*Research Paper*

# Healthy and walking friendly campus community in cold areas

## Taking the community of Harbin Institute of Technology as an example

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### Abstract

*The cold weather in winter in severe cold areas has brought many adverse effects on the local social and economic development. As an essential connecting element between buildings, the warm skyway not only provides convenient travel conditions for the community but also expands the functional richness of public space and promotes a healthy life. The core of this study is to build a walking system with good walking comfort and promote healthy activities by constructing a warm skyway to renew university campuses in cold regions. Harbin is a typical cold region city in Northeast China. Taking the community of Harbin Institute of technology as an example, using the GIS platform, POI data, OSM map, and other open-source data, through the methods of vector analysis, nuclear density analysis, correlation analysis, and mixing degree analysis, this paper studies the location of the warm skyway and the functional transformation of the connecting layer, and puts forward the planning strategies of the warm skyway system in the university campus community in severe cold areas, to provide a basis for the construction of a healthy walking-friendly community in cold cities.*

### Keywords

*Cold city, Skyway, Healthy community, Campus community,Sports facilities*

## 1. Introduction

The planning, design, and construction of human settlements have an important impact on human health. In the past 20 years, the research on the planning of healthy communities has mainly focused on the effective use of energy, mixed use of land, vibrant community centers, safe and convenient transportation systems, and fair and good neighborhood relations(Y. Wang, 2015). A healthy community, sustainability, quality of life, and performance evaluation are important aspects of the community index

evaluation system. The term "health" here has expanded from the traditional sense of physical health to include economic prosperity, social legal system, environmental quality, public safety, and other elements of community collective health (Besleme & Mullin, 1997; Swain & Hollar, 2003). Walkability has become an important topic in the fields of planning, urban design, and health (Leng et al., 2019; Tran, 2016).In health community planning, many planners have taken "how to stimulate people's daily exercise" as an important planning goal.

Walking is the most favorable form of short-distance travel, and walking friendliness is an important symbol to measure the high-quality development of human settlements(Xu, 2018). It is of great significance to study the urban walking environment and the street space suitable for people to improve the quality of healthy urban life and increase the leisure space of citizens(H. Zhang & Xu, 2009). The skyway system realizes the stratification of people and vehicles, which not only ensures the safety of pedestrians but also avoids the interference of vehicle emissions and avoids the influence of cold winter and hot summer climates(Leng et al., 2019). And the skyway system construction is an important means to promote walking friendliness, which is widely used all over the world. The new urbanism has led the city to return to the "urban texture suitable for walking and public transport", and opened the attention of domestic scholars to the pedestrian transport mode and vitality building in the urban center. In cold cities, the warm skyway can play the role of protecting against adverse climate, and at the same time, as an important connecting element between buildings, it expands the functional richness of public space and promotes healthy life. Skyway construction plays a role in improving travel convenience, providing climate protection, reconstructing the function of building space, and reorganizing the spatial sequence. At the same time, the application of pedestrian skyway also guides the green travel mode. The research shows that the establishment of the pedestrian overpass is beneficial to the improvement of the walking experience(Zhao et al., 2020), it is indicated that footbridges and underground links could enhance walkability when they are well connected with the ground-level networks(Sun et al., 2019). The “active design guidelines” put forward the concept of a “circulation system”, that is, through the comprehensive design of platforms, skyways, stairs, elevators, and other elements to achieve the purpose of encouraging people to walk and exercise (K. Zhang, 2021).

