Strategies for Improving Space Utilization Efficiency in Subway

Jiawen Li *

College of Design and Art, Lanzhou University of Technology, Lanzhou, China

* Corresponding Author Email: 222081300001@lut.edu.cn

Abstract. As subways have become more widely used, attention has turned to the experience of subway station spaces. Given their role in absorbing and transferring passengers, improving the efficiency and suitability of these spaces is crucial. Unfortunately, there are still deficiencies in the design of many domestic subway stations, particularly older ones, filled by issues like congestion, outdated facilities, and poor security. This paper aims to explore strategies for enhancing subway station space efficiency and passenger satisfaction by analyzing security, accessibility, entrance/exit placement, and flow line arrangement. By doing so, this research will offer guidance for designing and renovating subway stations.

Keywords: Subway station space efficiencies; subway station safety; subway station flow layout.

1. Introduction

With the ongoing urbanization and the subsequent rise in urban population, the development of subways has accelerated, making them a prevalent mode of transportation. This trend underscores the significance of this research, which focuses on enhancing the efficiency and suitability of subway station spaces [1] [2]. People rely on the subway as a cheap, efficient, and convenient way to get around on a daily basis. As the hub of subway transfer and operation, the subway station is the most frequently used space. The efficiency of subway station space often affects the passenger experience and commuting efficiency. There are also health and safety risks due to the large number of people who often gather there. Therefore, improving the suitability of subway station space is also conducive to improving the efficiency of subway station use.

However, with the reality of social and economic development and population expansion, the problems of urban rail transit are gradually exposed. For example, the rail transportation capacity is insufficient, the facilities are old, the transfer station is facing congestion and there are other problems. In turn, it also exposed the existence of subway station deficiencies. For example, crowded, imperfect infrastructure, poor safety performance, a lack of humanized facilities and poor air quality and so on. Especially in some old subway stations, the above problems are more serious. The above issues need to be improved with the upgrading and remodeling of subway stations worldwide. Through research and observation, this paper identifies shortcomings in the subway station space. From the security point of view, design point of view, and space flow arrangement point of view to explore ways to improve the subway station space use efficiency strategy. In order to guide the upgrading and remodeling of subway stations.

2. Increased Safety

The subway is an integral part of urban infrastructure. The design of subway station space should be closely related to the residents' lives and urban culture. At the same time, the subway station space should meet the basic conditions of "comfort, aesthetics, and safety." Improving safety can create an orderly and smooth space environment, which is very helpful in improving the overall efficiency of the station space.

2.1. Quality of the Spatial Visual Environment

The quality of the visual environment is defined as an ability to stimulate positive feelings (satisfaction, interest, etc.) or negative feelings (dissatisfaction, antipathy, distance, etc.). Subway

stations tend to be spaces where passengers are bored or irritated. Narrow passageways, single colors, dim lighting, and low ceilings underground often accompany such spaces. An excellent visual environment can improve people's lousy mood when using subway station spaces [3].

2.1.1. Width of passageway

The width of the passageway affects the evacuation capacity of the station. When facing a surge in passenger flow, a narrow corridor will also lead to crowding, resulting in great safety hazards. The widening of the passageway can reduce the impact of claustrophobic space on the human psyche. It can improve passengers' trust and sense of security. Therefore, widening the corridor is very necessary. Through the calculation of passenger flow, vehicle capacity, and station occupancy capacity. Calculations should be performed carefully to avoid over-widening the corridor and wasting space.

2.1.2. Color

Color selection in subway stations will have a certain degree of impact on the human psyche. Research results show that when the saturation of 48 % ~ 60 %, the brightness of 52 % ~ 68 %, or hues of orange, yellow, and green, people's visual experience is more comfortable [4]. The same applies to subway stations. Some of the overly bright billboards and colors will irritate passengers. Soft colors will ease the sense of depression brought about by people who have been underground for a long time.

