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Human-based Urban Underground Spaces Future Improvement

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Abstract: Supercities around the world concentrated on urban underground space (UUS) development and utilization as a solution to urban expansion issues. However, engineering and construction studies are far more prevalent than in other UUS fields. The underground has become an integral part of contemporary urban life, and an increasing number of people will be forced to coexist with it in the foreseeable future. Therefore, human-centered UUS strategies must be strengthened. The paper explores the development of UUS utilization in recent years by comparing Tokyo, Singapore, Boston, and China. It then examines the psychologically influential factors of human-based UUS development and utilization, including physiological needs, security needs, and affection needs, and suggests future UUS development based on the human-based underground space enhancement theory.

Keywords: human psychology, urban underground space, UUS future improvement, Maslow 's hierarchy of needs

1. Introduction

According to the Chinese Urban Underground Space Development and Utilization 13th Five-year Plan (2014-2020) [1], the government plans to complete 50 percent of the examination and certification of Chinese urban underground space planning. Moreover, numerous well-known underground utilization cases, such as the London and New York metro systems, the underground cities of Montreal and Toronto, the Paris underground expressway, and the underground shopping plaza in Tokyo, demonstrate the dramatic advantages of urban underground space (UUS) utilization in present and future cities [2]. Due to the rapidly expanding economy and population, urban land resources are limited in contemporary society, and the development of urban subterranean spaces becomes a crucial direction for future cities.

In recent years, human-based subterranean spatial quality and experience have been cumulatively emphasized in light of the UUS's accelerating growth. On Web of Science and Ei Village, research is conducted on the primary topic of underground space psychology. The results demonstrated that the psychological impact of subterranean space has increased over the past five years. In contrast to other engineering disciplines, the total number of literature records in underground space psychology remains minimal.

This paper will analyze the development of UUS utilization in recent years by comparing Tokyo, Singapore, Boston, and China. It will then analyze psychologically influential factors of human-based UUS development and utilization from physiological needs, security needs, and affection needs, and

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it will make systemic recommendations for future UUS development based on the human-based underground space improvement theory.

2. General Status Analysis of Underground Space

The development of urban planning theory and urban construction technology has accelerated in recent decades. Numerous developed nations and cities around the world had adopted a vertical mode of urban expansion to address urban expansion issues such as land use limitations, rapid population growth, and traffic congestion, etc. Here are a number of examples of current UUS strategies and applications in various cities. Subway, subterranean city complex, underground transmission and transformation project, artificial underground pipeline project, and deep underground development projects comprise Tokyo's multifunctional underground space utilization [3]. In recent years, the Japanese government has begun to enact regulations regarding the development of subterranean public space deeper than 50 meters and the deep UUS utilization beneath private land [4]. In addition, Singapore is among the nations with the greatest land-use pressure. Until 2021, Singapore's population will occupy only 714 km2 of land [5], and it will increase by 18% to 25% by 2030 [6]. Singapore financed the subterranean spaces master plan working group in 2007 and improved UUS utilization as part of its national long-term development strategy to address land-use issues [7]. And in 2015, the government of Singapore passed the Land Acquisition Act, allowing the government to acquire deep subterranean space beneath privately owned land [7]. In addition, there was extreme traffic congestion in Boston during the 1990s, with daily commute times exceeding 10 hours. Boston's government constructed underground 8-10 lanes to replace the surface roadways, which reduced commute times by over 62% [8].

The Three Centers and Three Axes are the central strategy for UUS development and utilization in contemporary China. In this strategy, the Three Centers refer to the Beijing-Tianjin-Hebei (BTH), Yangtze River Delta (YRD), and Pearl River Delta (PRD) metropolitan areas [9]. The Three Axes symbolize the East-coast Axe, the Yangtze River Axe, and the Beijing-Guangzhou line Axe. From 2015 to 2020, the UUS developed acreage in seven Chinese cities, including Shanghai, Guangzhou, and Shenzhen, increased by more than 2 million m2; 13 cities, including Beijing, Tianjin, Nanjing, and Xiamen, increased by 0.5 million m2; Xi'an, Chongqing, Zhengzhou, Taiyuan, and Zhuhai increased by 0.5 to 1 million m2 [10]. Different cities in different countries have different strategies and focuses for UUS development and utilization, but all of these examples demonstrate that underground space will be continued and developed over the long term to solve urban and land-use issues in the future, which means that humans will live primarily in underground space. However, the majority of UUS development and utilization research and strategies are focused on engineering and technology, and human-centered and psychology-based subsurface research is limited. Therefore, increasing UUS development and utilization strategies based on humans will be crucial for human welfare in future urbanism.

