INTRODUCTION

Passenger traffic hub’s main function is to ensure that every passenger can quickly, safely and comfortably reach the destination. Composition of hubs architectural space is different from the conventional passenger building’s single function which likes a bubble chart. It is characteristic of rapid transit and the transfer module tends to be independent, rapid, automated, which is a multi-faceted, multi-function, and high efficient use of space, greatly improving the utilization flexibility of space. But the difference of hubs is very large, and never could use a fixed pattern to generalize. Therefore, in the design process, applying different space-type for different transfer process is needed.

Also worth noting, interchanges in many traffic hub building are arranged underground, and the passengers’ sense of direction becomes weaker. Due to large crowds of people, passengers will not feel obviously the same as on the ground. Coupled with limited space, the underground area cannot be very big and set a large square which could be on the ground. The transfer flow could only be evacuated by space design quickly to various functional spaces. This multi-stream line mixing will make the space become relatively complicated, the flow lines appear intertwined, and the uncertainty in the running direction is quite exacerbated. So it is an effective research ideas and design methods, using the theories of space psychology and detail design to help passengers to determine the spatial characteristics and improve the transfer efficiency.

THE TRANSFER AREA FORMULA

Passenger traffic hubs are built to service people, so firstly pedestrians’ characteristics should be analyzed to determine the relative relationship of space. Firstly, the size of each pedestrian space must be determined, because the pedestrian behavior in space of transfer hub will directly affects the calculation indicators of transfer section. From the perspective of traffic subject, it will affect whether the transport space services could meet the requirements. The size of pedestrian space normally defines average area as a unit. Through the relevant traffic information, by selecting a reasonable pedestrian space as classification standard, it is possible to calculate the area and the channel width, and the width of the vertical member in the transportation hall (such as stairs and escalators, etc.). See Table 1.

During the design process, the design capacity is generally recommend in level 3. Because the characteristics of tidal flow are significant in China, so if the
design is defined as a maximum which depends on the intermittent of travel flow, it will lead to a large scale rarely seen and could be very empty in most operating time in transfer space. So it strongly recommends service level 3 which could be used in the peak period, could reach service level 2 or even level 1 in week-days.

By counting different transfer distance and the number of various transfer passengers in transfer hub’s peak-hour, combined with the relative relationship as shown in figure 1, a transfer area demand formula in transportation hub could be deduced, as follows:

\[ S = A_{(k-5)} \times \frac{P_t}{3600} \times \frac{D_{avg}}{V_0} \times K \]

\( K \) means medium and large hub adjustment factor, \( K = 0.9-1.1, V_0 \) means walking speed, \( V_0 = 1.1-1.4m/s \), \( P_t \) means total number in peak hour, and \( D_{avg} \) means the transfer average distance in hub

Of course, in reality, many building conditions of projects have been already identified, so the transfer section only could be designed to a certain size as a result of the surrounding circumstances. In this case, the feedback of passengers to light also affects the evaluation of channel experience. Many interior spaces are mainly relied on artificial lighting, interior brightness are generally proportional to the speed of identification, so the control of illumination is also very important.

3 THE MAIN TRANSFER TYPE

3.1 Linear transfer hub

In linear transfer hub, a spacious master channel is formed along the main transfer flow in and out direction. All transfer entrances are arranged along the main channel, so it is a transfer center which organizing kinds of transportation types by linear channel. Passengers could transfer into the hub, shunting through the long direction into each traffic function blocks. It could be considered that setting up a separate transfer channel between stations to provide ways to transfer different kinds of passengers. Channel design should avoid a two-way transfer, because it will disorder with the passenger transferring out of the station. As the two station halls’ spatial distance is relatively large, it will cause a longer walking distances. Linear transfer hub is quite suitable in scattered transfer function layout or joint use of old and new buildings, which main direction is clear, transfer traffic flow is normal, mainly to meet the City level transport services as small and medium hubs. Linear transfer hub is shown in Figure 1.

Shenzhen Luohu hub in China used this kind of transfer organization. The entire transfer channel leading to the port security entrance is to the main flow direction. It is a classical linear channel-type transfer center more than 400 meters. Through the transfer channel, passengers could be accessible to every entrance of railway, bus, coach, taxis and other transport modes. Interior of Shenzhen Luohu hub is shown in Figure 2.

