663: Towards urban design guidelines from urban morphology description and climate adaptability

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Abstract

This paper discusses how to make urban climatology a better help for the formulation of urban design guidelines. Therefore it restudies the relationship between urban climatology and urban design. It proposes a cooperation mode to make more effective communication between urban climatology and urban design: the appropriate urban form description methods at the beginning and the pertinent expression form of guidelines at the end of the mode. And then it suggests a research frame dedicated to urban design guidelines in hot-summer and cold-winter area, and takes the *Sixin* project for example to explore how to express climatic design guidelines for urban forms control.

Keywords: expression form of design guidelines, urban form description method, urban design for climate adaptability, urban form typology, morphological indicators

1. Introduction

In the design criterions promulgated by the Ministry of Housing and Urban-rural Development of China, there are few provisions for climatic design concerning urban scales [1]. For example, in the latest design criterions for energy efficiency [2], the relevant provisions for urban form control still remain in building scale (shape coefficient, glazing ratio and building orientation). Therefore, it is necessary to develop the appropriate climatic design guidelines in urban scales to complement the design criterions in hot-summer and cold winter area. In the project *Design Guidelines of Urban Characteristics of Sixin Area in Wuhan* [3], except collecting design experiences, we faced to the research of urban design and urban climatology to search for some useful results that can help the formulation of design guidelines. But there are few researches that we can find to dedicate to the formulation work. To search for the reason, we turn back to the cooperation mode of urban climatology and urban design.

As Oke [4] have argued, from a research view, urban climatology can become a more predictive science so that its findings can be of direct value in urban planning and design. Mills [5] proposed that examining the relationship between urban forms and climate can employ the results of urban climatology into urban design guidelines.

However the urban designers haven't well communicated with climatologists before formulating the urban design guidelines. Take our work in Sixin project as an example, without proposing an urban forms research frame to explain what we want, we blindly search in a mass of research results for something that has the possibility to be beneficial to the local climatic design. On the other hand, when studying the relationship between urban forms and climate, the climatologists employed various qualitative and quantitative urban form description methods. For example, Ratti [6] presented a digital elevation model (DEM) which is an image that has a grey level proportional to the level of the urban surface. Chen [7] divided a plot into meshes with corresponding numbers to define locations of buildings (Fig.1), etc. These methods may give big contributions to urban climatology, but meanwhile bring difficulties to the designers to digest and translate the results for the formulation of design guidelines. These ineffective communications are one of the reasons that lead to difficulties to employ the research results into urban design guidelines.

Fig 1. Urban form description methods: left-Ratti, right-Chen

As Golany [6] have proposed, it is the urban designer's responsibility to provide climatic urban forms based on the study of local climate. Therefore, we need to think about what we could propose to improve the cooperation of urban climatology and urban design, and what we could propose to formulate urban design guidelines.

2 Proposed works for the Cooperation Mode

We are focusing on the study of urban forms [5,9] for climatology and urban design, but we lack of a unified language for communication: the appropriate description methods of urban forms and the pertinent expression form of guidelines. Therefore, above all, we need to search for adaptive description methods of urban forms for establishing a better cooperation mode between urban climatology and design guidelines.

In urban climatology, with urban form typology and morphological indicators, Golany and Oke[8,9] demonstrated respectively that urban form typology and morphological indicators, can

well qualify and quantify the characteristics of urban forms in the study of urban forms and their climatic performance. In urban design guidelines, typology and indicators are well known as the general design tools and languages. They have good design operability and can be well translated and expressed in design guidelines. Brown [10] made big efforts on the study of climatic design with the strategies in the form of typology and indicators especially in building scale. This encourages the study to employ these tools and languages in urban scale.

Based on the synthetical consideration of studies in urban climatology and in urban design guidelines, we propose that urban form typology and morphological indicators can be adaptive methods for the formulation work of urban design guidelines. Meanwhile we propose the pertinent expression forms of design guidelines that can help us better digest and translate of relevant research results.

Therefore, with these appropriate description methods, we propose and study the works at the beginning and the end for the cooperation mode of urban climatology and urban design (Fig.2) and for encouraging the research results to be applied more effectively in climatic urban design guidelines.

