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# Urban Double Repair, Creating a Living City: A Healthy and Comfort Oriented Approach to the Planning and Design of Dynamic Urban Underground Space and the Application Strategy of the New TOD Model for Intelligent Rail Transit Station City Integration

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## Abstract

**In the rapid progress of the times, people's living standards have been rapidly improved, while posing higher challenges to urban construction and development. Since modern times, the process of urban construction and development at home and abroad, as well as related urban repair and ecological construction practices, as well as the correlation between ecological repair and urban repair, have proposed that architects should actively participate in the professional work of urban transformation and development and "urban double repair". In the renovation and repair of urban underground space, China's underground space planning and design mainly focus on the intensive use of space, saving resources and energy from the perspective of protecting the ecological environment, there is less attention paid to the health and comfort of underground space users. Based on the analysis of the concepts of health, comfort, and underground space, and based on the Vischer comfort theory in environmental psychology, a framework for the relationship between the health and comfort components of underground space is constructed. On the basis of summarizing relevant research at home and abroad and the main characteristics of underground space, the planning and design ideas for underground space under the guidance of health and comfort are proposed from four aspects: ventilation system, visual comfort, security, and acoustic comfort, From the construction of residential environments, transportation behaviors, and travel modes that affect residents' commuting patterns based on moving to TOD neighborhoods, to the exploration of the application strategy of "transportation space function" in traditional TOD and new street blocks, research on relevant theoretical mechanisms and vitality effects of urban underground space planning and design in China has been enriched.**

## Keywords

**Urban Double Repair; Urban Underground Space; Healthy Urban Planning; Underground Commercial Space; Underground Complex Building; New TOD Mode.**

## 1. Foreword

In recent years, with the development of economy and the acceleration of urbanization, underground space, as an effective measure to solve urban problems, has become an important development trend in urban space construction. The development of urban underground space in China has grown at an unprecedented rate, but a series of problems have also emerged, such as unreasonable layout of

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underground space and low utilization efficiency, which have caused a waste of urban underground space resources and affected the sustainable development of underground space resources. The development of urban underground space is influenced by various factors, including economic factors, social factors, environmental factors, and so on. Among them, urban population is the main demand for urban underground space, and its density distribution is an important factor affecting the development of urban underground space. Urban underground space, as a component of the urban space system, is an important resource in the supply of urban space, and population distribution density to a certain extent represents the demand for urban space. Examining the relationship between the two can determine the supply effect of underground space resources, further improve and optimize the planning and practice of underground space, and promote the sustainable development of underground space.

## 2. The Relationship between Health, Comfort and Underground Space

### 2.1 Definition of Underground Space

Nishi (2000) proposed that underground space is a physical space that is manually excavated under the urban ground surrounded by rock or soil, and has excellent seismic, thermal, and acoustic characteristics [2]. In China, the role of urban underground space changes with the times, from its early use for air defense, storage, and refuge to industrial, transportation, military, and public services, commercial, and civil uses. The underground space in this study refers specifically to large, medium-sized, and comprehensive underground space within the scope of urban planning land, which is developed and constructed with the three-dimensional development of the city and has two or more functions such as transportation, commerce, storage, entertainment, and municipal administration. The development of comprehensive underground space appeared around the 1960s and has developed rapidly since then, mainly due to the tension of urban ground space and the reduction of land use. Especially in the urban center, the limited space accommodates more and more urban functions. Therefore, through the integration of various urban functional buildings and their underground development, a comprehensive functional underground space has been formed.

### 2.2 The Relationship between Health, Comfort and Underground Space

Whether a person feels comfortable in underground space depends on various sensory organs, namely, their eyes, ears, nose, touch, and brain. Generally speaking, human comfort depends on various factors, including temperature, humidity, illumination, environmental conditions, air pollution, and quality. Odor, noise, ventilation, and body metabolism have a direct impact on human comfort [5]. Apart from body metabolism, all factors need to be given sufficient attention during the design process. According to the Vischer comfort triangle, the connotation of health and comfort, and the design elements of underground space, the research team has drawn a relationship diagram of the components of health and comfort in underground space (Figure 1).

