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Permeability and Wayfinding Analysis on Putuo Mountain New Passenger Transportation Centre

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Abstract

The transportation hub aims to ease traffic congestion and provide access to destinations. Completed in 2020, the Putuo Mountain New Passenger Transportation Centre in China replaces the former transportation hub to serve a capacity of more than 12 million annually. In this paper, wayfinding and permeability levels synthesize the space syntax of the selected case study. Employment of the Likert Scale, justified graph, and alphanumeric system illustrate and justify the overall space configuration in the Putuo Mountain New Passenger Transportation Centre. Most of the spaces (45%) in the case study are semi-public and easy to wayfinding. The inclusion of local context and the seafront view into the design as a visual navigating tool increases the circulation efficiency of the transportation hub.

Discipline: Architecture, Space Syntax, Spatial Design

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1 Introduction

Urbanization speeds up population increase in urban areas, an increase of 16% in urbanizing in China from 1995 to 2007 is recorded resulting in an annual increase of more than ten million urban migrants. Rapid urbanization has a dramatic impact on urban mobility activities, travelling for longer distances and traffic congestion are unavoidable downsides of urbanization (Wang, 2010). Multi-mode transportation involves at least two transportation modes in connecting two destinations and is believed to provide optimal efficiency in traveling (Yatskiv & Budilovich, 2017).

The transportation hub acts as a focal point in the transportation network, linking various mobility modes, and is a gateway symbolising the entrance or exit from a region (Zhong et al., 2016). Thus, permeability and wayfinding study on transportation hubs is vital in designing a sustainable and efficient urban transport plan.

In the modern world, local culture and context eventually diminish due to internationalization and globalization. Globalization contributes to the adoption of advanced technology and materials from all over the world. Nonetheless, standardization has contributed to the fear of loss of identity in architecture (Eldemery, 2009). The case study, Putuo Mountain New Passenger Transportation Centre expresses the localization in architectural languages. Local and cultural elements are applied to the space planning and façade to revitalize traditional Chinese architecture, highlighting regionalism and localization.

In terms of functionality, the Putuo Mountain New Passenger Transportation Centre is an interchange hub accommodating a port and bus station, allowing passengers to switch from land to water transportation or vice versa. The case study is one of the entry projects in the 2021 WAN Awards under the Transport category. Besides, renowned architecture websites such as ArchDaily, Dezeen, Architizer, and Designboom emphasise the importance of infrastructure and transport architecture as such topics are highly recognised.

1.1 Research Objective

This study aims to analyse the permeability and wayfinding of the transportation hub by looking into the spatial arrangement of the case study. The permeability and wayfinding level of a building is an architectural guiding tool in ensuring the efficiency of users' movement within the transportation hub. Moreover, the research objective is to evaluate the effectiveness of users' circulation throughout the building using space syntax as the spatial configuration and building layout impact the user's perception of spaces (Hassan, 2004).

2 Literature Review

2.1 Space Syntax

Bill Hillier believes there is an operational method to evaluate the spatial relationships between objects, space, and society (Hillier & Tzortzi, 2006; Yamu, van Nes & Garau, 2021). Space syntax develops identifiable mapping within the building determined by users' perceptions about the spaces they experience. Space syntax is the concept of evaluating and analysing the surrounding spatial structures in daily life (Munir et al., 2019; Peponis, 2005). Spaces interpret voids between walls, fences, or obstacles blocking their way or visual field in space syntax (Klarqvist, 2015; Bafna, 2003, Ratti, 2004). Various research has proven that users' spatial perception is related to the building layout (Tzamir, 1975; Lynch, 1960; Lynch, 1981). Space syntax can be presented in a mathematical presentation. For example, justified graphs simplify the understanding of complex building layouts (Macdonald, 2006; Hillier, 2007).

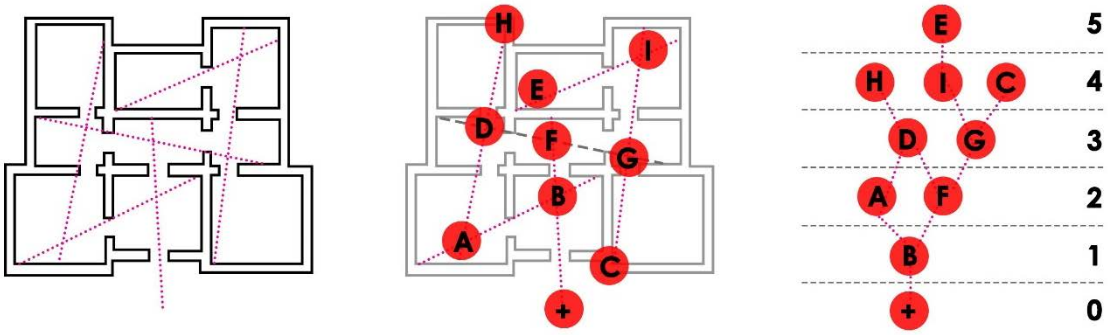

Figure 1: Level of Depth in Space Syntax Redrawn by author
Source: (Dawes & Ostwald, 2018)