Regular physical activity is proven to help prevent disease, enhance physical fitness and enhance mental health (D. Wang & Xing, 2022). According to current global estimates, one-fourth of adults and 81% of adolescents do not have enough physical activity (Physical Activity, n.d.). Lack of physical activity harms health and social well-being. Therefore, the World Health Organization will promote sports for all as a central policy recommendation in the WHO Global Action plan on physical activity 2018–2030(Ensuring Sports for All, n.d.). Community sports are an important link in urban public services. The key contents of community sports services include service effectiveness, residents' needs, serviceability, service content, etc(Lu & Yuan, 2021). Research shows that increasing the sense of community has a positive impact on the stay and satisfaction of sports participants, which enhances health by promoting behaviors through promoting physical exercise(Warner et al., 2017)。

China has a vast land area under the cold climate, accounting for about 1/3 of the land area. The average temperature in January is below -18℃ in severe cold regions such as Heilongjiang, Jilin, Liaoning, and the northeast Inner Mongolia Autonomous Region(Jiang & Leng, 2016). Harbin Institute of Technology is located in Harbin, Heilongjiang Province, Northeast China, which is a typical cold area city. The average minimum temperature in January of the last decade is -23.06℃, and the average maximum temperature is -12.34℃(Weather Records, n.d.)。 Affected by the climate of the Siberian polar continent, the city will be attacked by cold, ice and snow, and cold wind for nearly half a year. The typical cold climate features are low temperature, frequent snowfall, short days, and less sunshine(S. Wu et al., 2022). The cold climate greatly reduces the enthusiasm of residents for travel and fitness in winter, which is not

conducive to physical and mental health. At present, many cities in the world have skyway systems, for example, international metropolises such as Canada, the United States, Singapore, and Japan have built systematic skyway pedestrian systems(Ma & Xu, 2019). How to improve the suitability of walking in cold areas, create high-quality public fitness spaces and stimulate community vitality has become an important content of urban design in cold areas. The core of this study is to build a walking system with good walking comfort and promote healthy activities through the construction of warm skyways in the renovation of university campuses in cold regions.

## 2. Method

### 2.1. Analysis

Based on the QGIS 2.14.3 platform and ArcGIS 10.6 platform, the open source data of Open Street Map and poi are analyzed. Taking Harbin University of technology as an example, the building function and service radius of the campus community are analyzed. According to the typical characteristics of skyway construction, the skyway system planning is carried out based on feasibility analysis.

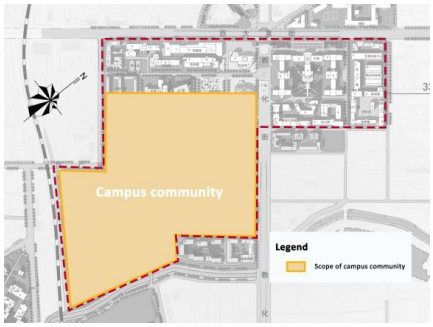
In this study, the Tyson polygon model is used for service radius analysis and performance analysis(H. Wu & Wang, 2019). The service points of sports facilities are taken as sample points to establish the Tyson polygon. Each polygon is taken as the service range of the facility points it contains. The distance between any point within the range and the facility point is the closest, to further calculate the service radius and service pressure of the facility points. This study also uses the network analysis method to simulate the campus community traffic network, establish the OD cost matrix, and analyze its traffic accessibility and service scope.

### 2.2. Plot overview

Harbin Institute of Technology is located in Harbin, Heilongjiang Province, China. It is located in a typical cold area and is one of the world's famous research universities. Harbin University of technology is a typical research-oriented high-level university in China, ranking 236th in the QS World University Ranking in 2022, and engineering and technology, materials science, computer science and information system, and other disciplines rank in the world.

It is a typical Chinese-style campus. The campus presents an enclosed form, which solves the accommodation problem of all students on the campus. Therefore, a campus community with complete functions and a huge size has been formed in the south of the campus. Its functional divisions are shown in Figure 1. The current campus is divided into seven functional areas: living area, teaching office area, sports activity area, scientific research and development area, service area, leisure area, and main square area.


(a) Functional partition.




(b) Scope of the campus community.

Figure 1. Current situation of Harbin Institute of Technology.

This campus has 6 indoor and outdoor stadiums with a total area of 90000 m2 and an average annual usage of 1.5 million people. The fitness facilities provided by each venue are different and the layout is relatively centralized, which can meet the fitness needs of most students. In the analysis process, each venue is regarded as a sports facility point to analyze the rationality of the layout.

