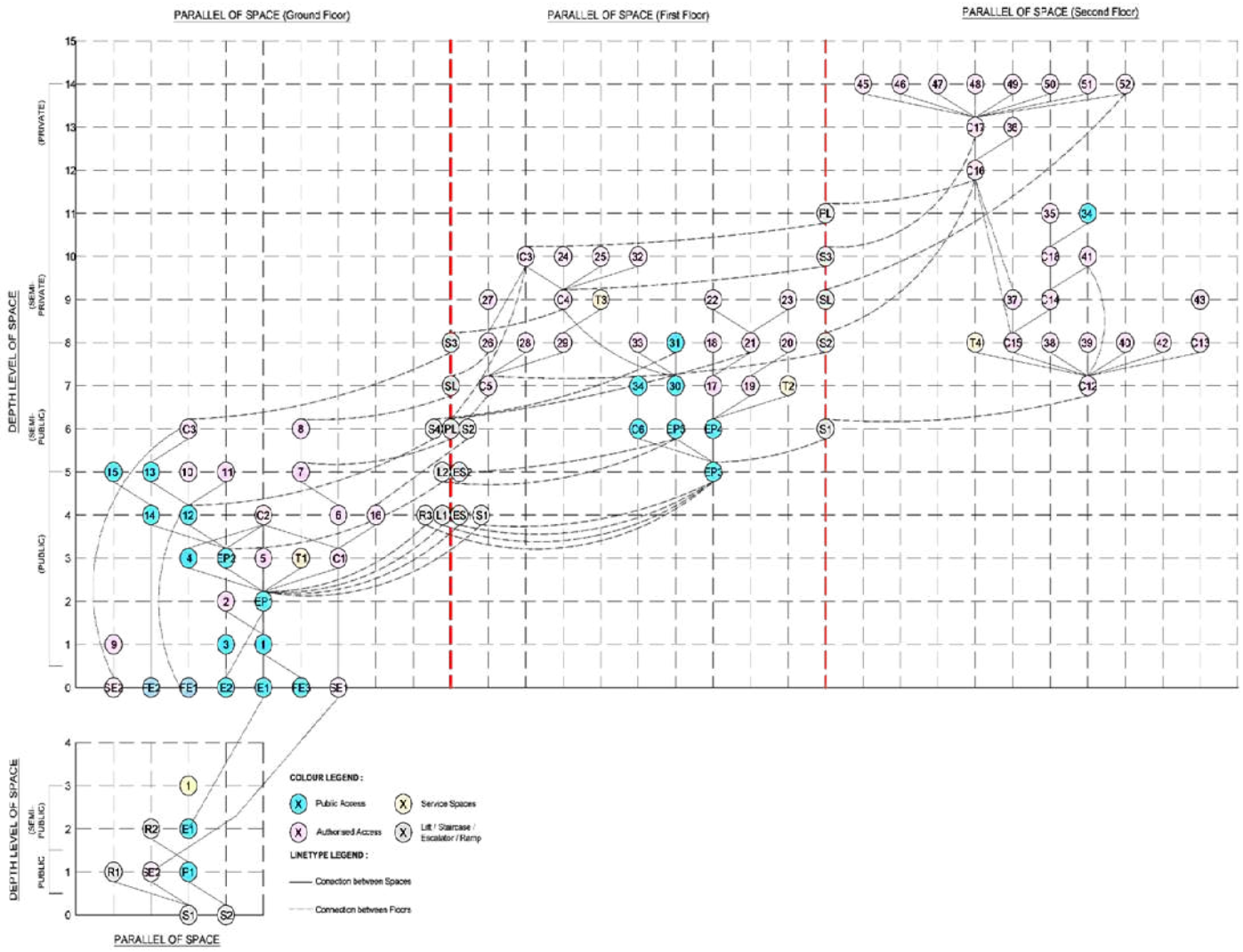

Figure 2: Overall Justified Graph of SHNM

4 Result of Analysis

4.1 Overall Justified Graph

Figure 2 shows the overall justified graph of SHNM. As a public institutional building, this research focuses on two main user categories: visitor and staff, differentiated using colours in the justified graph: Public (Visitor) blue colour, and Private (Staff, Authorized Area) pink. In addition, vertical access such as lifts, escalators, ramps, and staircases are indicated using grey colour.