2.2 Building Typology

A transportation hub is a focal node in the web of urban corridors, connecting destinations within a city or town. Transportation hubs allow multi-mobility under one roof involving interchange and transit to other transportation modes. Transportation hub houses at least two transportation modes safely and efficiently (Elshater & Ibraheem, 2014). To ensure the efficiency of users' movement, most of the spaces in a transportation hub are accessible to the public. Transportation hubs are equipped with retail, food, and beverage outlets.

2.3 Introduction of the Case Study

Located on Mount Putuo Island, Zhousan, Zhejiang Province, the Putuo Mountain New Passenger Transportation Center is a design of the Architectural Design & Research Institute of Zhejiang University Co., Ltd. (UAD) with a gross floor area of 10782 m^2. Completed in 2020, it functions as the public port serving the Putuo Mountain Scenic Area. The case study is separated into the land side (ticket office, waiting lounge, visitor centre, service centre station square, bus station, etc.) and waterside (pontoon dock area, wharf, coastal trail).

The new passenger transportation centre replaces the former transportation centre due to overload capacity as the scenic area is visited by more than 12 million visitors annually. The architectural style of the case study is contemporary vernacular architecture. Instead of approaching the design with a large volume and iconic image as conventional transportation hubs, the case study divides spaces into smaller modules to express the "5 layers" traditional Chinese architectural system: bracket, bay, courtyard, building, and city. The breaking down in volume allows the integration of modern architecture and local cultural elements into the design, balancing internationalization and localization to ensure diversified architectural approaches in the future.

3 Method

The author has employed qualitative research methods such as online research, articles, journals, and books in the preliminary research on the background and project information of the selected case study. To undergo quantitative analysis through justified graphs, the author has redrawn the floor plans of the Putuo Mountain New Passenger Transportation Centre from reliable sources. The level of permeability and wayfinding analyse the spatial networking. Determining the hierarchical order of each space according to the movement leveling system is the most convincing way to implement wayfinding analysis (Yusoff et al., 2019).

3.1 Likert Scale

The Likert Scale classifies spaces into five categories of privacy: public, semi-public, semi-private, private, and extremely private (Yusoff et al., 2019).

Table 1: Likert Scale of Measurement for Space Syntax Analysis

Likert Scale Rating	Permeability Level	Wayfinding Level
0-2	Public	Very Easy
3-5	Semi-Public	Easy
6-8	Semi-Private	Average
9-11	Private	Difficult
12-13	Extremely Private	Very Difficult

Annotation using numerical order on spaces in the building layout indicates the users' movement order. The numerical labels are categorised into the five ranges of the Likert Scale, illustrating the level of permeability and wayfinding as shown in Table 1. The higher the ranking on the Likert Scale rating, the more private the space is and the more difficult it is for users in wayfinding.

The permeability and wayfinding study consists of three levels, which are the primary, secondary, and tertiary levels. The space with the highest percentage in hierarchy weightage would be the primary level providing the simplest access to the users.

3.2 Justified Graph

As shown in Figure 2, the justified graph portrays spaces in numerical order to indicate the depth of space within a building. The higher the numbering, the deeper the space from reach (Lee, 2020). The justified graph starts with "Root" which will be the entrance to the building, spreading into nodes that have higher depth levels and eventually connecting to the very last node in the building. The linkage shows the relationship between spaces in the building (McLane, 2013).