Table 1. Venue details.

| Venue name | Code | Functional | Area($m^2$) |
|---|---|---|---|
| Gymnasium | X01 | Basketball, badminton, gym, dry skating | 9372 |
| Zhengxinlou Gymnasium | X02 | Badminton, table tennis, fencing room, aerobics room, dance room, gym | 6900 |
| Stadium | X03 | Track and field, aerobics room, football field | 35000 |
| Natatorium | X04 | Gym, standard swimming pool | 11547 |
| Small football field | X05 | Football field, track and field field | 11700 |
| Indoor sports arena | X06 | Basketball, volleyball, tennis | 15755 |

# 3 Results

## 3.1 Current situation analysis of campus fitness facilities

3.1.1. Service radius analysis

Take fitness facility points as sample points to generate Tyson polygon, as shown in the figure. The campus space is divided into six service areas. The existing six fitness facilities are all distributed on the south side of the campus, while the north side lacks fitness facilities.

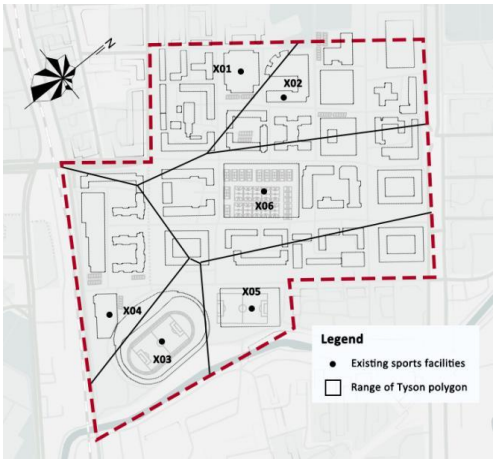



Figure 2. Tyson polygon range of existing fitness facilities.

From the perspective of space, the students living in the same area of Tyson polygon are more likely to choose the fitness facilities in the area for sports. The farther the distance, the lower the tendency to choose. The coverage area of the Tyson polygon service area in the south of the campus community is small, which reflects that there are many facilities in the area; The coverage area of the Tyson polygon service area on the north side of the campus community is large, which reflects that the users in this area have fewer choices of fitness facilities and insufficient coverage. Calculate the service radius of each facility point according to the first circle, as shown in the figure. It can be seen that the service radius of the service range is 170 ~ 250m except for the Tyson polygon.


**Figure 3. Service radius of existing sports facilities.**

3.1.2. Perfection of service facilities

Before and after the sports and during the sports, we need to do a good job in support and preparation, which is inseparable from perfect basic service facilities, such as showers, catering, medical and other services. Use the service radius and the POI points collected in the campus community to analyze the service facility's perfection. The service facility perfection refers to the POI point density within the service radius area of the sample point. There are 57 POI points collected on the campus, including life service, learning service, catering and shopping, shower, medical treatment, etc., as shown in the following table.

**Table 2. Statistics of POI.**

| Type | Quantity | Specific functions |
|---|---|---|
| Life service | 13 | Hairdresser, optician's shop, bank, etc |
| Learning services | 12 | Printing and copying, bookstores and training institutions |
| Catering and shopping | 15 | Student supermarket, mobile dining car, snacks, beverage shop, coffee shop |
| Shower | 16 | Shower room of each dormitory and shower room of the swimming pool |

| | | |
|---|---|---|
| Medical care | 1 | Pharmacy |

According to the formula: service facility perfection = proportionality coefficient * the number of POI points (PCS) / area of the service area ($m^2$), the service facility perfection around the existing facilities points can be obtained as shown in the figure. Among the six blocks, only one block in the middle has a service facility perfection of more than 2. It can be seen that the POI distribution in the middle of the campus community is more concentrated and the service facilities are the most perfect. It can be seen that the service facilities in the middle of the campus, that is, the junction of the living service area and the teaching office area, are the most concentrated and highly complete. However, there are few service facilities in the marginal areas. On the one hand, it brings inconvenience to the life and work of teachers and students; on the other hand, it cannot provide necessary support and guarantee for the sports of teachers and students, which is not conducive to promoting users to carry out fitness activities.