4.2 Space Syntax

Several floors have been selected between the six-story SNHM: Ground Floor, First Floor, and Top Floor. First, the circulation throughout the spaces of the selected floors is analysed for its permeability and wayfinding. Then, the data obtained are translated into justified graphs format to verify the depth level of permeability.

4.2.1 Site Plan

As for a start, the analysis begins with the Site Plan and its Justified Graph, as shown in Figure 3. From the northwest and southeast sides, there are two primary access for the staff and visitors into the building. The northwest side, which is on the S1, is accessible for staff and authorised persons only because it is near the area services and private access location. Meanwhile, the southeast side, which is from Jing'An Sculpture Park, is the visitor's access to the pedestrian or concourse where the main entrance to SNHM is located. R1 is the ramp for visitors' vehicles going up and down to the basement parking. At the same time, R2 is the ramp for pedestrians going up to the vegetated rooftop area, which is connected directly with P1.

Table 1 shows the space syntax analysis for the site plan. Every space is connected, and most of the spaces are easy to find. The areas are located within the building's perimeter and direct for the users to see the areas from the open surrounding landscape. However, the E2 has an average level of wayfinding. The design at E2 is partially closed with a perimeter wall which made the area not directly accessible from the S1 and P1. The access is only by the staff and authorised person.

Table 1: Space Syntax Analysis for Site Plan

Code of Space	Area	Depth Level	Level of Permeability	Level of Wayfinding
S1	Street 1	0	Public	Easy
S2	Street 2	0	Public	Easy
P1	Pedestrian 1	1	Public	Easy
R1	Ramp to parking	1	Public	Easy
R2	Ramp to Roof Top	2	Public	Easy
1	Roof Top	3	Public	Easy
E1	Main Entrance 1	2	Public	Easy
SE2	Staff Entrance 2	1	Public	Average