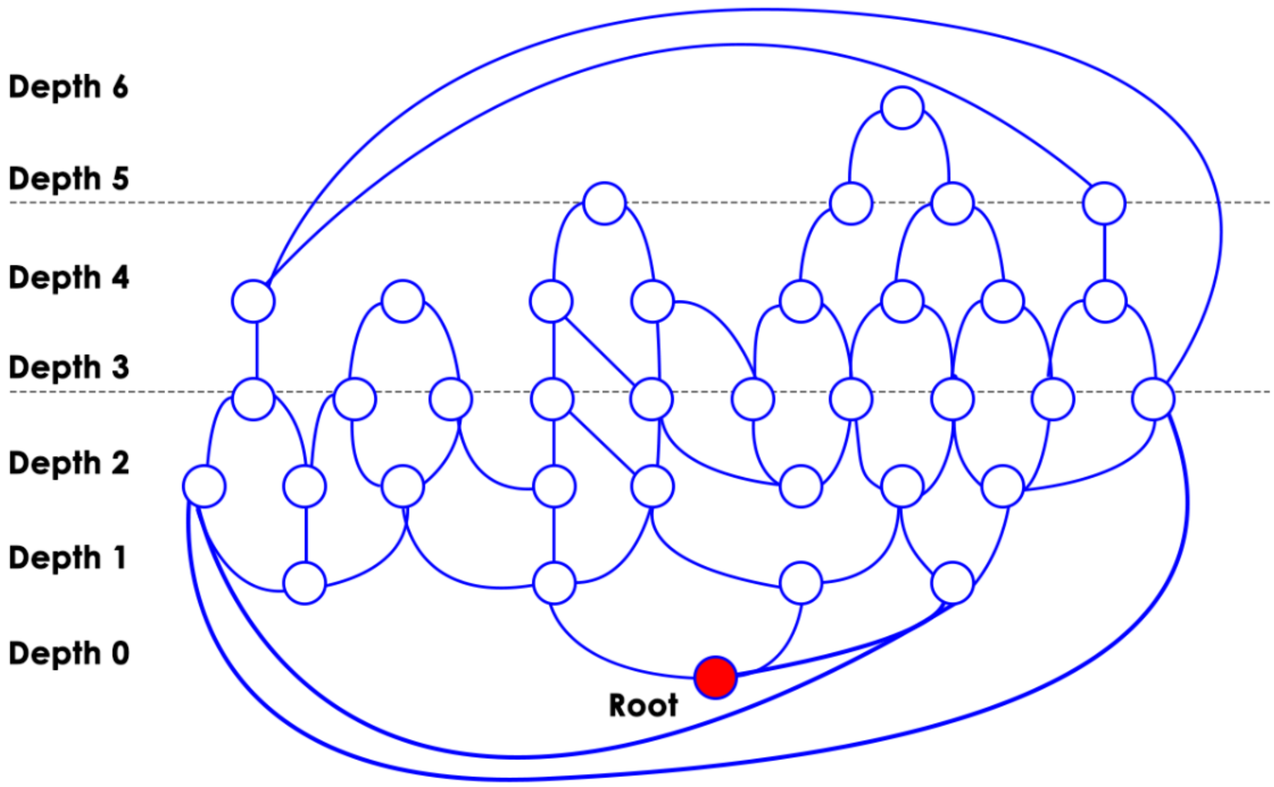

Figure 2: Justified Graph Redrawn by Author
Source: Lee (2020).

3.3 Alphanumeric System

Table 2 shows the alphanumeric system analysis done by labeling each space in the building layout using alphabets, numbers, and colours according to their functions. The hierarchy of space is determined by the numbering sequence (1,2,3 etc.).

Table 2: Categorization of Alphanumeric and Colour Based on Building Function

Function	Alphanumeric	Colour
Building Access	E (E1, E2, E3, etc.)	Yellow
Common Space	(1, 2, 3, etc.)	White
Services	S (S1, S2, S3, etc.)	Grey
Administration/ Control	C(C1, C2, C3, etc.)	Orange
Amenities	R(R1, R2, R3, etc.)	Brown
Transportation	T (T1,T2,T3, etc.)	Red
Ticketing Area	K (K1,K2,K3, etc.)	Pink
Retail	A (A1,A2,A3, etc.)	Blue