**(a) Schematic diagram of POI distribution and service radius.**

**(b) Completeness of service facilities.**

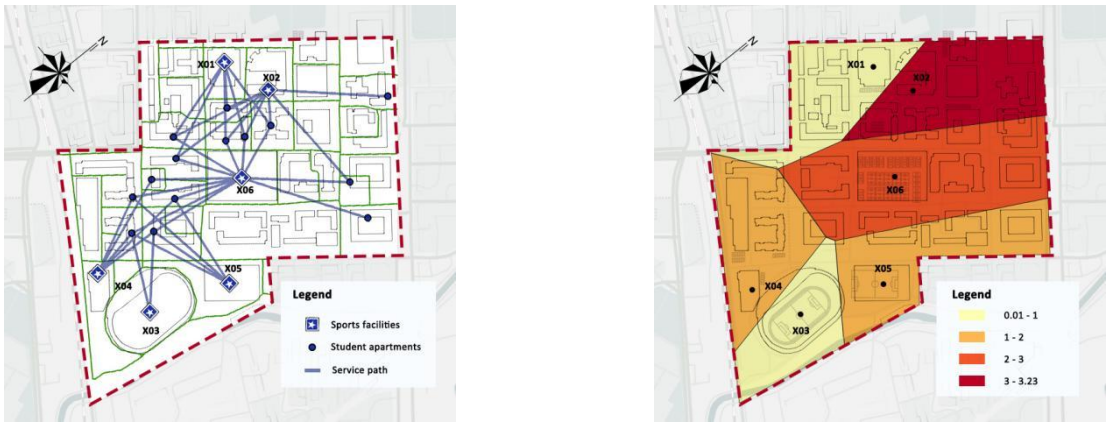
**Figure 4. Perfection of existing sports facilities and surrounding service facilities.**

3.1.3. Service pressure analysis

The main service objects of sports facilities on campus are students and faculty members. However, the characteristics of Chinese boarding universities are that there are concentrated student apartments on campus, and faculty members rarely live on campus. Therefore, the service pressure of fitness facilities is studied by taking students as an example. There are 15 student apartments on the first campus of Harbin University of technology. According to the vacancy rate of available beds of 5%, the number of accommodations in each apartment is roughly the same as the number of existing students on the first campus of Harbin University of technology.

Set the apartment as the request point and the sports facilities as the response point. Conduct network analysis using the ArcGIS platform, as shown in the figure, get the weight of the corresponding facilities of each apartment, and calculate the expected number of people from each apartment to each sports facility. Use the formula service: Pressure (P) = The total number

of students served (person) / Available area of sports facilities ($m^2$) to calculate the service pressure of each service area.




(a) Location assignment. (b) Service pressure.

Figure 5. Service pressure analysis.

It can be seen from the figure that according to the service scope divided by Tyson polygon, the service pressure distribution of existing fitness facilities is uneven, and only 2 of the 6 blocks have a service pressure index less than 1. Due to the relatively central location of the X02 and X06, they need to share the service pressure from all over the campus. However, the area of the X06 is relatively small, so the service pressure is large. The total area of X03, X04, and X05 in the south is large, and the average service pressure is small.

3.1.4 Walking accessibility

Accessibility generally refers to the traffic convenience from a certain place to other places in the city, and the most common mode of transportation in the campus community is walking. Therefore, this study only analyzes the walking accessibility of the campus community. Use the ArcGIS platform to build the road traffic network of the campus community, take the walking speed as 4km/h, and draw the walking isochronous map, as shown in the following figure.

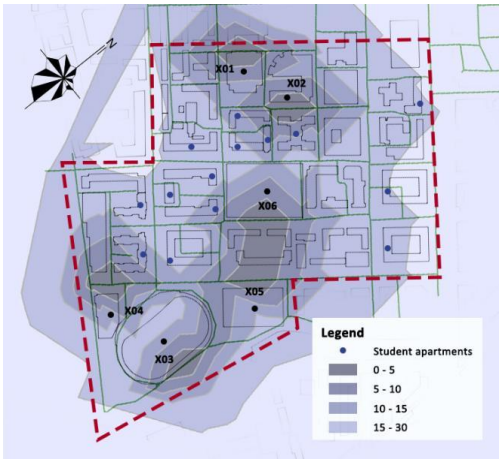



Figure 6. Walking accessibility of existing facilities.