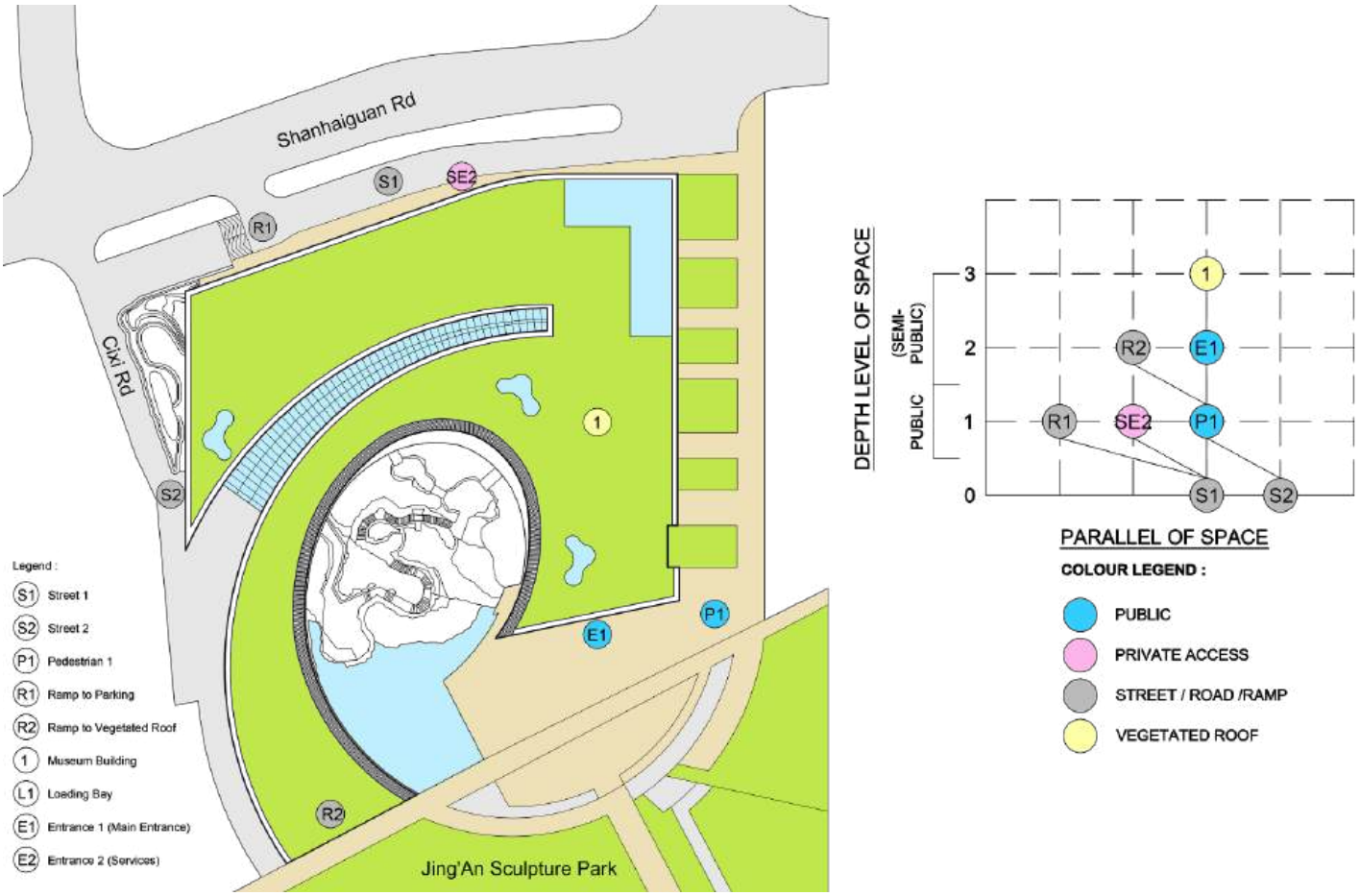

Figure 3: Site Plan (left) and its Justified Graph (right) of SNHM

4.2.2 Ground Floor Plan

Figure 4 shows the ground floor plan and its depth level in the justified graph of SNHM. The ground floor plan is labelled with main spaces and circulation spaces in a specific numbering format. This ground floor level indicated seven areas at the depth level of 0. Two of them are the main entrances for the public, labelled with E1 E2, located at the front and right side of the building plan. The other two are the entrances for the staff or authorised person tagged with SE1, and SE2, located at the rear and right side of the building plan. The FE1, FE2, and FE3 are the fire escape routes located at the left and front sides of the building to cater to many visitors during extreme situations. As mentioned in the site plan justified graph, most of the spaces at the building perimeter are easy to find. However, as the users go deeper into the ground floor level, some of the connectivities within the spaces are straightforward, and some areas have pretty complex connectivity.

The exhibition area indicates a radial or spiral-like connection. Starting from space 1, the entry lobby, visitors can access space 2 and vertical access to R3. Then, the entry lobby connects EP1 and EP2 for the public, connecting directly to the spaces labelled 12, 13, and 14, the exhibition area. Until here, the level of wayfinding is apparent, easy, and straightforward, which serves the purpose of having high effectiveness of direction to guide the visitors in the museum building.

