Wind Environment Optimization for Sustainable Development: The China Experience in Urban Air Path Planning

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Abstract. Urban path planning is an exploration of urban sustainable development by urban planners. With the continuous increase of urban scale and urban construction density, cities in China begin to face the ventilation problem faced by developed countries. The article reviews the process of urban air path research in China and summarizes the current situation of urban air path planning practice in China, in order to provide a reference for other developing countries. Based on the reflection on the development of urban air path, this paper puts forward four suggestions for urban air path construction in developing countries, including formulating formal technical guidelines, integrating with national urban planning system, strengthening the support of wind environment research, and constructing evaluation and feedback mechanism.

1. Introduction
The increasing heat island effect and air pollution are hindering the sustainable development of global cities. A number of scholars in the fields of ecology, geography, and architecture have studied it for a long time; a series of theories and methods have been generated. But how to practice effectively in complex urban environments has always plagued urban planners and managers. Building air path has proved to be a viable option [1]. Existing research shows that the urban air path system can strengthen the air circulation inside and outside the city, alleviate the heat island effect and reduce air pollution [2, 3]. Therefore, this article summarizes the research status and construction experience in China to clarify theoretical system, in order to provide a reference for other developing countries.

2. Research origin and development
A review of the origin and development of urban air path planning in China is helpful for us to have a clearer understanding of the research status and deficiencies.

2.1. Research origin
Urban air path refers to the passage that introduces fresh air from the suburbs into the urban area with the help of various open Spaces in the city, which can increase the air flow in the urban area, promote the benign circulation of the atmosphere, and discharge waste gas, heat island effect and haze effect [1, 3]. Developed countries have completed the urbanization process earlier, and the urban climate problem has become prominent in the continuous expansion of urban scale. In order to improve the quality of urban environment, they began to study how to strengthen urban ventilation. The German scholar Kress...
put forward the theory of "effect area -- ventilation path -- compensation area" in 1979 by studying the operation law of local circulation, which became the beginning of urban air path research [4]. With the advance of urbanization, cities in China begin to face the same problem. In 2006 Chinese scholar introduced the concept of air path to China, demonstrated the necessity of construction of urban air path, and started the Chinese exploration of urban air path planning.

2.2. Research development

2.2.1. Stage division. Research on urban air path planning in China has gone through three stages in terms of time dimension. 2006-2009 is the emerging stage, and it began to pay attention to urban ventilation problems and urban air path theory. 2010-2013 is the basic research stage. Due to the influences of urban smog, the research on urban air path planning in china was continuously increased. Since 2014, it has been in rapid growth stage. The deteriorating climate in Chinese cities is a major driver of the research [5].

2.2.2. Focus evolution. The focus of urban air path planning research shows the development process from basic principle research to theoretical system construction and then to planning application exploration. The statistical analysis of the research focus shows that the early research focus on the urban wind environment and the principle of the air path. With the deepening of research, the focus gradually turns to air path construction, air path control and air path application. Recent years the focus have been gradually turned into air path management. The change of research focus conforms to the general law of the emerging research development. From the theoretical basis to the application exploration shows a trend of gradual deepening.

3. Research and practice status

3.1. Theoretical research

The purpose of urban air path research is to provide guidance for the construction of urban air path. Therefore, the current research content is mainly from the perspective of application, including four links of thinking, methods, implementation and management (Table 1).

The research focus of the thinking link includes the role and principle of air path [1, 6], the law of wind operation [3], the relationship between wind and city [7, 8], the relationship between wind and architecture [9, 10], etc. It reveals the attributes and elements of the interactive mechanism between wind and the urban material space, in order to provide the basic theory support for the air path construction.

Method link solves the problems of the identification of air path and the theoretical construction of air path [11, 12]. Identification of air path involves a comprehensive assessment of the urban basement environment and the basic conditions of the urban wind environment and surface roughness distribution. Air path identification involves a comprehensive assessment of the urban base environment, to find out the situation of urban wind environment, such as surface roughness distribution. The theoretical construction of air path needs to consider the ventilation demand and the wind permeability of urban space in a comprehensive way.

The implementation link is to study how to realize the application of the air path construction, and to explore the corresponding construction control and guidance scheme in combination with planning system in China, such as the control elements and indicators [13, 14].

Management links focus on evaluation and maintenance after construction of air path, i.e. air path evaluation and air path management [9, 15].

In general, the current Chinese research is mainly focused on the thinking link and method link, and the research on the implementation link is gradually increasing, and the research on management link is less concerned. This is in line with China's urbanization. With the advancement of urbanization, urban climate problems have emerged, and relevant theoretical research has become a hot spot, and practical
research has also gradually emerged. However, due to the lack of practical experience, a normative method system has not been formed, and at the same time, there is a lack of research on continuous management. With the increase of practical cases, related construction problems will gradually be exposed, and management needs will push the research to focus on the management link.

| Table 1. Framework of research contents and factors |
|---------------------------------------------------|
| **Research links** | **Research issues** | **Research contents and factors** |
| Thinking (Basic theory) | Roles of air path | Air pollution, heat island effect, urban heat distribution |
| | Principle of air path | Hydrodynamics |
| | Law of wind operation | Prevailing winds, local circulation, topographic winds, urban microclimate |
| | Relationship between wind and city | urban scale, urban structure, urban road network, urban green space |
| | Relationship between wind and architecture | Street form, architectural layout, building height, architectural form |
| Method (Air path construction) | Identification of air path | Wind environment assessment, surface roughness, surface thermal conditions |
| | Theoretical construction of air path | Urban ventilation demand, urban space wind permeability, air path construction standards, computer wind field simulation |
| Implementation (Air path control) | Control method | Urban construction, industrial distribution, urban energy consumption |
| | Control factors and indicators | Development intensity, building height, street width, building orientation, building frontage |
| Management (Feedback and adjustment) | Planning and application | Air path practice, laws and regulations |
| | Air path evaluation | Evaluation mechanism, method and standard |
| | Air path management | Management mechanism, main body and control method |

