On public space design for Chinese urban residential area based on integrated architectural physics environment evaluation

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Abstract. The residential public space is an important part in designing the ecological residence, and a proper physics environment of public space is of greater significance to urban residence in China. Actually, the measure to apply computer aided design software into residential design can effectively avoid an inconformity of design intent with actual using condition, and a negative impact on users due to bad architectural physics environment of buildings, etc. The paper largely adopts a design method of analyzing architectural physics environment of residential public space. By analyzing and evaluating various physics environments, a suitability assessment is obtained for residential public space, thereby guiding the space design.

1. Introduction

At present, the research on the method of designing a residential public space mainly centers on two aspects: one is the study of the humanized public space, and the other is the application of the physics environment evaluation of the public space. The former focuses on the attributes of public space community and the impact on people’s psychology and behavior, while the latter emphasizes digital simulation of physics environment[1]. However, both aspects are closely interacted and integrated with each other without separation. People’s outdoor behavior and psychology are largely affected by the physics environment. Thus, only by combining the two aspects can we realize the process design of residential public space and reflect a sustainable concept in the initial design.

Architectural physics environment is a vital part of people’s living environment. Every day, people are living in a variety of space environments where stimuli from heat, light, sound and other factors are faced constantly[2]. People’s abilities of maintaining the normal physiological and psychological functions and effectively engaging in various kinds of activities depend on their environmental conditions, but people are limited to adjust the spatial environment stimulus. Therefore, it is necessary to adjust and control quantity of stimulus caused by the spatial physics environment, with a view to optimizing the stimulus of environment. Meanwhile, the design plan should also take into account the possible spatial physics environment after construction, and create suitable environment stimulus to provide their users with the best range of environmental stimulus, namely making users feel comfortable[3].

Thanks to the advanced technology, a lot of software can be used to simulate architectural physics environment nowadays. In the design planning, physics environment quality of the public space is the
main basis for evaluating ecological feature in the residential area, so the designer should gradually introduce physics environment to the design, with a desire to create a more pleasing space.

2. **Analysis on architectural physics environments**

2.1. *Research ideas analysis*
The urban space is complicated, variable and uncertain in regard to its physics environment, so is the public space of residential area. Different architectural layouts may exert different impacts on the physics environment. Also, this complexity is far beyond the designer’s experience or manual calculation. Fortunately, digital simulation technology specific to the physics environment makes it possible for scientific and accurate construction and sustainable design planning. Wind, light, heat and sound are main environmental factors affecting residential public space. Among the diverse related simulation software, Ecotect Analysis, CFD and Cadna/A are most commonly used.

2.2. *Analysis on architectural physics environment factors*

2.2.1. *Wind environment analysis*. The wind environment of residential area mainly refers to the wind field formed by natural wind when passing through the building group. An improper construction type or layout likely results in a bad wind environment, making pedestrians uncomfortable and impeding the natural ventilation in buildings and pollutant diffusion.

2.2.2. *Thermal environment analysis*. The outdoor thermal environment mainly refers to the impact of solar radiation on the residential public space environment. The amount of solar radiation incident on the ground determines the change of air temperature, and forms a series of thermal environmental indexes. Thus, solar radiation should be focused on in design planning.

2.2.3. *Light environment analysis*. The light environment in residential area does not involve the traditionally direct light, diffuse light and reflected light. Instead, sunlight is the most critical issue in light environment.

2.2.4. *Acoustic environment analysis*. How to avoid and reduce the impact of noise in residence has long been concerned. The acoustic environment researched mainly includes traffic, especially the environmental noise in road.

2.3. *A combination of integrated architectural physics environment*

![Figure 1. Environmental stimulus analysis](image)
For these 4 kinds of stimuli, thermal environment, wind environment and light environment are more closely related to each other, and they are interrelated in real life and analysis; while acoustic environment is relatively independent (Figure 1). The meteorological data involved in the study are mainly from the *Meteorological Data Set Exclusively for the Analysis of Chinese Architectural Thermal Environment* and the meteorological data downloaded from the Energy Plus website[5].