3.2 Single-net transfer hub

Single-net transfer hub is the building organizing various traffic types in one hall, and all transfer traffic entrances are arranged in the same hall. Transfer center hall is convenient to centralize the arrangement of vertical transport, and very suitable for three-dimen-
sional, intensive transport hub. This is currently the most frequently used modes for the new hubs. Features of such transfer center are that the transfer entrance layout is more homogeneous and transfer distance is shorter. But in the medium and large transport hub, there are intensive multiple traffic types, transfer type are complex and transfer crowd is large. In this case, they tend to spend more time to find and identify the transfer direction and take a stop, which triggers a standstill at the traffic diversion and impacts the transfer efficiency seriously. In addition, although the transfer distance from the transfer center hall style is short, when complex interchanges between varieties of passenger flow are focused on a plane, it will produce more flow lines cross and reduces the transfer efficiency. So the model is not perfect, which has both advantages and disadvantages. This Single-net transfer hub is quite suitable for national special cities with intensive land development, large transfer scale, various transfer types, and the external hubs, which are located in the downtown area or important internal-city node transfer station. Single-net transfer hub is shown in Figure 3.

Figure 3. Single-net transfer hub.

Changzhou new passenger transfer hub in China used this kind of transfer organization. In transfer center, the interchange entrances way to the bus, coach, metro, parking and other traffic social are set up inside. Transfers between all modes of transportation can be completed within this hall which connecting to each traffic functions through escalators, stairs and galleries. Interior of Changzhou new passenger transfer hub is shown in Figure 4.

Figure 4. Changzhou new passenger transfer hub.

3.3 Multi-net transfer hub

Multi-net transfer hub is a combination of linear transfer hub and single-net transfer hub which has the advantage of the two transfer hubs. Large hub could set multiple transfer joint halls and interconnect to form a unified transfer hall. Whether passenger are inbound or outbound in stations, they both have to through the transfer hall and reach to the transfer point according to the guide sign and then go to the next outbound transfer platform. It reduces the transfer distance and avoids the inconvenience of passenger who carrying big bag to travel a long distance. It also increases the comfort and convenience of transfer, and reduces the number of vehicles and vertical space occupied, which increases the effective use of space; it helps controlling the width of the platform, and reducing narrow dispersion of the lined platform. Hub functional layout is composed of several waiting rooms, and is gradually developed into a centralized hall. This kind of hub is quite suitable for mega-cities with large interchanges traffic flow, complex transfer type, and requiring intensive development of land, which the mainly large hub is located in new city district or suburbs to serve railway, aviation and other external services. Multi-net transfer hub is shown in Figure 5.

Figure 5. Multi-net transfer hub.
Shanghai Hongqiao hub in China used this kind of transfer organization. Designed in accordance with the transfer amount, transfer type, mode of transportation, it divides all kinds of transportation into several groups; then organized a second traffic in each group. Transfers between different groups use hall, while those between the groups use channel connection. It could organize transfer very efficiently so as to avoid concentrating too much to brought identification difficulties and other more issues into the flow of people crossing. It could also chooses transfer mode according to the characteristics and different passenger needs, which is a more humane, reasonable and effective transfer combinations. Interior of Shanghai Hongqiao hub is shown in Figure 6.

Figure 6. Shanghai Hongqiao hub

4 PRINCIPLES OF SHUNT ARRANGEMENT

4.1 Multi-spaces entry set

Firstly it needs to provide multi-channel space and streamline for passengers. It can be divided into various forms of the main entrance, secondary entrance, and hall and so on. The main entrance needs to be arranged in the bottom of the transportation hub facing to passengers entering the main direction. If the base area allows, secondary area can be arranged at the periphery of the main entrance, and should meet the fire safety requirements. If the base area is in a tense situation, the secondary entrances can be combined with large-scale hub’s three-dimensional space measures to layout in three-dimension: entrance hall is not only a leading hall, also shunt hall, so passengers here could take two forms of diversion on the plane and space, optimizing space level, and enriching spatial modeling.

4.2 Different transfer groups shunt

Solving complex problems must be from its main aspects. Streamline design of transfer space should be firstly considered as the dispersion of large numbers of passengers. Large numbers of people need to apart with fewer crowds, and provide the main transfer flow specialized spaces and flow lines. Traffic in the city needs relatively short residence time, more transport trips and take relatively short distance which can use a relatively small channel to transfer. Railway and long-distance coach needs relatively long waiting time, which is likely to cause a certain degree of flow lines intersect and needs the use of relatively large channels to transfer. It should be sufficient to make dynamic and static flow line flow line to apart from space and time.