3.2. Practical exploration

3.2.1. Planning strategy. In the planning strategy, the exploration and innovation of current research mainly focus on two directions. The first is the collaborative planning with urban multi-system. Most of the urban air path construction is based on the built urban environment, and few are reserved in the construction of the new city. Therefore, coordinating the relationship between air path system and other urban systems has become the key to air path construction. The current research focuses on how to leverage existed systems to reduce construction costs. It includes collaboration with urban structure [16], collaboration with urban green space system [8, 17] and collaboration with urban road network [7]. The second is grading and zoning planning. Different levels of urban areas have different ventilation needs and purposes, and the same level of areas also have different characteristics. We usually use grading and zoning planning strategies to meet the differentiated needs [13, 19].

3.2.2. Planning case. The practice of Air path planning in China is still at the initial stage. It mainly focuses on the pilot exploration of urban planning in large and medium-sized cities. Hong Kong, Wuhan and Changsha have earlier carried out urban air path research and construction, and in recent years, Beijing, Xi'an, Nanjing, Fuzhou, Anqing have also carried out special research. At present, in terms of practice, the government mainly entrusts universities and other scientific research institutions to carry out research, and then brings the research results into the urban planning management system. The planning idea is mainly based on the localization practice of the planning strategy in Stuttgart, Germany,
to explore the method and strategy of air path planning and construction applicable to this city. At the same time, these explorations have different emphases on specific contents.

Hong Kong focuses on climate assessment to provide planning and design basis for the improvement of areas that existing climate problems. Wuhan pays attention to the integrated planning that can effectively alleviate the urban heat island effect, and establishes the air path system in different levels and strengthens the construction control guidelines. Xi'an proposes a collaborative planning scheme with the urban scenic area space, in order to improve the overall ecological pattern of the city. Beijing pays attention to the current situation of urban land use and the realistic conditions of air path construction, and emphasizes the meteorological condition foundation of air path planning and construction. Changsha lays particular emphasis on the concrete implementation and management of urban air path, and compiles technical guidelines for ventilation of urban main functional areas.

4. Conclusion and suggestions

The current research covers the whole process of urban air path planning from theoretical construction to method exploration, from practical application to follow-up management. A comprehensive and systematic framework for urban air path planning research and application has been established basically. However, there are also insufficient underlying principles, such as the insufficient exploration of urban wind operation law, the low degree of coordination with urban multi-systems, and the disconnection of multi-level air path construction. At the same time, the practical application is insufficiently integrated with the current urban-rural planning system, and the planning control and management are weak. Due to the lack of evaluation and feedback mechanism, there is no widely accepted methodology system and practice paradigm.

Based on the systematic review of the current research, and combined with the urban development background of developing countries, we think that the research on urban air path planning in China and other developing countries should be extended to the application layer. There are three specific suggestions.

4.1. Formulating formal technical guidelines

The experience of China's urban air path planning shows that a unified technical guideline can make the planning more scientific and effective. As a systematic project, urban planning cannot be separated from the leadership of the government. Similar to other types of special planning, the compilation of relevant technical guidelines can quickly promote the implementation and application of planning and establish a relatively unified framework for the practice of various cities. Under the background of low planning technology level in developing countries, technical guidance is the key to ensure the air path planning is scientific and effective.

4.2. Integrating with national urban planning system

Although urban air path planning has been developed for more than ten years in China, and planning practice has been carried out in dozens of cities, it has not yet become a technical content which is generally considered in urban planning systems. During the process of compiling planning, the government has less special research on the wind environment and urban air path planning. The planners also pay little attention to the wind environment in the actual projects. An important reason is that China has not been able to integrate urban air path planning into the existing national planning system, and the compilation of urban air path planning cannot be guaranteed by a reliable procedure. Therefore, when other developing countries are faced with urban ventilation problems and need to carry out urban air path planning, they should incorporate air path planning into their national planning system as soon as possible, so that air path planning can become a legal content.

4.3. Strengthening the support of wind environment research

Developing countries should strengthen the research on urban wind environment before urban air path planning, because the foundation of air path construction is the basic principle of urban wind operation.
As an independent part of urban wind environment research, the research boundary of urban air path should be extended and the research findings of other part of urban wind environment research should be introduced into air path planning. Macro-level control only provides basic conditions for the improvement of urban wind environment, while the improvement of medium-micro spatial scale where human settlements activities in can ensure that the benefits of urban air path construction be implemented into the urban space that can be directly felt.

4.4. Constructing evaluation and feedback mechanism

A complete evaluation and feedback mechanism can effectively improve the long-term effectiveness of urban air path planning. Developing countries, including China, often make the mistake of focusing on construction rather than management. This makes planning and construction a short-term activity in many cities, and it decayed rapidly after construction was completed. Urban planning is a long-term tool for urban development, and it can't be without evaluation and feedback. Therefore, it is a necessary work to construct the evaluation and feedback mechanism of urban air path planning, which can comprehensively monitor the planning and construction, timely find problems and deficiencies, and timely adjust the planning according to the new urban development trends.

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