2.1.3. Light environment

Most subway stations are located underground. Therefore, most subway stations use artificial lighting. Excessive fluorescent lights will cause glares, while dim lights will make people lose their sense of security. Inappropriate lighting is an issue to be concerned about. On the one hand, the passenger's spatial experience will be affected. On the other hand, it will also undermine the overall security of space [5]. At the same time, natural lighting can be used as much as possible to eliminate the insecurity caused by closed spaces. For example, sunken plazas, sunken courtyards, and other forms of natural lighting can provide a better experience of the space-light environment.

2.1.4. Ceiling height

The height of a ceiling can greatly influence the overall ambiance and comfort of a space. Our daily experiences allow us to perceive how a space feels, and if the ceiling is too low, it can create a sense of melancholy. This can have negative impacts on both our physical and mental well-being, leading to emotional instability. Conversely, a spacious and open environment can promote comfort and enable people to express themselves freely. Such an environment can also provide a sense of psychological and physiological satisfaction.

2.2. Spatial Clarity

Subway station space mainly contains entrances and exits, waiting halls, stairs, escalators, and so on. Such spaces often have complexity. The complexity of the underground space reduces people’s ability to recognize the things around them, resulting in a sense of loss and unease. This often harms the human psyche. Therefore, it is necessary to strengthen the clarity of the circulation system at subway stations [6].

Highly visible graphic components can be placed at station entrances and exits or in important transportation junctions. These graphics can attract passengers' attention and serve as way-finding cues. These graphics can also brighten passengers' mood while they are in a closed and depressing environment. A good example is the Danish NORREPORT subway station. Architectural sketches, urban furniture, and vegetation landscapes decorate the station’s entrance. The stations complement the surrounding public places and become a strong cultural hub of the city.

2.3. Ventilation and Smoke Control

Nowadays, with the continuous development of society, the subway passenger traffic surge and limited railroad transportation facilities lead to the deterioration of the spatial environment of the subway station. Especially during peak traffic hours. For example, in Beijing and Shanghai, daily subway traffic exceeded 10 million passengers. There are potential health and safety risks in narrow and closed underground spaces, such as subway stations. Viruses and pathogens are easily spread. Therefore, ventilation is an important component when optimizing the physical environment of subway stations [7].

On the one hand, ventilation helps improve the environment of subway stations from a public health point of view. Ventilation plays a crucial role in regulating room temperature and humidity while also removing harmful particles from the air. It is particularly important in high-density areas such as subway stations. By analyzing outdoor wind pressure and resistance within the station, the optimal location for vents can be determined, leading to more effective natural ventilation. These measures contribute to a healthier and more comfortable environment for people [8]. On the other hand, ventilation may exacerbate the spread of smoke if it is not designed appropriately. Subway stations are complex and closed environments. The ventilation system needs to be studied carefully. This is not only to effectively reduce the concentration of pollutants but also to avoid the risk of spreading fire and smoke.

2.4. Comprehensive Considerations for Enhancing Subway Safety

Regarding safety enhancement, it is necessary to combine the width of the passageway, lighting, color, building materials, roof height, and other factors in the subway station to jointly create a pleasant spatial atmosphere. Spatial clarity should also be considered. So that passengers will not be confused by the complex spatial relationship when using the closed underground space. The impact of ventilation system design on ground subway stations should be more fully considered.

3. Sensible design

In the process of subway station design, designers can create a good spatial experience through rational design. For example, it is necessary to consider the connectivity of the entrance and exit of the subway station and the urban environment. As well as the convenience of the interior space of the subway station. Through this design, we can ensure that people are in a comfortable and convenient environment for efficient commuting.

3.1. Entrance and Exit and the Connection of the Urban Environment

The choice of the location of subway station entrances and exits is crucial. Most of the buildings in Chinese cities are centralized and closed. For example, many residences, schools, and office buildings are surrounded by walls. The flow of people in this part of the city is also very dense, and the flow of people is concentrated at the entrances and exits of these areas. Therefore, the accessibility of the subway station entrances should be considered when setting up the entrances and exits of the subway station in order to reach people in crowded areas. Too long a walking distance may reduce people's willingness to use this mode of transportation. Being too close to crowded areas may affect the evacuation.