As shown in the table, the accessible area of each facility accounts for 36.67% of the total area of the campus community. According to the existing transportation network, except for A15, A08, and A01

apartments, most of the student apartments are more than 15 minutes away from the service facilities, which brings inconvenience to the students' sports and fitness and needs to be improved.

**Table 3. Accessibility range proportion**

| Arrival time | Area ratio |
|---|---|
| >30 | 10.94% |
| 15~30 | 52.39% |
| 10~15 | 18.08% |
| 5~10 | 13.38% |
| 0~5 | 5.22% |

## 3.2 Campus community renewal based on skyway construction

Through the above analysis, it can be seen that the existing fitness facilities in the campus community are mainly distributed in the south, which is relatively concentrated and has less service pressure, but the supporting service facilities are not perfect; The north part of the campus community is located in the core area of the campus, and the service pressure is large, but the supporting service facilities are relatively perfect. In addition, the existing fitness facilities are far from the student apartments, which is not convenient for students to exercise independently in their spare time. Therefore, in the process of updating, the distribution of users, the division of campus functional areas, service radius, and support services are comprehensively considered to improve the overall health system.

In the process of updating, the campus warm skyway system is built. On the one hand, it can provide more convenient walking conditions for the campus community and shorten the time for students' apartments to go to sports facilities. On the other hand, it can provide rear protection, provide temperature protection for students' Sports in cold winter, enhance students' willingness to go out for sports activities in winter, and promote health.

3.2.1 update strategy

(1) Increase the coverage of sports and fitness facilities. Fitness facilities should be set up in areas with too large a coverage area and too long a service radius of Tyson polygon, to increase the coverage of facilities and make the public resources such as sports facilities more equitable.

(2) The service scope of each sports fitness service area shall be uniform. From the perspective of user distribution, a reasonable layout should be made, and more facilities should be set up in areas with high service pressure, to average the service population served by each fitness area and reduce the service pressure of sports fitness facilities.

(3) Improve the perfection of service facilities. Corresponding supporting service facilities are arranged around the sports facilities. Each sports facility forms an independent group. All sports facilities are interconnected to form the whole campus community health system.

(4) Improve the convenience of physical fitness. In consideration of the local special cold climate, the convenience of users for sports and fitness should be improved. Climate protection is carried out through the warm skyway, the straight-line connection between buildings is realized, and different functional areas are connected while shortening the path.

3.2.2 update scheme

Relying on the construction of the campus skyway, create a campus community health system that can "keep fit without leaving home". Considering the complexity and accessibility of functions on the campus, the campus skyway system is planned. The skyway system planning is shown in the figure. In this plan, the sports fitness system is divided into outdoor public fitness facilities and indoor apartment fitness facilities. In combination with the setting of campus warm skyways, a campus community health system is formed.