3. Analysis on the architectural physic environment of residential public space—a case study of a residential area in Changchun

3.1. Selection of research object
Located in Yitong River, Changchun City, Jilin province of China, the research object covers a total area of 18.7hm², and the volume rate of 1.8. The base is divided into 4 groups, centering on the green space. The east of base is the city expressway where a greening protective isolation area is distributed[6]. The public space analyzed largely includes the central green area of community, greening space of 3 groups, and protective greening space and kindergarten at east. In summer, Changchun is extremely hot characterized by sparse cloud and strong solar radiation, and is prone to persistent hot weather; while in winter, Changchun can be rather cold. Therefore, it is quite important for its residents to enjoy a fine architectural physics environment[7].

3.2. Outdoor wind environment analysis
First, a base model is established in Phoenics, and the conditions related to model are set according to the meteorological condition in Changchun, including the wind inlet, wind outlet, wind speed, etc. Then, analysis should be conducted from the most wind direction in winter, summer and all year, calculated by the average wind speed in winter and summer shown in meteorological data. Meanwhile, wind speed is calculated and simulated based on the relationship between wind speed and comfortableness.

Once foreign researchers did a lot of field tests of discomfort resulted from wind in pedestrian areas. As a result, the relation between pedestrian’s comfort and wind speed is demonstrated in Table 1. It is set that the CFD analysis reference level is 1.5m.

| Wind speed (m/s) | Human feeling               |
|------------------|------------------------------|
| v<5              | Comfortable                  |
| 5<v<10           | Discomfort, action affected  |
| 10<v<15          | Very uncomfortable, the action is seriously affected |
| 15<v<20          | Insufferable                 |
| v>20             | Danger                       |

Under the southeast wind in summer, wind environment of base is relatively good, because the entrance, the center green and garage entrance can all form a wind corridor, and each group space can also structure their own gallery. In this instance, wind speed in the front of building is greater than that in the back, which can explain the large wind pressure difference. And this pressure can improve the ventilation inside the building (Figure 2a).

In the case of the prevailing northeast wind all year round, most of the wind environments are favorable except the groups in southwest corner. The upper and lower parts of the central green space are better than the middle in terms of ventilation, and northern and eastern groups enjoy a relatively fine ventilation where wind gallery can be formed (Figure 2b). Based on this, it can well identify the places suitable or unsuitable for activities under the northeast wind.
3.3. Outdoor thermal environment analysis
Following the Changchun meteorological data downloaded from Energy Plus website, Ecotect model is established. Then, the outdoor thermal environment is analyzed on the basis of this model, but only the solar radiation of base is considered. The base faces a stronger solar radiation in summer, and each group covers a relatively strong solar radiation patch except the central greening space and eastern protective greening area. Therefore, the public activity space should be designed in areas with weak solar radiation (Figure 3a).

The central green area, kindergarten and protective greening space have the largest solar radiation in base throughout the year. An intense radiation belt extends toward south and southwest along the central green land, and all groups have an intense radiation patch. First, according to the annual solar radiation degree, it can determine the scope suitable for the human activities in residential public space, and then further determine a proper position based on the nature of activities; second, it can determine the range suitable for planting, in which heliophilous, largely leafy and deciduous plants are fit for the area with strong radiation, while sciophilous and coniferous evergreen plants are prone to weak radiation (Figure 3b).

3.4. Outdoor light environment analysis
According to the meteorological data, the Ecotect model is established to analyze the outdoor light environment. In cold winter, it is best to cover direct sunlight when having body-building exercise in the morning. In this regard, it should choose the place without shadow above to arrange the site and facilities (Figure 4a).

On the contrary, in hot summer, it is best to avoid direct sunlight when having body-building exercise in the morning. Therefore, it should choose the place with shadow above to arrange the site and facilities (Figure 4b).
3.5. A comprehensive analysis of wind, thermal and light

Through gathering images above of architectural physics environment analysis, a superimposition analysis can be conducted for the previous wind environment, thermal environment and light environment.