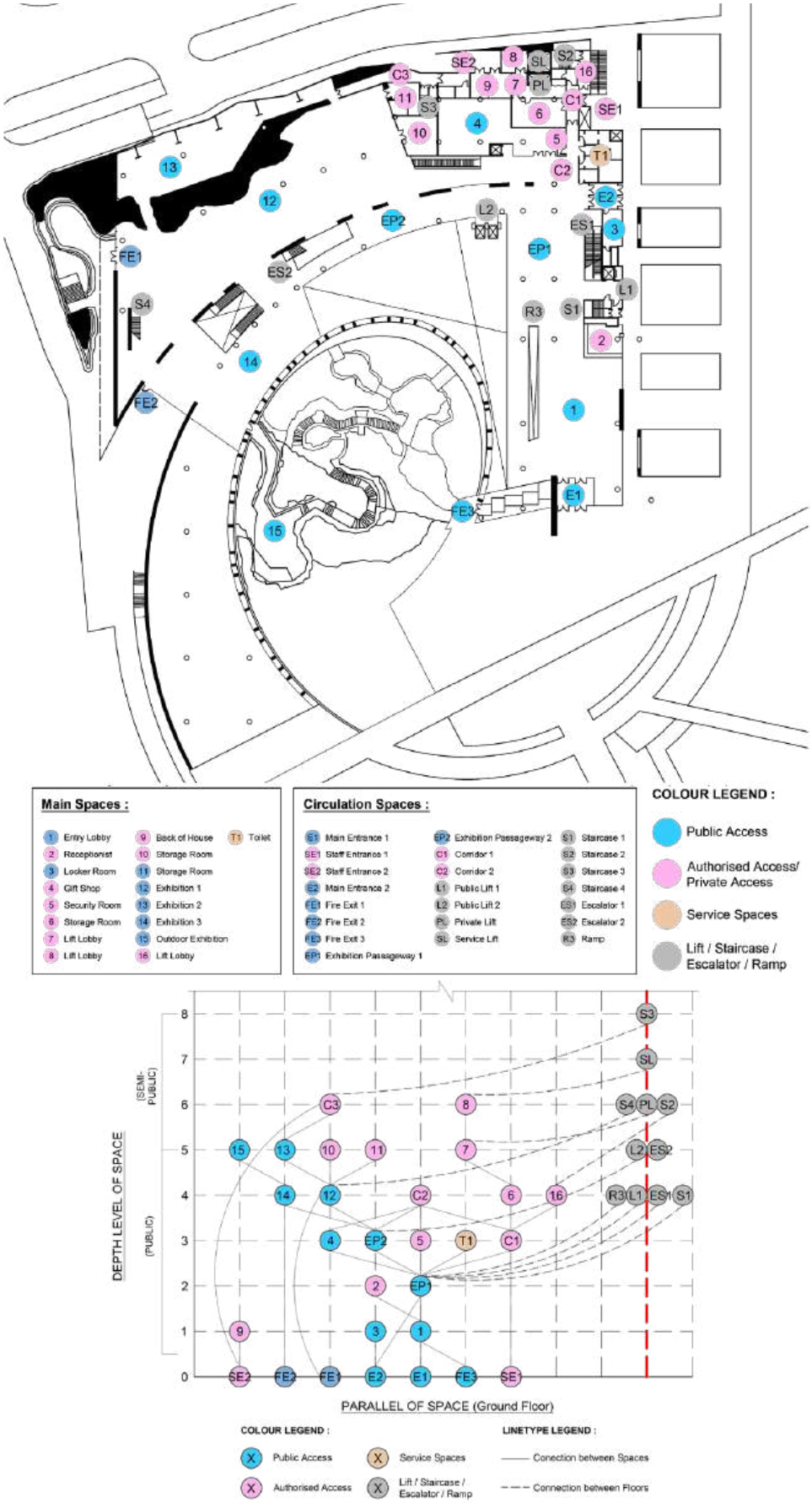

Figure 4: Ground Floor Plan (left) and its Justified Graph (right) of SNHM.

The complex area mentioned before is where the related parties can only authorise it. Most of the areas are at the top right corner of the building plan, where SE1 and SE2 are located. From within the museum space, the privately accessed area is started from C2 and directly towards

spaces 5 and C1. As shown in Figure 2, the visitor and staff can vertically access the building through lifts, ramps, staircases, and escalators. The stairs (S4, S1) are for the public to use; meanwhile, the staircase (S2, S3) is mainly for the staff. Lifts (L1, L2) and escalators (ES1, ES2) can also be used by the public. However, PL and SL are strictly for the staff only.

Table 2: Space Syntax Analysis for Ground Floor Plan

Code of Space	Depth Level	Level of Permeability	Level of Wayfinding
E1, E2, SE1, SE2, FE1, FE2, FE3, EP1, EP2, C1, C2, 1, 2, 3, 4, 5, 6, 12, 14, 16	1-5	Public	Easy
7, 8, 10, 11, 13, 15, C3	6-8	Semi-Public	Average
-	-	Semi-Private	Difficult
-	-	Private	Very Difficult

Table 2 shows the space syntax analysis for the ground floor plan. The depth level for the ground floor level is up to 8. It indicates that the depth level of 1-5 is for the public and has an easy level of wayfinding. Meanwhile, the depth level of 6-8 indicates the starting point of the semi-public level of permeability and has an average level of wayfinding.