4.3 Recognizable streamlines

Major transfer hub is characterized of huge crowd and a variety of space crisscross, so those first-coming passengers to large-scale transport hub are easily to get lost. Therefore streamline design must be easy to identify. It can use prioritized, clear hierarchy space to locate, take advantage of shape, color, light, etc., as the direction of recognition of reference, it can also use numbers, signs and other marks as a guide. Passengers can be either indicated by position and different transfers’ whereabouts. In short, complex spatial should be concreted, visualized. Different flow lines should avoid similarity, making it easy to identify. Shunt arrangement is shown in Figure 7.

Figure 7. Shunt arrangement.

According to passenger diversion functional needs, persuading as soon as possible, it can significantly improve the efficiency of the transfer hall. Optimizing is based on passenger transfer flow and the importance which can make the following layout strategies:

A. Top density transfer interaction split vent should be priory located in the front of the transfer flow line (e.g., subway);
B. Convenient public transportation split vent should be priory located in the front of the transfer flow line (e.g., public transport);
C. City short transportation split vent should be priory located in the front of the transfer flow line (e.g., taxi).

5 TWO-DIMENSIONAL ANALYSIS OF TRANSFER SPACE

On the two-dimensional plane, the scale of transfer space design should follow the functional requirements and intensity of use. For lack of passage or lobby area, it is easy to cause congestion or even stampede. Pedestrians are impacted by the scale ratio
and thus clear the walking direction, width, height, and depth (length) of the confined space becomes very important to the designer. When space’s longitudinal aspect ratio is much larger than 1, the path line is a linear channel, which is generally based on the direction of the pedestrian walking path direction. In efficient service levels of passage or hall, the path needs to be widened, the ceiling needs to be heightened, the main channel links the main functions body to form the backbone of the network, the other secondary space is linked with a small channel network, and design way includes the sink courtyard or high atrium.

Plane processing strategy

Consider optimizing design from the plane, it generally includes edges part processing, such as channel selection line, corner, and overall length.

A. Channel lineal type: it consists of straight line and curve. In the actual design, it could be combined with each other according to the function. Psychological feeling of a straight line distance is short, which is mainly applied in important flow line. The feeling of curve walking transfer area is interesting but distant, and it is generally applicable to transfer area, which involved in the commercial area, and the increase in operating streamline detour is in order to enhance business efficiency. Therefore, these two line-types should match each other, which is not only necessary to clear the main transfer direction, but also make space design unique.

B. Corner: Many transfer area’s flow lines will be carried out due to the 90 degree or 180 degree turn, which often become congested points here and hedging point, so it should pay special attention to the corner place. One method is designing the structure to be rounded, obtuse, or more natural transition flow direction; another method is diverting into two-way by the addition of railings, separating the transfer area, and it is particularly applicable in the transformation of many projects which have been completed.

C. Total length: Through a lot of investigation and practical experience, it is more suitable to define 150-250m as the maximum of the transfer space length. For more than the value, pedestrians’ stamina will be significantly decreased, and the experience of space evaluation also began to show the corresponding negative tendencies. So if there is no escalator or pedestrian path set by the transfer area, it is generally recommended to control the transfer length within 200m. While setting automatic class facility, or the presence of three-dimensional space, the continuity of human cognition will be quick updated by new things. The passengers’ endure degree could be lengthened slightly, but it generally should be controlled within 300m. Considering that the main function of transfer hub is to transport interchanges, and pedestrian carrying a lot of heavy baggage to make a long-time commercial consumption is unlikely, it is recommended to take control of the flow line length within 300m even if the transfer area sets commercial space, and tries to increase the rest areas and landscape areas to sooth the mental fatigue of people.

6 THREE-DIMENSIONAL ANALYSIS OF TRANSFER SPACE

Three-dimensional space based on the two-dimensional plane is to consider the effects of high aspect ratio, or called cross-sectional, longitudinal. Due to human vision correction, the designer must consider the spatial distortion caused by perspective. Aesthetic theories insist that different proportions of the space feel different. D and H in 2D mode are shown in Figure 8.