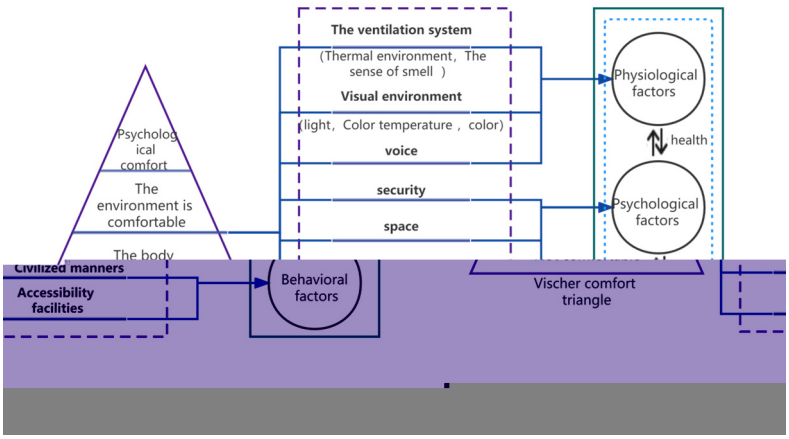


**Figure 1.** Relationship Framework of Health and Comfort Elements in Underground Space

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The top of the comfort triangle in Figure 1 is psychological comfort, followed by environmental comfort, physical comfort, and discomfort. Among them, physical comfort is a functional comfort provided by the basic attributes of underground space. Without these attributes, the place may not be able to make people stay. Underground space improves functional comfort by providing good thermal comfort, hearing, vision, smell, and equipment conditions, thereby improving physical comfort, and helping people achieve their expected functional goals at the location [6]. Poor lighting, air conditioning, and noise can hinder people from achieving their desired goals, resulting in stress and discomfort to the human body. As people's requirements for comfort continue to increase, the minimum expected comfort level will increase above the physical comfort level (livability threshold), transforming into environmental comfort, i.e., the impact of people and objects in the underground space environment on comfort. Individuals can have an impact on the comfort of the crowd, such as the words and behaviors of others; Personal appearance and clothing may enhance the comfort of others, such as wearing beautiful clothes; Or damage the comfort of others, such as using perfume that will affect the air quality, or blocking sunlight and vision with obstacles; Crowds can also have an impact on personal comfort. When people are poorly organized, users may still feel uneasy even if they are not crowded. As the population increases, concerns about safety, theft, and health also increase.

Various facilities in the spatial environment, such as barrier-free facilities that meet specific needs, smoking rooms, etc., can also have an impact on people's comfort. Psychological comfort is relatively abstract and difficult to describe. It involves emotions and behaviors caused by the environment. Factors such as a sense of belonging, a sense of space, privacy, health, and security all have important effects on psychological comfort. In addition, psychological comfort has a two-way impact on environmental comfort and physical comfort. According to Khainga's research, there are two types of psychological effects of underground space on people. One is positive impact, which refers to satisfying the psychological experience of novelty hunting and strengthening self-awareness; The second is negative impact, which refers to insecurity, claustrophobia, and lack of spatial awareness caused by changes in the physical environment [7]. Considering that hygiene is a fundamental element of a place and civilized behavior is a requirement of civic morality, this study does not further elaborate on these elements.

According to Maslow's hierarchy of needs theory, physiological needs are the foundation of the hierarchy of needs. If physiological needs are not met, they will offset other needs. Ensuring good comfort and meeting people's physiological needs is crucial to improving the environmental quality of underground space. Based on existing research results, the research team summarized them into the following aspects: ventilation system [indoor air quality (ventilation, air pollutants, odor); thermal environment (temperature, humidity)], visual environment (lighting, color, color temperature, interior design), sound, safety, spatial sense, hygiene, etc. Among them, ventilation systems, visual environment, and sound affect people's physical health, while safety, spatial awareness, and hygiene affect people's mental health. Civilized manners, barrier-free facilities, etc. affect people's behavior, which in turn has an impact on mental health. At the same time, mental health has a feedback effect on behavior, and physical and mental health also have a two-way impact.