4 Result

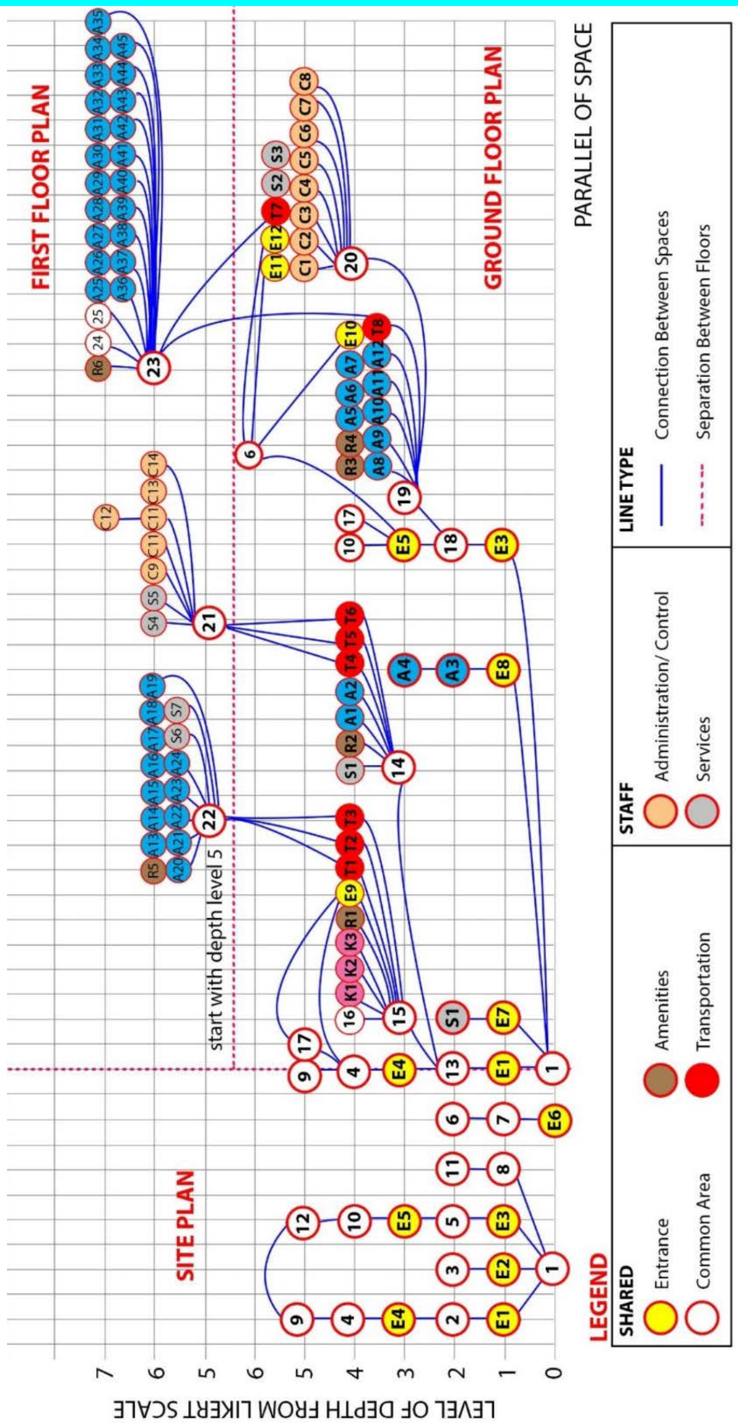

Figure 3: Overall Justified Graph for Putuo Mountain New Passenger Transportation Center

As shown in Figure 3, the overall justified graph contains three plans. For example, the site plan, ground floor plan, and first-floor plan. The pattern of the justified graph is atypical due to the double entrance from the landside and waterside. The building entrances are set on the landside while fixing the waterside as exits. The wayfinding for spaces on the first-floor plan is straightforward, as the offices are in rows, each connected by a common corridor. There is only a positive axis of depth level due to the absence of the basement level in the case study. The overall space syntax analysis portrays those visitors can only access the common shared spaces. The administrative offices are separated from the visitors by corridors and by floors. Both visitors and staffs share common areas such as station square, pontoons, wharf, entrance, amenities, and transportation.