4.2.3 First Floor Plan

Figure 5 shows the first-floor level and its depth level in the justified graph of SNHM. As the users go to the first-floor level, more authorised access spaces are found. The graph indicates the level of permeability of semi-public at the depth level 6-8 and starts with semi-private at the depth level 9-12. The reason for more authorised access, when the users go upper, is that 80% of the exhibition halls are at the basement level, from basement 1 to basement 3. However, the basement levels are not chosen in this case study. Anyway, there are still spaces 30 and 31 for the public to access. Space 34 can also be accessed by the public through a specific authorisation due to its space typology, the auditorium. The vertical access of stairs (S4), escalators (ES1, ES2), ramp (R3), and lifts (L1, SL) will stay up to the first floor only and will no longer go up to the top floor.

Table 3: Space Syntax Analysis for First Floor Plan

Code of Space	Depth Level	Level of Permeability	Level of Wayfinding
EP3, EP4, EP5, C6	1-5	Public	Easy
C5, 17, 18, 19, 20, 21, 26, 28, 29, 30, 31, 33, 34, T2	6-8	Semi-Public	Average
C3, C4, 22, 23, 24, 25, 27, 32, T3	9-12	Semi-Private	Difficult
-	-	Private	Very Difficult

Table 3 shows the space syntax analysis for the first-floor plan. The depth level for the first-floor level is up to 12. It indicates that the depth level of 9-12 is semi-private and has a difficult level of wayfinding. It is the administrative activities were found at this level and should not be able to access by the public except for spaces 30, 31, and 34.