In the classical book External Space Design of the Japanese scholar, Yoshinobu Ashihara, he used design analysis to propose a formula D/H to measure the sense of space adjacent buildings, where H represents the height of buildings, D represents the pitch. In his opinion, “when D/H> 1, it means a sense of keeping away; when D/H <1, it means getting close; when D/H=1, it means there is some symmetry between building height and spacing.” (See Table 2)

![Figure 8. D and H in 2D mode.](image)

<table>
<thead>
<tr>
<th>D/H</th>
<th>Lack of direction sense</th>
<th>No pressure</th>
</tr>
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<tbody>
<tr>
<td>&gt;4</td>
<td>Free walking direction</td>
<td>Comfort space</td>
</tr>
<tr>
<td>2</td>
<td>Walking regularly</td>
<td>Compact space</td>
</tr>
<tr>
<td>1</td>
<td>Walking direction</td>
<td>Strong sense of oppression</td>
</tr>
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Yoshinobu Ashihara’s outside space concept is also applies on the transfer space inside. When the distance between both sides of the channel wall is narrow, pedestrians’ feeling becomes oppressive, and the walking turns to be urgent and uncomfortable. As the distance between the two walls increases, people will feel more and more comfortable. But when it is beyond a certain distance, a sense of direction began to weaken. People began to feel the sense of urgency space, the reason for this fluctuation is that the space shapes influence psychological sense of proportion. At the same time, high aspect ratio of passage or hall also has additional effects on the psychological feelings, when the aspect ratio is fixed, the longer the length is, the worse the feeling is. When the length is fixed, the
bigger the aspect ratio is, the worse the feeling is. So co-ordination of the three dimensions is very important and designer can use a psychological comfort index \( F \) to measure the evaluation of three-dimensional design.

\[
F = d \times \frac{D}{H \times L}
\]

\((H / D)\) is the aspect ratio of the space, \( L \) is the length of the space and \( d \) is the correction factor. \( H \) and \( D \) in 3D mode are shown in Figure 9.

Comfort index correction factor is mainly affected by the following aspects: First, it’s greatly influenced by internal light. Strong lighting could improve a higher degree of comfort, while weak lighting cause a lesser degree of comfort, so designers have to control the distribution of internal light, and try to select a proper light illumination which people feel comfortable. Second, the internal wall material also has a great impact. In general, the use of relatively hard material, such as fair-faced concrete or stone, could give people a feeling of exclusion, while the choice of some colors soft material relatively, for example, wood or glass, could give people a feeling of large space, thereby improving passengers’ comfort. Evaluation varies between 1-3, the higher the evaluation is, the higher the correction factor value of \( d \) is.

In actual projects, the height of interior space couldn’t vary in large scope which the basic value between 3.6-6m. However, if the transfer area is set just based on transfer function, passengers will feel bad. In Chinese scholar Peng Yigang’s classical book *Combination of Space Theory*, he proposed a concept of relative height. It is suggested that the wide space should be changed into several small spaces as far as possible which should be suitable for the human scale relatively. Transfer hall is the main space used by pedestrian, so it is an effective method to change large unbalanced spatial scales into several small one by using internal colonnades and roof to separate the interior space.

The change of space level is a more effective method of internal transformation. In the transformation of Shanghai People’s Square subway station, the original underground space was very boring, but by setting dormer it obviously improved passengers’ feeling of underground space. The method of space shift made use of increasing a virtual height of overall underground space. In another way, designers can also use a strategy of moving the space down. Through the communication with each other to form a large space between the layers, introducing some vertical transportation facilities to create an internal atrium, this kind of strategy is use of the increasing actual height of underground space. A virtual height of overall underground space is shown in Figure 10.

The change of space decoration is also an effective way to improve comfort of space. In many cases which civil engineering has been completed, designers cannot change spaces through the transformation of original structure, but could only use interior renovation to make spatial change. It is supposed to increase ceiling height or make partial sink, form a non-continuous state of space. For example, by changing the rhythm of ceiling system design, passengers could be guided effectively in traffic flow lines, or by conceiving in floor design, making use of pattern or color to certain passengers’ transfer orientation.

Figure 9. H and D in 3D mode.

Figure 10. A virtual height of overall underground space.

7 CONCLUSION

Transfer space design is not only a complex systems engineering, but also relates with many other things closely. Through summarizing the combination of transfer types, it could certain the design strategy of hubs’ main space. By increasing the hub’s capability of gathering and evacuating flow, the transfer time could be reduced for passengers who need a fast, convenient, comfortable and safe environment. If the hubs could provide a good transport environment and development environment, ultimately urban external passenger traffic systems will show an optimum effectiveness and efficiency.

Meanwhile, in the view of the space geometry, by changing the height, length and depth of the space, could indeed affect the feeling of passengers in hubs.
Through analyzing the human behavior psychology, it is necessary to sort out the transfer spatial section. Considering people-oriented is the future design trend, the architect should balance hub design under a limited conditions. This paper tries to provide some proposal from an architectural perspective.

REFERENCES