On the one hand, the relationship with urban public facilities should be considered. Data integration and analysis can be used to determine the direction of pedestrian flow. Special attention should be paid to public buildings with high pedestrian flow. Such as large shopping malls, train stations, office buildings, etc. In the choice of subway station entrance and exit locations, it is also necessary to consider the location of urban roads, urban squares, sidewalks, and green spaces. The entrances and exits are set at reasonable spatial nodes [9]. On the other hand, the connection with urban public transportation should be considered. For example, walking transfers, bicycle transfers, bus transfers, cab transfers, and so on.

The subway, a large-scale and widely used infrastructure, is one of the most important and complicated parts of urban construction. The subway station entrance design should part of the cityscape. The city's sustainable development should be fully considered. The role of urban rail transportation should be fully embraced. The overall organic development of the city should be promoted.

3.2. Convenience and Accessibility of indoor Space

3.2.1. Establish barrier-free facilities

In the subway station, the human-cantered design can make the indoor space more convenient and accessible. Such a design can often enhance spatial comfort and spatial efficiency. Barrier-free facilities should be set up in subway stations. These include tactile paving paths for visually impaired people, handrails, wheelchair ramps, elevators, etc. It is convenient for passengers with mobility issues to enter and exit the station and ride the train. In a recent observation of subway stations in China, the author noticed that the blind passage in the subway station is designed to allow visually impaired individuals to navigate safely. Tactile paving paths are arranged strategically at the gates, elevators, stairs, and platforms, providing clear direction for visually impaired individuals to get on and off the train and exit the station. Additionally, the width of the subway gates has been increased to make them more accessible for individuals using wheelchairs. (Figures 1).



Fig 1. Design of blind alleys in subway stations. (Images from the author's self-timer).

3.2.2. Installation of escalators and vertical elevators

Equipping the station with escalators and vertical elevators can facilitate passengers entering and exiting the station more quickly. It can also reduce the inconvenience of carrying large luggage for people with disabilities. Many old subway stations, such as Beijing Subway Line 2, are not equipped with escalators and vertical elevators. Passengers are often congested at the stairway, and a large number of passengers with luggage have a hard time walking on the stairs.

3.2.3. Signage system in subway stations

Equipping the station with escalators and vertical elevators can facilitate passengers entering and exiting the station more quickly. It can also reduce the inconvenience of carrying large luggage for people with disabilities. Many old subway stations, such as Beijing Subway Line 2, are not equipped with escalators and vertical elevators. Passengers are often congested at the stairway, and a large number of passengers with luggage have a hard time walking on the stairs.

3.2.4. Public space design

The subway station should set up a public space as a buffer zone. Humanization and comfort should also be considered in the design of public spaces. Some artistic decorations, green plants, rest areas, etc., can be set up to create a pleasant and cozy atmosphere. Let the passengers enjoy a wonderful experience while traveling.

3.3. Comprehensive Consideration for Optimizing Subway Design

Thoughtful design can create a good spatial experience in the subway station. The connection between the entrances and the city connects the urban space on the one hand. On the other hand, it is important to consider the transfer needs of passengers leaving the subway station. The transformation

of space by design is also reflected in the impact on spatial convenience and accessibility. The interior space's quality is enhanced by installing barrier-free facilities, elevators, and clear signage systems.

4. Sensible Circulation

4.1. Reasonable Division

Subway station areas can be categorized into paid and non-paid areas. The paid area refers to the exhibition hall level and the platform level leading to the train platform. A non-paid area refers to the area of the municipal underground passage. Reasonable division of the two areas, combined with the different needs of users, will improve the efficiency of the subway station.

4.1.1. Paid area

(1) Subway ride: the flow line from the showroom to the platform should consider the quickness. Therefore, it can be equipped with 2 to 3 sets of transportation boxes (2 escalators and 1 vertical elevator), which are placed at both ends of the station hall and in the middle. Passengers can enter the platform from both ends according to the direction of entering the station. Passengers leaving the station can leave the platform from the stairs and elevator in the middle. Realize the reasonable diversion of the crowd.