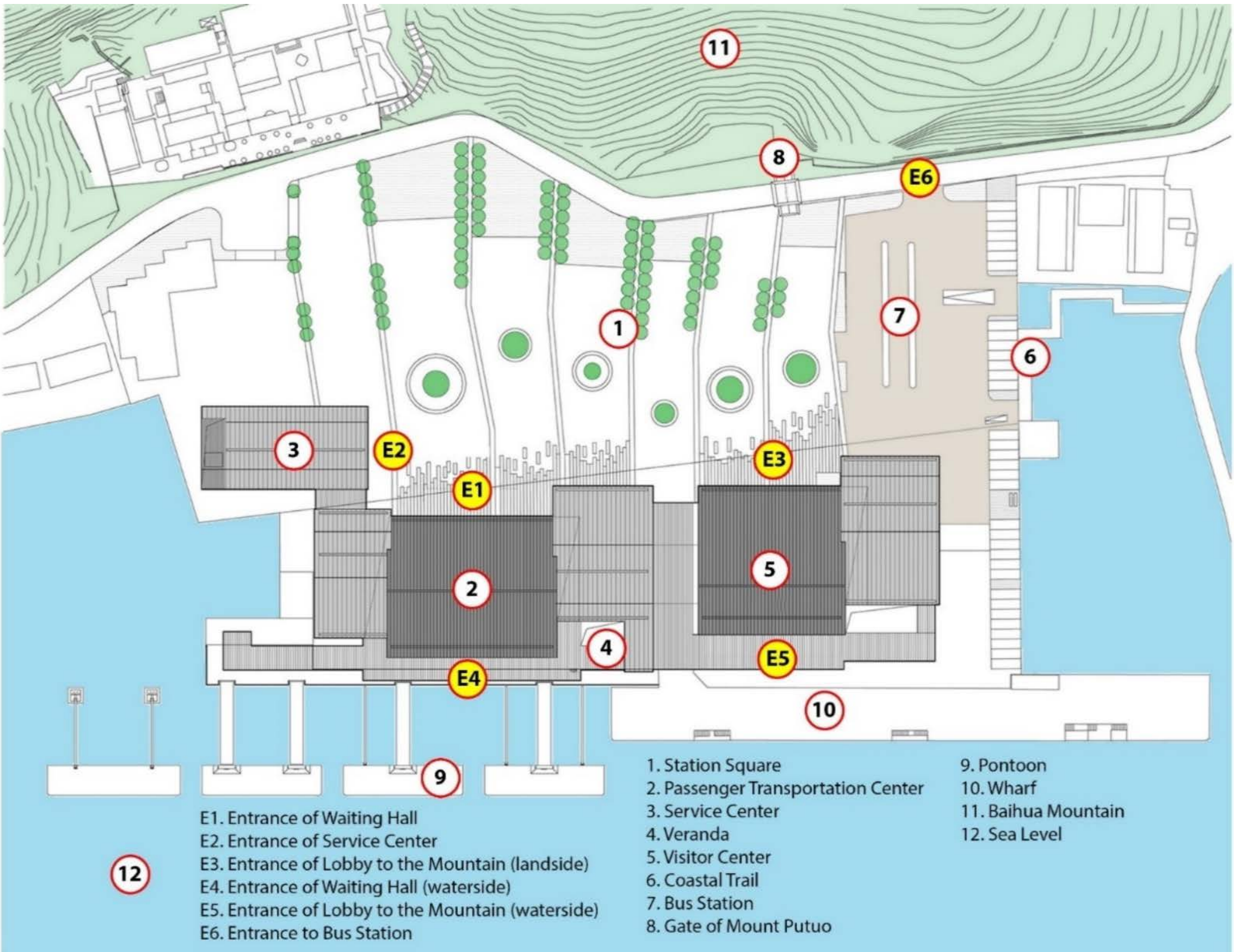

Figure 4: Site Plan with SOA

There are two categories of users, including visitors and staff. Acting as a jetty accessing Mount Putuo island; thus, instead of driving their vehicles, most visitors come to the site by the boat service offered. After having prayers at Mount Putuo, the visitors then access the Putuo Mountain New Passenger Transportation Centre by foot, leaving the island by boat service. Based on the overall justified graph (Figure 3) and Likert Scale table (Table 3), the station square (1) and entrance to the bus station (E6) are the starting points. They connect the surrounding spaces such as the entrance to the building, bus station, and the gate of Mount Putuo with different levels of permeability. The permeability level of the site plan ranges from public to semi-public. The station square (1) connects the public access to the visitor centre and passenger transportation centre with a highly permeable network with very easy wayfinding. The entrance to the bus station (E6) is the direct building access only serving the bus station (7). It is considered a public space according to the permeability level with very easy wayfinding. Despite the double frontage terminal building connecting both the landside and waterside entrances, the landside entrance is prioritised as the starting point in the justified graph, resulting in rating the sea level (12) as semi-public in the permeability level with easy wayfinding.

The majority of the level of wayfinding is rated as very easy as the station square (1) connects to the entrances accessing main terminal buildings such as the visitor center and the passenger transportation center. The waterside facilities such as the veranda, pontoon, and wharf are under easy wayfinding level. The sea level (12) has easy wayfinding despite being hidden by the terminal buildings.

Table 3: Likert Scale on Space Analysis for Site Plan

Area	Category	Depth Level	Level of Permeability	Level of Wayfinding
1	Common Space	0	Public	Very Easy
E6	Building Access	0	Public	Very Easy
E1, E2, E3	Building Access	1	Public	Very Easy
7, 8	Common Space	1	Public	Very Easy
2, 3, 5, 6, 11	Common Space	2	Public	Very Easy
E4, E5	Building Access	3	Semi-Public	Easy
4, 10	Common Space	4	Semi-Public	Easy
9	Common Space	5	Semi-Public	Easy
12	Common Space	5	Semi-Public	Easy