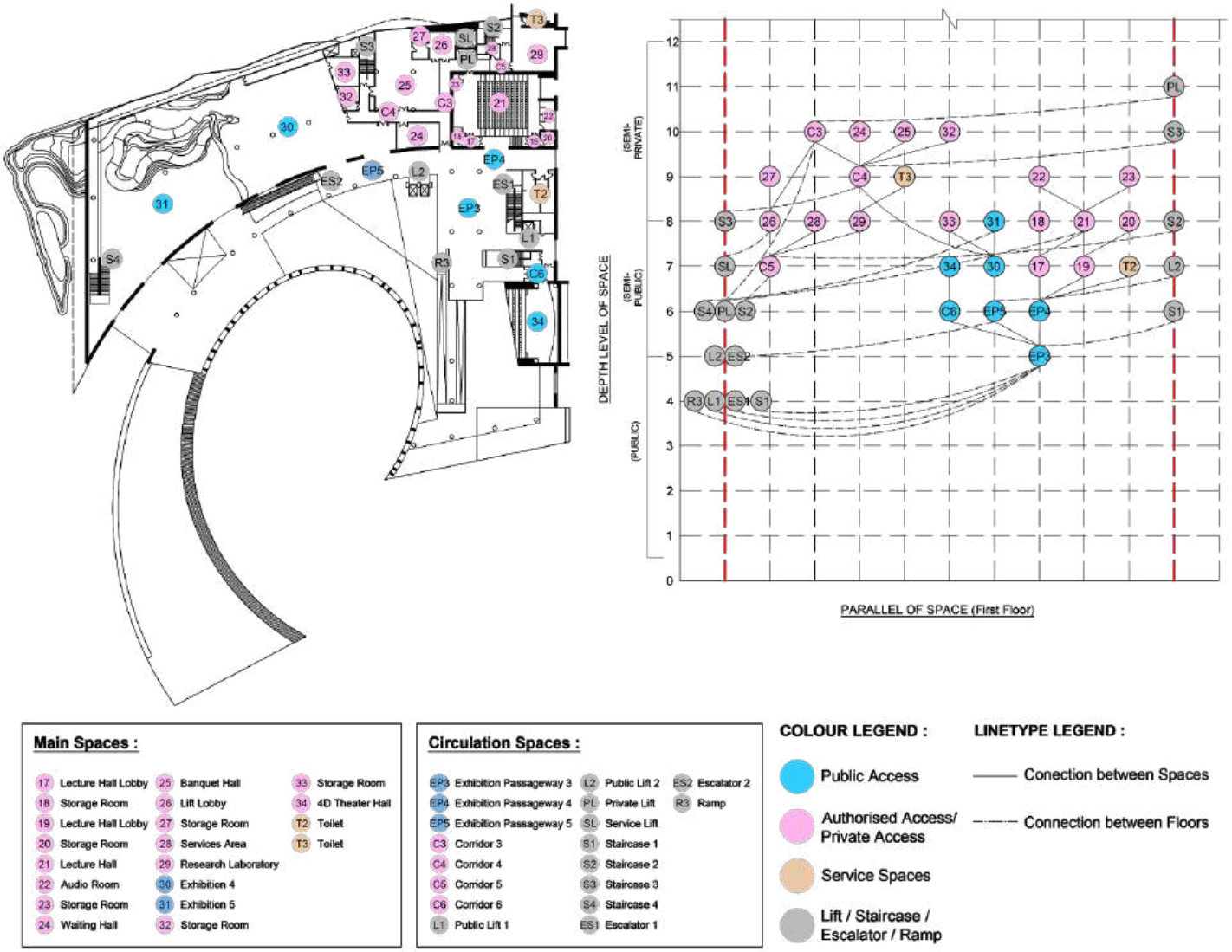

Figure 5: First Floor Plan (left) and its Justified Graph (right) of SNHM

Figure 6 shows the second-floor level and its depth level in the justified graph of SNHM. The second-floor level is the topmost floor in the SNHM building, and it serves most of the administration activities, including the conservation room and storage areas. More than 90% of the area is used for administrative activities. One of the corridors, C13, can be accessed by the staff to enter space 34. The reason is that the auditorium is a double-volume space accessible from the top or lower level. In this case, the top level is accessible by the authorised person; meanwhile, the public can access the lower level.

4.2.4 Second Floor Plan / Top Floor Plan

Table 4 shows the space syntax analysis for the second-floor plan. The depth level for the second-floor level is up to 14. It indicates that the depth level of 13-14 is for private authorised access only and has a very difficult level of wayfinding. It is because the second-floor area is fully served the staff for administration activities. In response to that, all of the vertical access is strictly for the staff only.