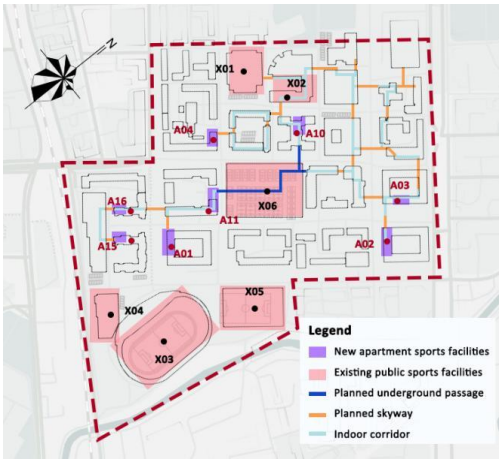



**Figure 7. Skyway system planning**

(1) According to the planning, the fitness facilities in the campus community are divided into a "stadium" and "fitness room in the apartment". The stadium facilities have a large area and can accommodate many users. It provides a variety of fitness facilities and equipment, including gymnasiums, wind and rain playgrounds, small football fields, Zhengxin building gymnasiums, natatoriums, stadiums, etc. The fitness room in the apartment has the characteristics of a small area, high flexibility, and fewer supporting facilities so that users can exercise themselves. According to the plan, a total of 7 apartment fitness rooms will be added, and the area of each apartment fitness room is 1000 ~ 1500 m2. An elliptical machine, treadmill, spinning bike, yoga mat, and other equipment can be placed. It is flexible and light and has low noise. It is suitable for exercise in the apartment.

(2) The skyway planning is combined with the life circle. Each functional area in the campus community is connected through the layout of the skyway to form a group, which can meet the needs of teachers and students for daily study, life, and fitness within 5-15min. The skyway will greatly improve the convenience and comfort of pedestrians and promote the generation of vitality in winter. In addition to meeting the fitness needs of users, it should also consider the needs of changing clothes and bathing after fitness. The existing bathing facilities are mostly distributed in the apartment buildings and separated from most fitness venues, which is not in line with the natural behavior procedures of users, especially in the cold winter, It is not good for your health to go back to the apartment for changing clothes and bathing after sweating. Therefore, the warm skyway system can give play to its convenient walking characteristics, provide users with cold protection, and reduce walking time. The macro layout combined with the life circle makes sports more convenient, thus encouraging users to carry out more fitness activities.

The updated Tyson polygon service area is shown in the following figure. It can be seen that after the fitness facilities are added, the coverage area of the Tyson polygon service area on the north side of the campus community is reduced. The service radius of each service area is between 80 and 180m, which is significantly shorter than that before the update, and the distribution of facilities is more uniform.

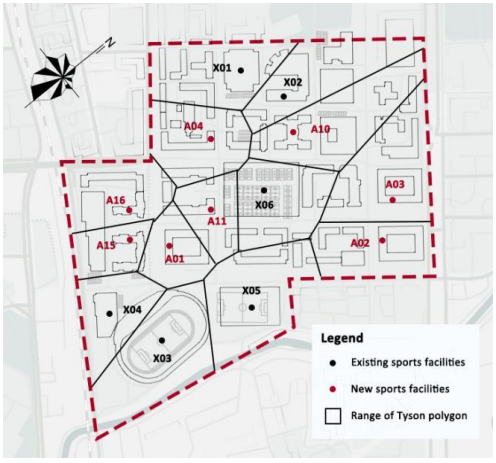



**Figure 8. Updated Tyson polygon range**

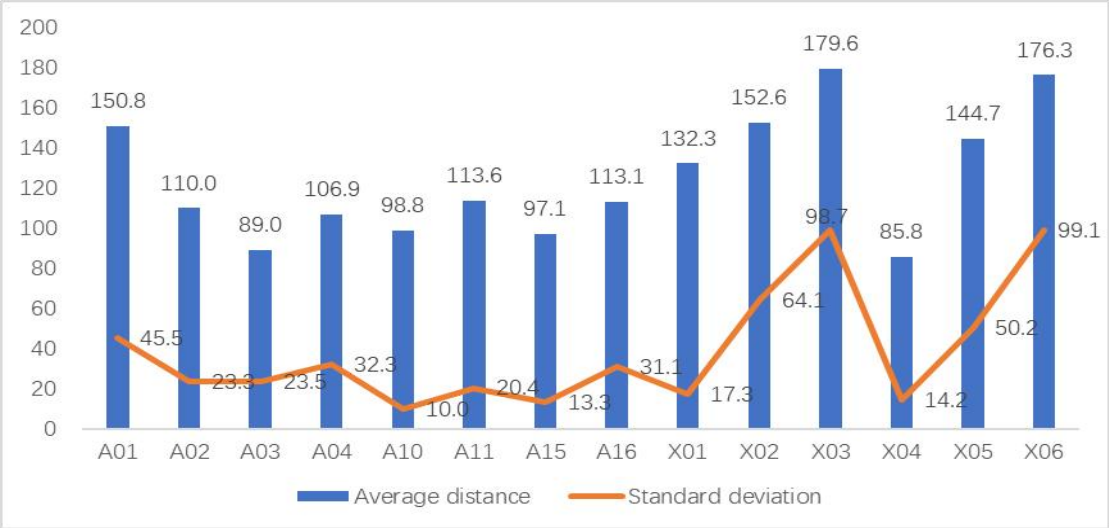
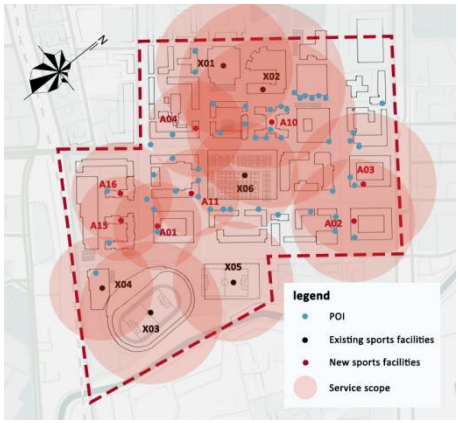