## 3. Current Situation of Underground Space Development and Utilization in China

At the beginning of the Industrial Revolution, China gradually developed urbanization, and the utilization of underground space gradually extended to the municipal construction of cities, from the early wartime civil air defense project to the combination of civil air defense and urban construction. After the reform and development, China has focused its work on the construction of urban rail transit, promoting the development and utilization of underground space along the line through the construction and development of rail transit [8]. With the continuous advancement of urbanization, the planning and management of urban underground space in China has become increasingly large-

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scale and networked. In order to expand urban spatial capacity and alleviate urban conflicts, in addition to basic municipal construction, other types of underground facilities have also begun to develop rapidly [9]. There are countless projects such as underground complexes, underground cultural and recreational facilities, comprehensive pipe corridors, underground substations, underground sewage treatment plants, and underground storage facilities, gradually forming an underground space development model with rail transit as the main body and other municipal and cultural infrastructure developing in parallel. The construction of underground space in China is developing rapidly, with the total scale continuously expanding. The construction speed of urban rail transit is the first in the world, and far surpasses that of other countries. By the middle of the 21st century, China's urbanization rate will reach around 75%, and the requirements for space will become increasingly high. The construction of urban underground space in China has gradually embarked on the road of accelerated development [10]. Combining urban transportation facilities and moving to TOD neighborhoods, the author has constructed a theoretical framework for studying the mechanism of residential environment, transportation behavior, and travel mode affecting residents' commuting patterns (Figure 2).