(2) Subway transfer: as far as the subway system is concerned, the transfer station often has a large flow of people and complex lines. Therefore, the operational efficiency of the system depends largely on the safety of its passengers in these transfer stations, and on comfortable and fast transfers. At present, the main reasons leading to the inefficiency of the interchange stations are shorter distances between platforms, poor connection between old and new stations, long transfer corridors, etc [10].

The subway interchange is divided into parallel interchanges and T-shaped interchanges. Parallel transfer refers to the same platform or building (escalator) and public hall level, completed between the different lines of the transfer. These lines of the platform are parallel to each other. Different interchange stations can share the same vertical elevator, or additional direct elevators can be installed to enhance interchange efficiency. T-shaped interchanges are interchanges between two stations that intersect at the top and bottom, with the end of one station connecting to the middle of the other. For such a transfer mode, you can also consider setting up a special transfer channel and transfer hall. For example, The Fuitian Station in the Shenzhen subway system, hasparallel elevatorsset up in the transfer channel to achieve rapid transfer.

4.1.2. Non-payment area

The non-paying area refers to the space in front of the ticket gate from the ground entrance and exit through the channel down to the station hall after security checks until the ticket gate. This area often plays a role in the underground through the two ends of the street and can be used as a cross-street underpass. The non-pay zone is often connected to the entrance,and the flow should not overlap with the passenger flow. Therefore, it is important to ensure the continuity of the space to ensure fast pedestrian flow. At the same time, the non-payment area should also take into account the nature of commercial and public welfare. For example, set up coffee shops, convenience stores or simple food restaurants. Therefore, it is necessary to ensure that this part of the space is separated from the passenger space.

4.2. Crowd Gathering and Evacuation

As an important hub of urban transportation, the subway is often accompanied by a large number of people gathered. Especially during rush hours or holidays. The evacuation of large crowds presents a significant challenge to the space. The crowd can be evacuated through the location of the gate arrangement, the building elevator diversion and the setting of fast channel.

4.2.1. Diversion of gates in and out of stations

The gate is one of the areas where crowd congestion is severe. To solve this crowded situation, the gate width can be adjusted appropriately. For example, Shanghai Metro Hongqiao Terminal 1 station has added multiple extra-wide gates and passenger aisles.to facilitate the passing of passengers carrying large luggage, improve the speed of entering and exiting the station, and reduce congestion. At the same time, by moving the gates, it can also quickly disperse the flow of people. Arrange the inbound gates away from the entrance and the outbound gates near the entrance. Inbound passengers reserve enough buffer space but also guide outbound passengers to quickly leave the station [11].In addition, two-way gates can also be added. For example, the Shanghai subway has Yuyuan Station. According to the flow of people to flexibly adjust the direction of the gate, the crowd evacuation degree greatly improved. Under normal working conditions, the gate capacity of No. 1 increased by 57%, No. 6 and No. 7 inbound capacity increased by 54%, and No. 5 outbound capacity increased by 37%.

4.2.2. Special channel diversion

The security checkpoint is another area with severe crowd congestion. It is possible to reduce unnecessary waiting time by setting up two channels, "with a bag" and "without a bag." Set up a manual channel next to the information desk for free rides and special needs passengers. This part of the crowd can quickly enter the station through the exclusive channel, reducing the pressure of security checks into the station area. For example, Xi'an Subway Xiaozhai Station is one of the busiest subway stations in Xi'an. The flow of people is well organized through the sensible diversion of people at the security checkpoint. At the same time, this subway station will also set up a back-shaped queuing bar in front of the security checkpoint, avoiding congestion in the queue (Figure 2).