**Figure 9. Updated service radius**

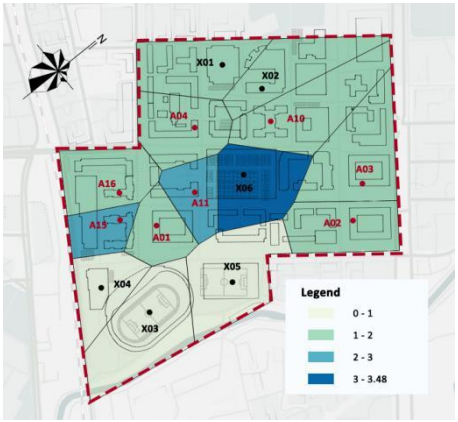
By adding 7 fitness facilities, the service pressure of each Tyson polygon service area has been effectively reduced. Among the 14 updated blocks, 10 blocks have a service pressure index of less than 1, which is significantly lower than that before the update. Among the updated 14 blocks, 11 blocks have more than 2 service facilities, which is more reasonable than the previous service allocation.

Connecting each apartment with the fitness facilities through the skyway, on the one hand, it increases the diversity of students' fitness space choices. When the apartment sports facilities where the students are already full, they can pass through the skyway to enter another sports facility at any time. On the other hand, by connecting the supporting service facilities such as bathing and dressing in the apartment with the stadium and the fitness room of the apartment through the skyway, it can provide convenient walking paths for the users, avoid the adverse weather in winter affecting the physical health of the users, and encourage and promote the users to carry out fitness activities.

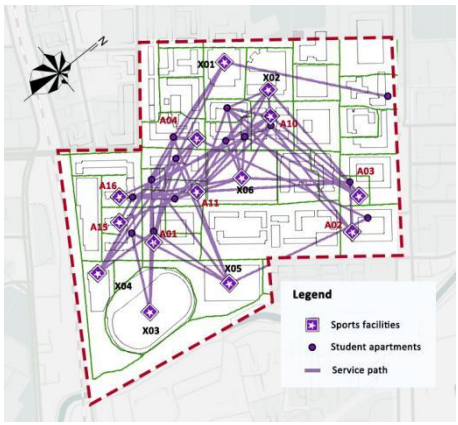
First, the buildings are connected through warm skyways, which can be more convenient and efficient; Secondly, the construction of warm skyways can provide better climate protection for cold cities; The skyway connects different functional areas to form a multi-functional complex integrating life, work, leisure, and fitness; At the individual level of walking, the application of walking skyway guides the green travel mode and promotes human health.