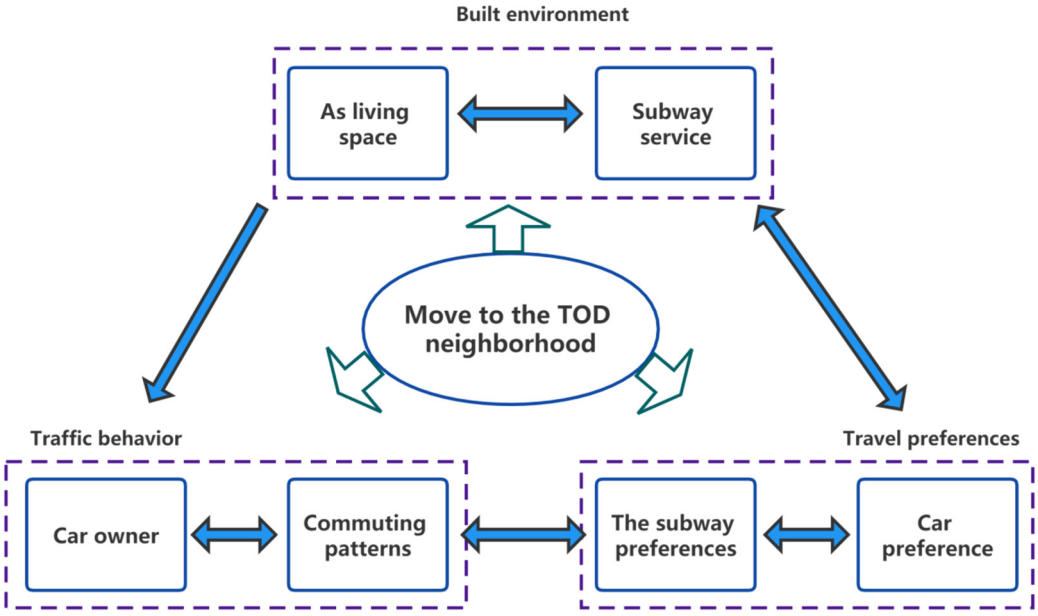


**Figure 2.** Theoretical framework of TOD affecting residents' commuting patterns

## 4. Main Characteristics of Underground Space

### 4.1 The Space is Relatively Closed

Underground space is generally considered as a closed environment below the surface of the Earth. This means that unlike the aboveground environment, it cannot directly enter the outdoor open space. Therefore, users of underground spaces cannot directly see the ongoing events outside. Compared to aboveground space, underground space is relatively closed, with limited escape routes in the event of disasters such as fires, and a lower sense of safety than aboveground space. In addition, due to the absence of natural light and the fact that artificial light sources do not change throughout the day, it is easy to cause people to lose their spatial perception of the environment, leading to anxiety and claustrophobic reactions.

### 4.2 Poor Ventilation

Ventilation systems provide appropriate temperature and humidity control and ventilation for people. Poor ventilation can affect indoor air quality, is harmful to people's health, and is not conducive to

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improving people's comfort. Due to the fact that underground spaces are surrounded by rocks or soil, and the flow of air to the ground only passes through entrances and artificial ventilation systems, their overall sealing performance is good, with good air tightness and poor ventilation effect. If the artificial ventilation system does not operate smoothly, it is easy to generate problems such as high concentration of carbon dioxide in the air, high concentration of harmful gases, high humidity, and obvious odor, affecting people's health and comfort.

### 4.3 The Acoustic Environment is Relatively Closed

Due to the closed nature of underground space, sound is difficult to spread, and due to improper handling of shapes, structures, materials, etc., it is not possible to spread outward to form an echo. This makes the sound pressure in the underground space 3 to 8 dB higher than that in the ground space under the same noise source [11]. External sound cannot enter and lacks the environmental noise that is commonly used in daily life, which can easily lead to psychological discomfort.

### 4.4 Constant Temperature Heat Insulation and Light Shielding

Compared to aboveground space, underground space has better thermal stability due to being surrounded by soil or rock. Therefore, compared to the external temperature environment, underground space has the characteristics of being warm in winter and cool in summer, and the internal temperature difference of underground space is less affected by the external temperature. At the same time, it is difficult to fully utilize sunlight for lighting in underground spaces, resulting in insufficient natural light. In addition, underground space is not well connected with the outside world, making less use of ground landscapes, and people are also unable to contact the outdoor natural environment, making it impossible for those living in it to form a sense of time, resulting in adverse psychological feelings such as fear, anxiety, anxiety, nervousness, and a weakened sense of direction [12].

## 5. Characteristics of Urban Underground Space Development and Utilization

Underground space facilities are divided into two types: built-up and single built. However, in the process of development and utilization of either type of facilities, due to the one-way nature of urban underground space development and utilization, it is necessary to consider supporting facilities and underground buildings as a whole in the early stage of development [13]. For structured underground space facilities, when planning, it is necessary to develop and utilize them as a whole together with surface buildings. For example, when planning a subway complex, it is necessary to plan the surface buildings and underground stations as a whole, and also consider the integration of entrances and exits, sewage facilities, power traffic, and ventilation openings. When developing and utilizing single built underground space facilities, such as underground storage depots, it is also necessary to comprehensively consider flood prevention facilities, ventilation openings, and other supporting facilities from the perspective of the integrity of underground space development and utilization, in order to achieve the maximum utilization of underground space resources.

## 6. Research on the Design of Contemporary Urban Underground Space

### 6.1 The Trend of Integration of Underground and Aboveground Buildings

The planning and design integrate the above ground and underground space, and the underground space is above the ground. In the planning and design, the above ground and underground space is taken as a whole, giving full play to the respective advantages of the above ground and underground space, and comprehensively considering, the underground space is above the ground by reasonably introducing air and light into the underground space [15]. The ultimate goal of space design is to serve people. In the integrated design of above ground and underground, the connection and transition between underground space and underground space is particularly important. Through the detailed treatment methods of architectural space such as sunken squares, sunken courtyards, steps, ramps, rest platforms, escalators, lighting skylights, and lighting wells, pedestrians should achieve a natural

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transition from above ground to below ground, without a sense of estrangement during the journey A sense of tiredness and boredom [16]. In order to achieve the integration of aboveground and underground space, the aboveground design of underground buildings is a specific design operation method, which provides spatial experiences that are consistent or similar to those of people in the ground space during the design of underground space, such as light, air, greening, landscape, etc.