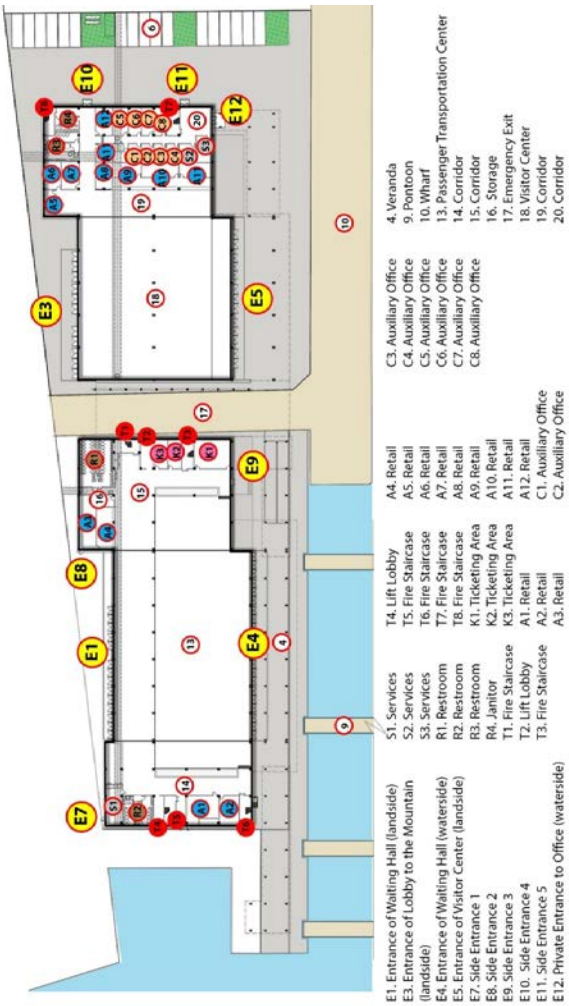

Figure 5: Ground Floor Plan with SOA

Table 4: Likert Scale on Space Analysis for Ground Floor Plan

Area	Category	Depth Level	Level of Permeability	Level of Wayfinding
1	Common Space	0	Public	Very Easy
E1, E3, E7, E8	Building Access	1	Public	Very Easy
13, 18	Common Space	2	Public	Very Easy
S1	Services	2	Public	Very Easy
A3	Retail	2	Public	Very Easy
E4, E5	Building Access	3	Semi-Public	Easy
14, 15, 19	Common Space	3	Semi-Public	Easy
A4	Retail	3	Semi-Public	Easy
4, 10,16, 17, 20	Common Space	4	Semi-Public	Easy
E9, E10	Building Access	4	Semi-Public	Easy
R1, R2, R3, R4	Amenities	4	Semi-Public	Easy
S1	Services	4	Semi-Public	Easy
T1, T2, T3, T4, T5, T6, T8	Transportation	4	Semi-Public	Easy
A1, A2, A5, A6, A7, A8, A9, A10, A11, A12	Retail	4	Semi-Public	Easy
K1, K2, K3	Ticketing Area	4	Semi-Public	Easy
9, 17	Common Space	5	Semi-Public	Easy
T7	Transportation	5	Semi-Public	Easy
E11, E12	Building Access	5	Semi-Public	Easy
S2, S3	Services	5	Semi-Public	Easy
C1, C2, C3, C4, C5, C6, C7, C8	Administration/ Control	5	Semi-Public	Easy
6	Common Space	6	Semi Private	Average

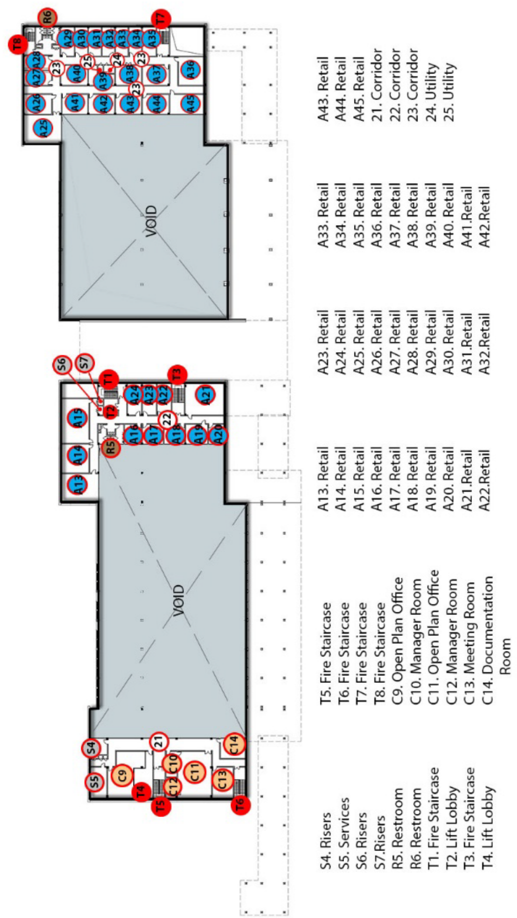

Figure 6: First Floor Plan with SOA

Based on the justified graph in figure 3, there are 6 depth levels discovered in the ground floor plan. According to the overall justified graph (Figure 3) and the Likert Scale table (Table 4), the level of permeability of the ground floor plan ranges from public to semi-private due to the typology of the building as a transportation centre.