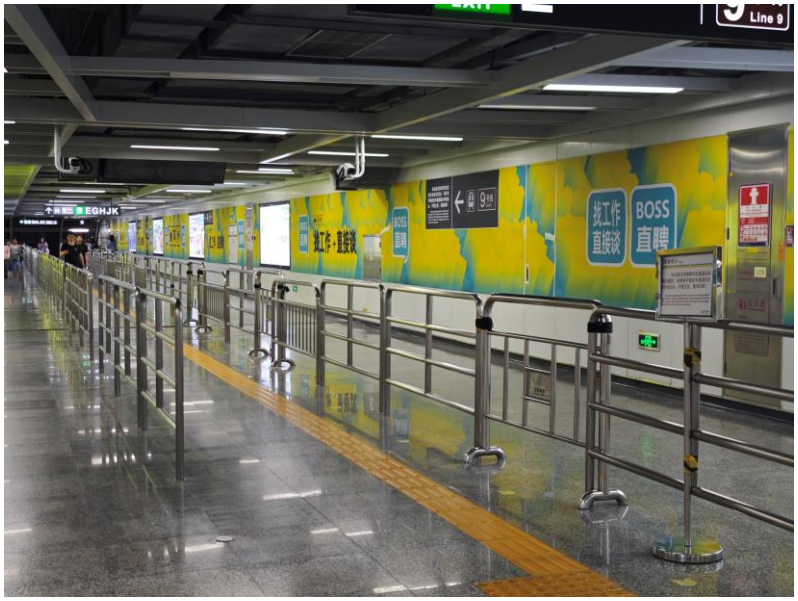


Fig 2. Returning queuing barriers in front of security checkpoints. (Images from the author's self-timer).

5. Summary

This paper analyzes the deficiencies in subway station space. It also introduces the strategy to increase the efficiency of subway station space by improving space safety, rationalizing design, and enhancing space flow. The subway station space has a large flow of people and is located in the underground. The design should fully consider the relationship between the user's psychology and the reality of the use of demand. The use of scientific and technological means to continuously improve and optimize the efficiency of subway station space. At the same time, focus on demand-based, passenger-centered urban platforms to promote their spatial design accessibility, comfort, and

specialization. Not onlyto enhance the passenger experience but also to create a better standard of urban life. However, the design of China's subway stations is gradually becoming homogenized, and the uniform design does not take into account the different environments and needs of different uses. Whether it is possible to increase the richness and interestingness of subway station space while pursuing efficiency and economy of use remains to be further discussed and researched.

References

[1] Xu, H.; Jiao, L.; Chen, S.; Deng, M.; Shen, N. An innovative approach to determining high-risk nodes in a complex urban rail transit station: A perspective of promoting urban sustainability. Sustainability 2018, 10, 2456. [CrossRef]

[2] Newman, P.W.G.; Kenworthy, J.R. The land use-transport connection: An overview. Land Use Policy 1996, 13, 1–22. [CrossRef]

[3] Aghajani S, Shahhosseini H. The relationship between visual preferences of passengers in subway stations and the interior design of their space; case study: Tabriz subway stations [J]. Armanshahr Architecture & Urban Development, 2021, 13(33): 15-26.

[4] Zhang L, Li X, Li C, et al. Research on visual comfort of color environment based on the eye-tracking method in subway space [J]. Journal of Building Engineering, 2022, 59: 105138.

[5] Burnett J, Pang A Y. Design and performance of pedestrian subway lighting systems [J]. Tunnelling and underground space technology, 2004, 19(6): 619-628.

[6] Junjun Jiang. Analysis of the impact of spatial environment design on passenger psychology in subway stations [J]. Urban Rail Transportation Research,2023,26(12):309-310.

[7] Wen Y, Leng J, Shen X, et al. Environmental and health effects of ventilation in subway stations: a literature review [J]. International journal of environmental research and public health, 2020, 17(3): 1084.

[8] Liu Y, Hu Y, Xiao Y, et al. Effects of different types of entrances on natural ventilation in a subway station [J]. Tunnelling and Underground Space Technology, 2020, 105: 103578.

[9] Lahoorpoor B, Levinson D M. Catchment if you can: The effect of station entrance and exit locations on accessibility [J]. Journal of Transport Geography, 2020, 82: 102556.

[10] Lahoorpoor B, Levinson D M. Catchment if you can: The effect of station entrance and exit locations on accessibility [J]. Journal of Transport Geography, 2020, 82: 102556.

[11] Kim C, Kim S W, Kang H J, et al. What makes urban transportation efficient? Evidence from subway transfer stations in Korea[J]. Sustainability, 2017, 9(11): 2054.