### 6.2 Layout Design of Underground Commercial Space

The underground commercial space can be divided into shops, logistics equipment rooms, and transportation spaces. At the beginning of the scheme design, the design of the transportation moving line is crucial, which is related to the design of the underground commercial space sequence, the guidance of the flow of people to the destination, and the size of the shops after the division of the passive line [17]. With the continuous acceleration of urbanization in China, the development of underground commercial space is of great significance for the current situation of continuously shrinking available land area. However, due to the shortcomings of airtight, dark, and poor air circulation in the space of underground commercial buildings, the mainstream concept of modern underground commercial building design is to ground the underground buildings, advocating introducing greening, sunlight, and air into the ground to eliminate the sense of claustrophobia. A clear spatial sequence of underground commercial lines is crucial for the design of underground commercial spaces. The underground commercial lines consist of one or more main axes or branches that organize different shops and supporting service facilities. They are usually connected to urban transportation nodes such as subway stations and underground passages, and are connected to aboveground commercial spaces through open spaces such as atriums and sunken squares to improve the accessibility of underground commerce [18].

### 6.3 Planning and Design of Ventilation System with Both Subjectivity and Objectivity

Objectively, the temperature of underground space can be adjusted to a good range through air conditioning systems, but humidity environments are prone to problems. In humid areas, improper ventilation and dehumidification measures for underground space can also cause relative humidity to be difficult to control within the design requirements, so natural ventilation systems should be appropriately designed to provide sufficient air flow. Natural ventilation systems are recognized as traditional passive cooling technologies, especially in hot and humid areas [19]. However, in reality, the design of underground ventilation systems is relatively complex, and most underground spaces should also be equipped with mechanical ventilation systems and emergency ventilation systems to dilute and remove pollutants from underground spaces.

Subjectively, the olfactory environment is a subjective feeling of people, and the smell of underground space has a very important impact on people. Due to the enclosed nature of underground spaces, the elimination of various odors mainly relies on manual means, which can eliminate unpleasant odors through physical or chemical methods, such as mechanical ventilation, chemical deodorization, etc. Smoking areas or smoking rooms should have independent ventilation facilities leading to the outside, effectively isolated from nonsmoking areas and nonsmoking rooms, and should be provided with obvious signs. In addition, optimization can be carried out from the following aspects, including overall air replacement, control of pollution sources, and isolation of spaces that generate pollutants (such as generator rooms, toilets), to prevent the indoor spread of odorous air from causing discomfort among people [20]. At the same time, it is possible to design a fragrance system. In the HVAC system of underground space, fragrant odors similar to the natural environment, such as roses and orchids, are used to make the air in the underground space fresh and odorless [21].

### 6.4 Visual Comfort through Lighting and Lighting Design

Reasonable natural lighting design can achieve reasonable light utilization and distribution. Combined with the reasonable design of underground space, it can meet the needs of the general population for open space, allowing people to have higher visual comfort in underground space. In addition to lighting and energy saving, natural lighting also has a more important function - satisfying

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people's psychological needs for information perception such as natural light and spatial orientation, thereby reducing or eliminating people's sense of oppression. However, in most underground spaces, it is difficult to daylighting naturally. In order to reduce the sense of closure and dark space caused by lack of light, natural terrain can be used to design sunken courtyards, sunken squares, etc., effectively introducing external natural light and scenery into the ground, increasing the visual connection and accessibility of underground spaces and external open spaces [22]. In addition, color temperature is also a point that cannot be ignored in lighting design. In lighting design, appropriate light colors should be selected based on the different properties of the lighting space, the climatic characteristics of the area, and the illuminance requirements of the space.