The level of wayfinding ranges from very easy to average. The visitors are only allowed to access common spaces, retail, amenities, and some of the transportation that leads to retail on the first floor (1, E1, E3-E5, E8-E9, A3 – A12, K1-K3, T1-T3, T7-T8, R1-R4). The private auxiliary offices (C1-C8) are hidden from the public with independent accesses from (E11, E12). Transportation spaces such as fire staircase and lift lobbies for easy wayfinding instead of very easy since not all the upper floor spaces are for the public. There are also offices for staff access only.

The depth level of the first-floor plan ranges from level 5 to level 7. As shown in figure 6, the first-floor plan consists of two separate buildings, the passenger transportation center and the visitor center. Both the buildings have their first floor as retail and auxiliary offices accessed from either lift lobbies or fire staircases (T1, T2, T3, T4, T5, T6, T7).

Table 5: Likert Scale on Space Analysis for First Floor Plan

Area	Category	Depth Level	Level of Permeability	Level of Wayfinding
T1, T2, T3, T4, T5, T6, T7	Transportation	4	Semi-Public	Easy
21, 22	Common Space	5	Semi-Public	Easy
23	Common Space	6	Semi-Private	Average
R5	Amenities	6	Semi-Private	Average
S4, S5, S6, S7	Services	6	Semi-Private	Average
A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24,	Retail	6	Semi-Private	Average
C9, C10, C11, C12, C13, C14	Administration/ Control	6	Semi-Private	Average
24, 25	Common Space	7	Semi-Private	Average
R6	Services	7	Semi-Private	Average
A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45	Retail	7	Semi-Private	Average

According to the overall justified graph (Figure 3) and the Likert Scale table (Table 5), the level of permeability for public users varies from semi-public to semi-private. The public is not allowed to access the left wing of the passenger transportation centre. Nevertheless, staffs find it easy to access their working spaces as the offices (C9-C14) are arranged in rows, with each opening towards a common corridor. There is an exceptional case (C12), only accessible through (C11). The services (S4-S7) and amenities (R5) are rated at level 6 of depth, considered semi-private spaces. R6, 24, 25, A25-A45 accessible through T7 are rated at level 7 of depth as the extra partition separates T7 from the public on the ground floor.

Transportation such as lift lobbies and fire staircases (T1, T2, T3, T4, T5, T6, T7) are easily accessed and open to a common corridor (21, 22, 23) linking the rows of offices or retails. The majority of the spaces on the first floor ranked average in wayfinding level.

5 Discussion

The public route for the transportation hub illustrates a uniform spreading form graph model, where the lifts, staircases, and corridors connect to various functional spaces such as offices and retail. This idea of spatial design maximises the efficiency of users' circulation. Instead of addressing both entrances, the landside, and the waterside of the selected case study as starting points, the station square (1) at the landside is fixed as the starting point for analysis purposes. Hence, the sea level (12) is ranked at depth level 5 since the visitors enter the building from the landside. The visitors' route is clear and straightforward in the case study building, as the transportation-related activities are all programmed on the ground floor. To ensure the visitors are aware of the details on the first floor, double volume voids allow visitors to notice activities on the first floor. The offices are separated visually or physically from public access. Independent building entrances and partitions are installed on the ground floor to separate offices from retail. To separate the offices physically, they take up the first floor. Certain services (S1) on the ground floor are ranked with very easy wayfinding, as it has an independent building entrance (E7) to access the space from the external. The double-storey building results in a shallow justified graph, up to 7 levels. After considering the building as a one-way route instead of a double entrance, the justified graph form is common for most buildings.

Table 6: Number and Percentage of Spaces Based on Level of Permeability and Wayfinding

Level of Permeability and Wayfinding	Level	Spaces	Number	Percentage (%)
Public/Very Easy (0-2)	Site Plan	1, 2, 3, 5, 6, 7, 8, 11, E1, E2, E3, E6	12	
	Ground Floor Plan	E7, E8, 13, 18, S1, A3	6	
	First Floor Plan	-	0	
			18	15
Semi-Public/Easy (3- 5)	Site Plan	E4, E5, 4, 9, 10, 12	6	
	Ground Floor Plan	E9, E10, E11, E12, 14, 15, 16, 17, 19, 20, A4, R1, R2, R3, R4, S1, S2, S3, T1, T2, T3, T4, T5, T6, T7, T8, A1, A2, A5, A6, A7, A8, A9, A10, A11, A12, K1, K2, K3, C1, C2, C3, C4, C5, C6, C7, C8	47	
	First Floor Plan	21, 22	2	
			55	45
Semi-Private/Average (6-8)	Site Plan	-	0	
	Ground Floor Plan	6	1	
	First Floor Plan	A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45, 23, 24, 25, R5, R6, S4, S5, S6, S7, C9, C10, C11, C12, C13, C14	48	
			48	40
		TOTAL	121	100