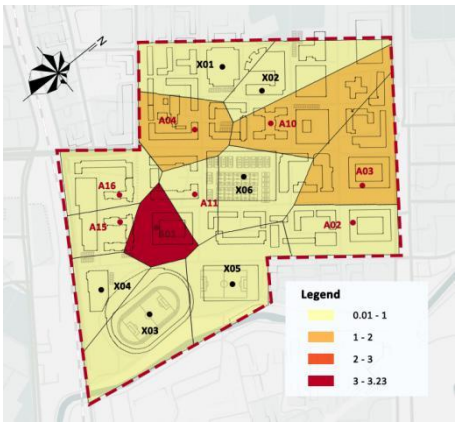

(a)Schematic diagram of POI distribution and service radius




(b)Completeness of service facilities




(c)Location assignment




(d)Service pressure

Figure 10. Updated analysis chart

After the traffic network of the skyway system is added, the walking isochronous circle is shown in the figure below. The area within the walking distance of fewer than 15 minutes accounts for 64.02% of the total area of the campus community, an increase of 27.35% over that before the update. The 15-minute isochron circle from the sports facilities to each student apartment is distributed along the skyway, which greatly facilitates the students' sports and fitness activities.

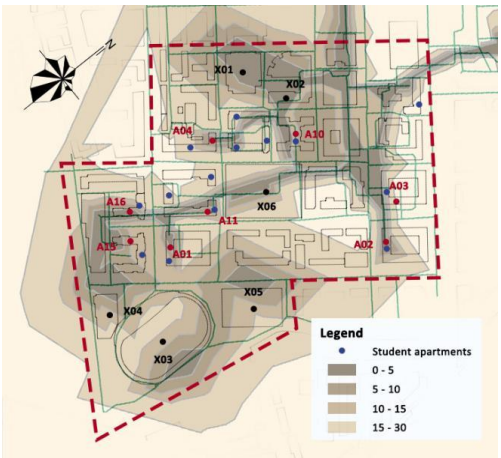



Figure 11. Pedestrian accessibility of updated facilities

Table 4. Proportion of reachability range after update

| Arrival time | Area ratio |
|---|---|
| >30 | 12.51% |
| 15~30 | 23.47% |
| 10~15 | 31.92% |
| 5~10 | 22.18% |
| 0~5 | 9.91% |

## 4 Conclusion

Through the renewal of the skyway function, 8 apartment fitness facilities are added to the campus, which is combined with the existing 6 gymnasiums and gymnasiums to form the community health and fitness system of Harbin Institute of technology based on the skyway system. In addition to meeting the fitness needs of users, the skyway has the characteristics of convenient walking, providing users with cold protection and reducing walking time. The macro layout combined with the life circle makes sports more convenient, thus encouraging users to carry out more fitness activities.

Taking the campus community of Harbin Institute of technology as an example, this paper puts forward the skyway system planning of Harbin Institute of technology through comprehensive consideration of accessibility and functional complexity, focusing on the upgrading of sports fitness facilities and supporting service facilities, and simulates and analyzes the use of the updated fitness facilities, which has been improved in the following four aspects: (1) service radius. The current sports facilities are less selected and less covered, with a service radius of 170-250m. The updated sports facilities are more reasonably distributed, with a service radius of 80-180m, which is significantly shorter than the current situation. (2) In terms of facility perfection. At present, the facilities around the sports facilities are less complete, with only 16.7% of the plots with better facilities, and 78.6% after updating. The distribution of service facilities is more reasonable. (3) Service pressure. Currently, the service pressure of fitness facilities is unevenly distributed. Only 2 blocks have a service pressure index of less than 1. Among the 14 updated blocks, 10 blocks have a service pressure of less than 1. The service pressure of fitness facilities after the update is significantly reduced. (4) Walking accessibility. At present, the service area of each fitness facility with a walking distance of fewer than 15 minutes accounts for 36.67% of the total area of the campus community. Most student apartments have a walking time of more than 15 minutes from the service facilities. The updated isochronous circle is mainly distributed along the skyway. The service area of each fitness facility with a walking distance of fewer than 15 minutes accounts for 64.02% of the total area of the campus community, which greatly facilitates the sports and fitness activities of students.

This study can also provide a reference for other cold cities to promote the construction of healthy communities and build walking-friendly communities.

## Funding

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