The lighting mode of underground space should be reasonably designed according to different spatial requirements. A good lighting mode can not only meet the use functions of various areas, but also enrich the spatial hierarchy, thereby creating a comfortable and pleasant underground lighting environment [23]. Successful underground interior design can come from various design methods, such as using warmer and brighter colors, and using more colors; Large use of green plants; Set up pools or fountains at appropriate locations; Set different lighting in special areas, such as setting very bright lights in areas where plants grow; Place some art works that replace windows, such as natural landscape murals, etc.

Due to the lack of reference objects in underground space, it is easy for people to lose their sense of direction. Therefore, when designing, it is necessary to ensure that the spatial layout is clear and consistent with people's spatial cognitive habits. Functional zoning should be reasonable and each area should have different characteristics. At the same time, the signage system should be improved. Guidance signs, emergency evacuation signs, etc. should be set up in the underground space to provide accurate direction information for pedestrians, so that people can quickly find targets, disperse the flow of people, and avoid congestion [24]. At the same time, based on the research results of architectural behavior and environmental psychology, technical measures such as arranging corresponding guidance signs and setting unique reference objects in some special locations should also be taken to further strengthen people's sense of orientation in underground space and reduce various negative impacts caused by the environmental closure of underground space on people [25].

### 6.5 Improve Security through Rational Spatial Design

Space design can increase the sense of security of people in underground spaces. Ringstad believes that the research results of environmental psychology can be applied to the design of underground facilities, thereby reducing the impact of potential fear stimuli, enhancing people's safety experience, such as increasing ceiling height, optimizing the layout of the room, suitable semi-private space design, reasonable seating arrangements, brightness and visually accessible safety passages, continuous indoor roads, and removing unnecessary interior walls where possible [26]. Designing personalized underground space environments, such as using specially decorated images, plants, and natural models, can reduce the fear caused by claustrophobic environments, thereby enhancing people's sense of security [27]. Due to the limited access between underground and aboveground, it is easy for people to feel lonely and deepen their sense of insecurity. Therefore, it is recommended to appropriately increase the number of entrances and exits from underground space to the ground, and increase the number of elevators and escalators connected to the ground. In addition, introducing natural light into underground space through design, such as building daylighting skylights, can further increase the sense of connection between underground space users and the outside, thereby enhancing their sense of security [28].

### 6.6 Acoustic Comfort through Control and Design of Sound Sources

For large spaces with dense personnel, such as subway hubs, underground stadiums, etc., architectural acoustics should be carried out Special design, from ensuring language clarity in large spaces, avoiding acoustic defects, controlling reverberation time, and controlling Noise and vibration are considered [29]. Improve the quality of the acoustic environment in underground spaces by

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controlling, designing, or increasing the types of sound sources people like, such as bird calls or running water sounds that represent nature, making them diverse and interesting, and reducing people's sense of oppression in underground spaces. It can purposefully weaken some sounds that people don't like, while retaining sounds that people like and have meaning for them. For example, increase the coverage of public broadcasting, ensure the language clarity and sound distribution uniformity of the information transmitted by the public broadcasting system, reduce the amount of advertising broadcast, and avoid information interference. Echo is controlled through the design of interfaces and the use of sound absorbing materials, such as wave shaped, perforated metal plate ceiling optimization, etc. [30]. In addition, attention should be paid not to increase the sound pressure level of underground commercial spaces and make them appear noisier due to increasing the types of sound sources that people like.

## 7. The Development Trend of TOD Mode for the Integration of Underground Space Stations and Cities in Dynamic Cities

(1) Intensive integration: Develop comprehensively and systematically, coordinate the development of underground space according to different functional forms [31], achieve organic integration of above ground and underground, improve the level of land intensification, and build a systematic scale comprehensive group sustainable development.