3. Psychological Influential Factors of Human-based UUS Development and Utilization

The psychological influence is essential for the future human-centered development of underground space. This section will examine psychologically influential factors in the development and utilization of human-based UUS. The psychological requirements of UUS spatial behavior can be divided into three stages based on Abraham Maslow's hierarchy of needs [11-12]: physiological needs, security needs, and affection needs. On the basis of these three stages, a hierarchical structure can be constructed (Table 1).

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Table 1: The psychological needs of UUS spatial element.

Hierarchy of needs	Specific needs	Spatial elements
Primary demand	Physiological needs	Light, Air, Sound
Intermediate demand	Security needs	Spatial recognition, Disaster prevention
Advanced demand	Affection needs	Aesthetic improvement, Landscape & greenery

3.1 Physiological Needs

Physiological needs are the foundation and primary need in UUS spatial behavior; the gratification of primary needs will directly influence the satisfaction of other hierarchical needs [11]. According to current research, the most influential factors on the physiological components of UUS are light, air, and sound [12-14].

Light. The inability to open windows in subterranean spaces will induce a feeling of being out of control, a crucial psychological factor that affects human psychological and physiological health [15-18]. The lighting system can accommodate the visual needs of subterranean visitors, which is one of the most fundamental requirements. According to Mao and Jiang [12-13], various types of underground space should utilize different lighting systems, with natural and artificial light being the most common lighting sources. Natural light can enhance the psychological needs of humans, which include the sensation of sunlight, the sense of spatial direction, the sense of day and night, and the sense of seasonal alternatives [15]. In order to reduce human psychological depression, it is beneficial to increase natural light usage [13].

Since natural light is limited in most subterranean environments, artificial light is the predominant source of illumination in UUS [13]. To reduce human psychological depression in subterranean spaces, artificial light should most closely mimic natural light in terms of illumination intensity, color, temperature, and visual perception [16]. According to research by You Lv, the minimum color temperature of artificial light that eliminates psychological depression in subterranean spaces should be above 4000k, and the lumen should not exceed 3500Lm [17].

Air (Ventilation). Lee et al. and Lundberg et al. found that most underground spaces lack the appropriate conditions to open apertures for ventilation [18-19], which contributes to the lack of perceived control. In addition, the majority of subterranean spaces are confined, resulting in an increasing concentration of CO2 and TVOC (Total Volatile Organic Compounds), which contribute directly to psychological discomfort and vertigo symptoms [20]. In a previous study, it was determined that a change in underground space's microclimate will cause humans to have various synthesis reactions, such as a low anion environment increasing human feelings of depression, weakness, and neurasthenia [12, 21]. The artificial production of anions will significantly mitigate the negative effects of underground space on human mental and physical health [22]. In addition to stabilizing temperature, humidity, and wind speed, an appropriate atmosphere will be created [16].

Sound. Compared to light and air, sound has a relatively smaller impact on the mental and physical health of humans [14]. However, noise pollution continues to have numerous passive effects on human health, including insomnia, cognitive disorders, hypertension, ischemic heart disease, and irritability disorders, among others [23]. Current research indicates a positive correlation between sound comfort and indoor environment, and a negative correlation between interior environment comfort and noise comfort [24]. In order to provide a comfortable acoustic environment in an underground space, noise levels should not exceed 84-85 decibels [23]. In addition to creating white

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noise, designers can also create cascades, fountains, public broadcasting systems, and background music [12-13].

3.2 Security Needs

After the primary requirements are met, it is necessary to meet security needs in order to reduce feelings of fear, unease, and nervousness in underground space. This section will focus primarily on two aspects: spatial recognition and disaster prevention.