*Note: *Percentage* = Number of Spaces / Total Number of Spaces x 100%

As shown in Table 6, 45% of the spaces in the transportation hub are semi-public and easy in wayfinding. Those spaces are located on the ground floor, followed by the first floor and the site plan. For instance, ticketing areas, retail, offices, staircases, and lifts. The offices are ranked easy in wayfinding and semi-public instead of private due to storey height constrain. If the case study is built higher, the offices at a higher level would be catagorised as private spaces.

40% of the spaces or 48 spaces are semi-private spaces with an average level of wayfinding. Those spaces consist of retail and offices on the first floor. Offices are built on the first floor to gain privacy. However, a double volume void design increases the exposure of the retailers on the first floor. Furthermore, the retail on the upper floor is directly accessible by lifts and staircases.

15% of the building is public space with very easy wayfinding. They are the entrances and common spaces. The layering entrances from the station square, the building entrance, and finally the exit towards the waterside have contributed to the results.

Table 7: Number and Percentage of Spaces Based on Connecting Spaces

Connecting Space	Spaces	Number	Percentage (%)
End Room	S1, A2, K1, A4, 11, S5, S7, R6, C14, A13, A25, A36, A45	13	11
Single Connecting Space	A4, 3, 6, S2, S3, R1, R2, R3, R4, K2, K3, A1, A5, A6, A7, A8, A9, A10, A11, A12, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A37, A38, A39, A40, A41, A42, A43, A44, C1, C2, C3, C4, C5, C6, C7, C8, C9, C12, C13, 16, 24 25, S4, S6, R5	66	55
Double Connecting Space	5, 7, 8, 9, 10, 12, E1, E2, E3, E5, E6, E7, E8, E9, E10, E11, E12, A3, C10	19	16
Multiple Connecting Space	1, 2, 4, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, E4, C11	15	12
Staircases	T1, T3, T5, T6, T7, T8	6	5
Elevators/ Lifts	T2, T4	2	1
	TOTAL	121	100

*Note: $Percentage$ = Number of Spaces / Total Number of Spaces x 100%

Based on Table 7, the majority of Putuo Mountain New Passenger Transportation Centre are single connecting spaces with 66 rooms, equivalent to 55%. The spaces comprise retail and offices arranged in rows connected by a common corridor. 16% of double-connecting spaces contain entrances and common spaces function to connect two spaces. 12% of the building acts as multiple connecting spaces, for instance, corridors that link to rows of offices or retail. 13 end rooms are found in the case study, making up 11% of the building. The end rooms consist of services, amenities, retail, and offices. Staircases contribute 5% of weightage while elevators take up 1% of the total building percentage.

6 Conclusion

Putuo Mountain New Passenger Transportation Centre is a well-designed transportation hub with simple spatial navigation. The visitors entering from the landside are guided by the tranquil sea view towards the ticketing area and move towards the pontoons. This visual illusion design increases the circulation efficiency of the transportation hub. Retail is introduced on both the ground and first floors to enhance the waiting experience. Services and amenities are located at the end rooms to free up space for other programs.

According to Figure 3, the overall space syntax performance of the case study is dominated by semi-public spaces with easy wayfinding, making up 45% of the total building spaces. To avoid congestion, it is reasonable to have a majority of semi-public spaces in the transportation hub. Due to the single-tenant characteristics, the retails and offices are connected by a common corridor. Hence, single-connecting spaces with a majority of 55% make up the case study.

The research mainly focuses on the effectiveness of the transportation hub based on space syntax analysis. The case study considers the two groups of users: visitors and staff, in determining wayfinding and privacy level. Individual straightforward circulation flows for both user groups are discovered. The case study allows visitors to access public to semi-public spaces while the semi-private areas such as offices and other services-related programs are hidden from them. In terms of wayfinding, straightforward spatial navigation efficiently guides the visitors to their destination. With the design of individual entrances, the private accesses are hidden from the visitors to avoid congestion, boosting the circulation flow for private personnel. The case study exposes the surrounding sea frontage as indirect guidance to navigate the visitors, resulting in the generous ground floor space to avoid blockage of view. The Covid-19 outbreak forbids travel abroad and is unavailable of having a physical visit. Hence, a site visit to Putuo Mountain New Passenger Transportation Centre is encouraged for future research.

7 Availability of Data And Material

Data can be made available by contacting the corresponding author.

8 Acknowledgement

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