(2) Intelligent and precise research: Digital research on underground space has become a necessary technical means for comprehensively controlling the current situation and forecasting the utilization of urban underground space resources, and is a powerful technical support for rational planning and effective utilization of underground space; At the same time, it is also an important technical measure for safety control, disaster prevention and mitigation of underground engineering construction [32]. Intelligence mainly relies on the support of artificial intelligence technology to achieve information sharing and multi-port real-time synchronous operation.

(3) Legalized management: The Property Law of the People's Republic of China only provides for general provisions on the right to use underground space, but detailed statements have not yet been provided, lacking practical guiding value [33]. Comprehensively legislate on various aspects, from the ownership of underground space to management subjects and spatial layout planning, to achieve all-round legalization of underground space.

(4) New TOD mode: conduct "dot shaped, district shaped, regular and irregular extension" in combination with traditional TOD traffic, block space, and functional organization in terms of scale, land area, public space, and function. Use the regular behavior modes of the new block such as environment, traffic, and travel to conduct mechanism and vitality effect research (Figure 3).

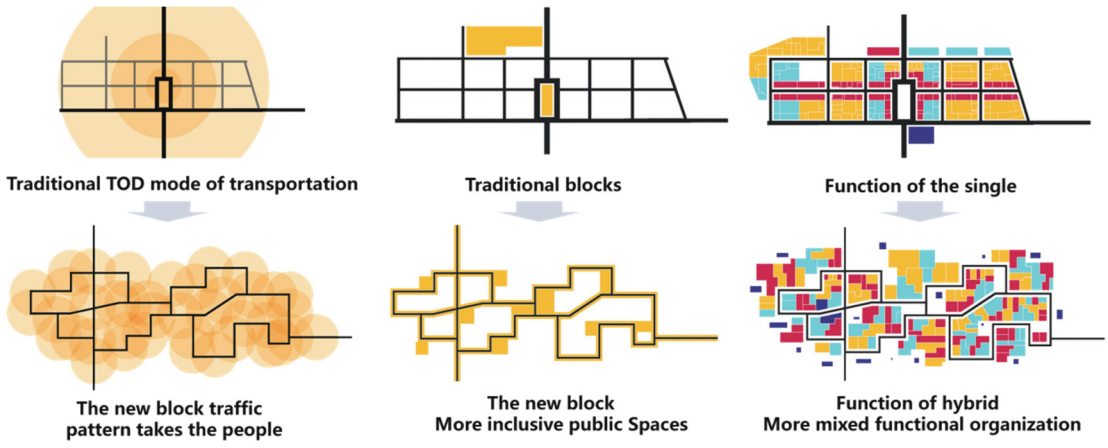


**Figure 3.** Analysis of the "traffic space function" mode of traditional TOD-new block

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## 8. Summary and Outlook

"Urban dual repair" has the characteristics of long-term, sustainability, and locality. In urban development, it is necessary to constantly adjust the relationship between human and nature, move towards "natural walking together", and grasp the orderly and moderate metabolic repair process. Thus, it is possible to rebuild the decadent and heterogeneous "urban repair" object into a "boutique and micro" livable urban living place. In summary, the paper studies and analyzes the concept of health and comfort in the context of "urban double repair", constructs a framework for the relationship between the components of health and comfort in underground space, and on the basis of summarizing relevant research at home and abroad and the main characteristics of underground space, proposes the planning and design ideas of underground space under the guidance of health and comfort and the strategic application of a new TOD model for intelligent rail transit station city integration, From the perspective of health and comfort, it enriches the theoretical and strategic research on urban underground space planning and design in China. Underground space planning and design is a complex and systematic issue, and it is difficult to reveal the impact mechanism and action path between the health and comfort perspective and underground space planning and design through qualitative exploration alone. In the future, data collection and a combination of qualitative and quantitative methods can be used to conduct in-depth exploration.

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