Spatial recognition. Underground spaces are typically enclosed and confined, making it difficult for visitors to locate spatial landmarks. The lack of landmarks directly interrupted navigation, resulting in a diminished sense of control [19]. In emergency situations, such as a fire or a tremor, the deterioration of navigational skills interrupts individual information processing [25]. Therefore, the design of UUS's landmarks is essential for minimizing the feeling of disorientation felt by individuals. There are numerous design elements that can serve as landmarks within UUS planning, including paths, borders, entrances, and transitions between underground space and ground surface. Even a purely aesthetic or visual landmark can provide a sense of security [19]. In addition, a comprehensive and systemic signage system reduces human feelings of disorientation and depression [12]. In the future UUS planning, spatial landmark design and signage system design should expand multi-sensorial interactivity.

Disaster Prevention. In the event of a catastrophe, the complexity and impermeability of underground space increase the difficulty of evacuating. In modern times, natural and man-made disasters posed the greatest threat to the urban subterranean environment [26]. Earthquakes, floods, typhoons, seaquakes, and ground sedimentation are examples of natural disasters [26]. Due to their low horizontal position, subterranean flooding is one of the most common natural disasters. For example, Shanghai's average altitude is only 3-4 meters. In certain extreme weather conditions, such as flood season, rainwater is easily accessible through ventilation and illumination openings, but cannot be drained simultaneously [26]. Wars, terrorist attacks, exploding, fires, and traffic incidents constituted man-made disasters. In subterranean space, fires account for more than 30 percent of all types of disasters [26]. Due to the unique and complex spatial environment at UUS, fire disasters can be readily triggered by aging equipment, electrical short circuits, arson, etc. [26]. Recent research indicates that digital aid technologies can assist in the development of evacuation safety models and the evaluation of the most effective evacuation strategies, such as path width extension, reducing evacuation distance, enhancing navigation, and enhancing emergency illumination [12, 27].

3.3 Affection Needs

The highest demand in the hierarchy of needs, affection requirements include aesthetic improvement and landscape & greenery improvement. Creating a diverse and colorful indoor environment by enhancing aesthetic elements in subterranean spaces has a positive effect on human psychology [13]. There are numerous aspects of UUS that can be enhanced. Increasing the variety of colors and materials in UUS design can increase human satisfaction, to begin with [12]. Warm colors (long-wave colors) will cause a person's perception of time to slow down, whereas cold colors (short-wave colors) will cause the perception of time to accelerate up [28]. In addition, introducing cultural elements into subterranean space could enhance the affective resonance and social identity of humans [12, 19], which is an essential human defense mechanism [29]. Landscape and vegetation enhancements make the underground interior environment infinitely reminiscent of the outdoors. Landscape architecture and horticulture can be applied to UUS interior design as a result of the rapid growth of interdisciplinary research in recent years, which greatly increases the likelihood of realizing UUS landscape and art atmosphere construction [12-13]. Through the construction of various

landscape and greenery elements, such as paving, horizontal and vertical greening, and public landscape installations, the environmental quality of the U.S. will vastly improve, resulting in a positive impact on human mental health [12, 30].

4. Conclusion

With the development and expected enhancement of urban underground constructions, a growing number of individuals will work, shop, and even reside in such spaces in the future, so human-centered research and development must be prioritized. The paper began with an analysis of current research and study in the subterranean space psychology area and concluded that the field is still in its infancy but developing rapidly. Comparing the status of current and prospective UUS development and utilization in multiple cities leads to the conclusion that UUS planning will play an increasingly important role in future urban life. According to all of these analyses and summaries, the Abraham Maslow-based psychological requirements of UUS spatial elements should be emphasized. The theory divides psychological requirements into three categories (Physiological, security, and Affectional needs) and provides specific strategies for each. Even though this theory is still in its conceptual stage, it provides a framework for inter-disciplinary inquiry into the future development and application of UUS. Therefore, the challenge for any further UUS development and utilization is to minimize the disadvantages of UUS construction in order to improve the quality of life and well-being of humans.

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