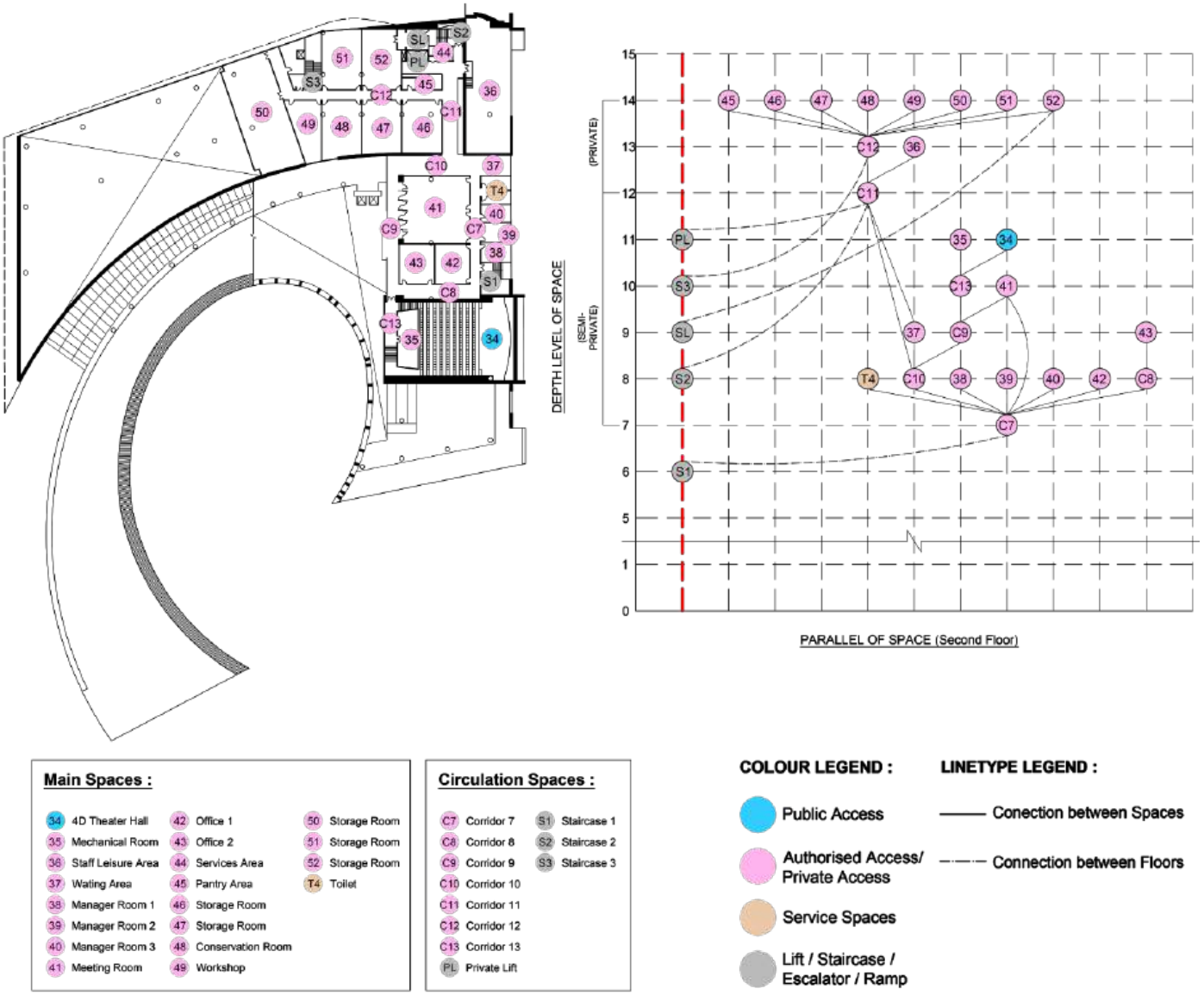

Figure 6: Second Floor Plan (left) and its Justified Graph (right) of SNHM

Table 4: Space Syntax Analysis for Second Floor Plan/Top Floor Plan

Code of Space	Depth Level	Level of Permeability	Level of Wayfinding
-	1-5	Public	Easy
C7, C8, C10, 38, 39, 40, 42, 43, T4	6-8	Semi-Public	Average
C9, C13, 34, 35, 37, 41	9-12	Semi-Private	Difficult
C11, C12, 36, 45, 46, 47, 48, 49, 50, 51, 52	13-14	Private	Very Difficult

5 Discussion

The SHNM space syntax analysis identifies two user categories: public and private. The complete result shows the level of permeability is balanced between the users of the total number of spaces. In general, a museum should be a public or semi-public category building. However, the selected floor plans of the ground floor, first floor, and top floor indicate that SNHM balances public and private spaces. 50% of the overall area of the selected floor plans is for exhibition spaces.

Meanwhile, the other 50% is used for administrative activities. However, the first-floor level shows some overlapping of permeability level between semi-public and semi-private. The overall justified graph indicates the highest depth level is 14, and 8 is the starting depth level of the semi-private spaces, but the public can also access some spaces. In response, it illustrates that the overall depth level is quite balanced but could be improved in SNHM.

The level of wayfinding can also be segregated into two users. As for the public, the level of wayfinding is quite clear and straightforward. However, the level of wayfinding is more than 80% for public users. The result is shown in the justified graph at the depth level of 1 to 7 level. The reason is that the museum has a radial or spiral-like organisation to guide the visitor to a specific exhibition hall where the central water garden becomes the focal point of the whole museum experience journey.

The level of wayfinding for staff and authorised persons can also be stated as excellent but complex. However, it is how the private area should respond to keep the public away from the area. It is also shown in the justified graph that some of the vertical access stops at a certain level, such as the vertical access of stairs (S4), escalators (ES1, ES2), ramp (R3), and lifts (L1, SL) will stop at the first floor and no longer going up to the top floor.