According to 5 standards: the best, preferable, ordinary, relatively unfavorable, inappropriate, the public space of base is divided and sorted. By overlay analysis on wind, light and thermal environments in summer and winter, coupled with the conditions of annually maximum wind direction and year-round sunshine radiation, a construction suitability evaluation map of public space is obtained.

![Figure 4. Morning sunshine condition](image)

![Figure 5. Comprehensive analysis of wind, thermal and light](image)

It can be seen that few areas have maintained a good architectural physics environment for a long period during a year, except the west of central green space and the entrance for pedestrians. The west of central green space should be built as the foremost hard open space, used for having morning exercise and entertainment of all ages. Meanwhile, areas for activities in summer and winter should be planned according to their special season situation. In accordance with the suitability degree in the map, each group can establish activity space of group in the yellow and green section, but should strictly limit setting the activity space in the blue section (Figure 5).

3.6. Sound environment analysis

The base is located along the urban express way, so the noise will exert a huge impact on future residents. At the same time, the secondary urban road at the south of base and southern Binghe Road can also bring noise to the base to a certain extent. As implied in Cadna/A analysis, the noise situation after the completion of base will be quite bad. In the horizontal distribution, the base noise is fairly serious. Affected by the express way, the east suffers a general noise intensity of over 60db and local noise intensity greater than 75db. For the rest three directions, the street noise is also higher than 60db.
due to the road noise. In vertical distribution, the first row of buildings adjacent to express way suffers noise of over 75db, and the second and third rows are above 65db noise, far beyond the national standard. Given that the largest source of noise pollution in the base is the express way, the sound insulation screen is provided in the surroundings to reduce its impact on the base. The analysis proves that sound insulation screen of 3 meters in height can achieve a better effect if installed along the express way, the border of northern parking lot and the border of southern kindergarten.

4. Conclusion
As residential area is a living place, its design of space environment is particularly important. In addition to fully considering the various influence factors, the design should also cater for the needs of different people, thereby coordinating and unifying the functional, ornamental, and ecological characteristics of residential space environment, and furnishing a comfortable living environment for the residents. Based on thoughts and trials in designing residential area, the paper introduces overall analysis of physics environment into the process of public space design. Furtherly, with Ecotect Analysis, CFD, Cadna/A and other software, the physics environment and space structure are simulated and explained technically. In this way, the land construction suitability of the whole public space gets determined by the final suitability evaluation, which provides a practical guidance for further design.

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References
[1] Junyan Dong, Hong Jin, Jian Kang. A pilot study of the acoustic environment in residential areas in Harbin, towards the questionnaire design. Journal of Harbin Institute of Technology, 2011(2):319-322.
[2] Junyan Dong, Wen Cheng. Based on the Characteristics of Respondents and the Voice of the Urban Neighborhood Public Space Business Facilities Noise Environment Evaluation Research. Journal of Harbin Institute of Technology, 2011(4):103-109.
[3] Junyan Dong, Hong Jin. The design strategy of green rural housing of Tibetan areas in Yunnan, China. Renewable Energy, Vol.49:63-67.
[4] Junyan Dong, Wen Cheng. Research on Optimized Construction of Sustainable Human Living Environment in Regions where People of a Certain Ethnic Group Live in Compact Communities in China.Renewable Energy and Environmental Sustainability, 2016(1):1-7
[5] Junyan Dong, Hong Jin, Jian Kang, Research of acoustic environment in public space in urban residential community in China, Huazhong Architectuce, 2012(2):61-63
[6] Junyan Dong, Hong Jin, Jian Kang, Research on the evaluation of the traffic acoustic environment in public space of residential community based on the characteristics of residents, Architecural Journal. 2013(2):124-129
[7] J.Kang, M.Zhang.Semantic differential analysis of the soundscape in urban open public spaces.Building and Environment.2009(1):265-267