6 Conclusion

The SHNM expresses a specific vertical separation. It is divided into three zones vertically; the ground floor level is entirely public, the first and top-level semi-public to private and the basements level is public to semi-public. The museum's spatial configuration successfully guides all groups of users to public and private access and clearly defines the limitations of some spaces for public users. It is essential to have restrictions on some areas to have different space functions act as they should.

The spatial configurations are generally suitable for public users, with 80% of the circulation serving the groups correctly. However, permeability can be improved significantly at the depth level of 6-8, where the semi-public and semi-private overlap each other. The 4D Cinematic Theater should not design within the ground floor and the first floor due to its permeability of public or semi-public. Instead, it can be developed within the ground level and basement 1 to have the same permeability level of public and public. In response, the overlapping or permeability level can be prevented within the depth level of 6-8. Overall, the SNHM has good permeability and wayfinding for both users, public and private.

7 Availability of Data and Material

All data and results of this study are included in this work.

8 References

Aguilar, C. (2021). Shanghai Natural History Museum/Perkins+Will. *ArchDaily*. https://www.archdaily.com/623197/shanghai-natural-history-museum-perkins-will

Albaum, G. (1997). The Likert scale revisited. *Market Research Society. Journal*, *39*(2), 1-21.

Bafna, S. (2003). Space syntax: A brief introduction to its logic and analytical techniques. *Environment and behavior*, *35*(1), 17-29.

Blitz, M. (2015). The New Shanghai Natural History Museum is Ancient, Modern and Uniquely Chinese. *Smithsonian Magazine*. https://www.smithsonianmag.com/travel/shanghai-natural-history-museum-and-new-age-museums-180955392

Dursun, P. (2007). Space syntax in architectural design. In *6th international space syntax symposium* (pp.1-56).

Elottol, R. M., & Bahauddin, A. (2011). A Competitive Study on the Interior Environment and the Interior Circulation Design of Malaysian Museums and Elderly Satisfaction. *Journal of Sustainable Development*, *4*(3), 223.

Halim, N. F. A., Hassan, A. S., Arab, Y., & Angood, R. S. A. B. (2019). Ocean Conservation and Waste Prevention Centre: The Study of Space Syntax in Recycling Facility.

Hillier, B., & Tzortzi, K. (2006). Space syntax: the language of museum space. *A companion to museum studies*, 282-301.

Maglic, M. J. (2012). Biomimicry: using nature as a model for design.

Natapov, A., Kuliga, S., Dalton, R. C., & Hölscher, C. (2015). Building circulation typology and space syntax predictive measures. In *Proceedings of the 10th International Space Syntax Symposium (pp. 13-17)*. London: Space Syntax Laboratory, The Bartlett School of Architecture, University College London.

Natapov, A., Kuliga, S., Dalton, R. C., & Hölscher, C. (2020). Linking building-circulation typology and wayfinding: design, spatial analysis, and anticipated wayfinding difficulty of circulation types. *Architectural Science Review*, *63*(1), 34-46.

Obeidat, B., & Rashid, M. (2017). Using Space Syntax Approach to Assess Signs'locations for Improving Wayfinding in an Educational Setting.

Ong, P.Y., Arab, Y., Hassan, A. S., Saeed, M., Onubi, H. O., and Witchayangkoon, B. (2024). Analysis of Permeability & Wayfinding Using Space Syntax Theory in Public Aquarium: Case Study on Antalya Aquarium in Turkey. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 15(1), 15A1E, 1-15. http://TUENGR.COM/V15/15A1E.pdf DOI: 10.15456/ITJEMAST.2024.5

Ricci, P. (2016). Shanghai Natural History Museum, the green building icon. *Alchimag*. https://alchimag.net/en/architecture/green-building-architecture/shanghai-natural-history-museum-the-green-building-icon

Sarzali, S.A., Arab, Y., Onubi, H. O., Hassan, A.S., Wichayangkoon, B. and Saeed, M. (2024). Analysis of Users' Level of Permeability and Wayfinding in Museum Hotel Building Typology. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, *15*(1),

Wineman, J. D., & Peponis, J. (2010). Constructing Spatial Meaning: Spatial Affordances in Museum Design. *Environment and Behavior, 42*(1), 86–109.

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