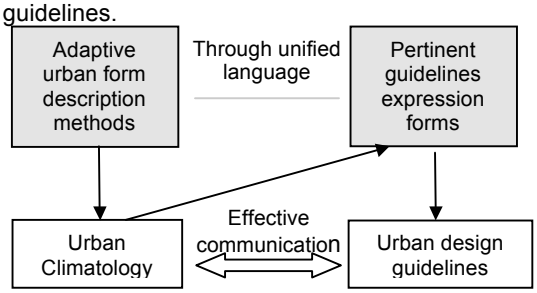


Fig 2. Proposed cooperation mode of urban climatology and urban design

3 Urban Form Description Methods at the Beginning of the Mode

Above all we need to trim and re-organize the results concerning urban form typology and morphological indicators; and then taking the existing research as reference, we propose a research frame corresponding to hot-summer and cold winter area for climatic urban design.

3.1 Research directions

The studies from theoretical urban forms are based on the archetype forms that are simplified urban geometry extracted from real urban complex. We can acquire the significant principles for local climatic design from theoretical urban forms' studies [11,12]. The studies from real urban forms can be a good reference or aid design in real urban projects [13,14], but few can dedicate directly to design guidelines. Therefore most of the studies that we cite are from the view of theoretical urban forms.

3.2 Research dedications to design

The following two urban form description methods usually benefit mutually and are employed simultaneously in urban forms analysis. While for better studying their features and dedications, we elaborate the examples respectively.

3.2.1 Research dedications of urban form typology

For generic built forms, Steemers [15] proposed six archetypal forms- Pavilion, slab, terrace, terrace-court, pavilion-court, court from simplified synthetic urban fabric and compared their incident solar radiation for the London site. Okeil [16] developed a generic built form pattern named residential solar block (RSB). After comparing the direct solar radiation distribution on urban surfaces among RSB, slab and pavilion-court, he proposed RSB as an interesting form for energy efficiency urban design in the cities at latitude 25°.(Fig.3)

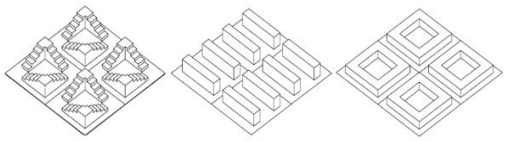


Fig 3. RSB, slab and pavilion-court [16]

For street, Ali-Toudert [17] developed three street form patterns for the study of hot-dry climate: street with galleries, asymmetrical form with large openness to the sky, asymmetrical form with overhanging façade (Fig.4). She proposed the asymmetrical form with overhanging façade is advisable for more shading in summer and more internal solar access in winter.

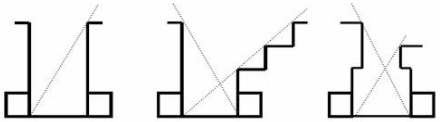


Fig 4. Three street form patterns [17]

For urban district, Fu [18] summarized the six general residential block patterns: parallel columns and rows, staggered rows, staggered columns, oblique rows, surrounding-style and free-style. He then demonstrated that the ventilation of staggered rows pattern, oblique rows pattern and free-style are better than parallel columns and rows pattern and surrounding-style. The former patterns are preferred in hot-summer and cold winter area. Cheng [12] proposed the urban form patterns with horizontal and vertical random, and proved that horizontal and vertical randomness has better performance on building solar potential in San Paulo, Brazil.

3.2.2 Research dedications of morphological indicators

Lang [2] and Fu [18] took a rectangular block to study the morphologic indicators such as shape ratio(S/V), main façade orientation and glazing ratio. These indicators have well dedicated to building design criterions for energy efficiency in hot-summer and cold-winter area.

For generic built form, Brown [10] defined directional space ratio (H/W_1, H/W_2 etc.) for court space to quantify the relation between directional H/W, court wind and incident solar radiation. That could give suggestions for court space control.

For street, we take space ratio (H/W) and street orientation as the basic indicators. A number of useful regulations existing between space ratios, street orientation and microclimate of street canyon have been found in various climate cases, they are potentially helpful to the establishment of urban design guidelines governing street dimension [19,20].

For urban district，quantification work becomes more complicated. We start from a simplified trimmed pattern that is composed of the same generic built form. A system of morphological indicators presented by Panão is exhaustive [21]. He combined variable values of each indicator to explore the optimum urban building efficiency potential in mid-latitude climate (35-50°). It gives suggestions of dimension control of district for solar potential design. From the theoretical urban forms, it is more difficult to make progress in the relationship study of irregular arrangement and climate, therefore fewer results could dedicate directly to urban design guidelines.

3.3 Research frame corresponding to the local climate

The studies that we have analyzed reveal that each urban form research well corresponds to its local climate. For example, we can't employ the results of hot-dry climate into hot-humid climate [11]. The current situation of the research in hot-summer and cold-winter is that there are large numbers of studies in architectural scale but few are involved at the urban scale [1]. Thus we need to establish a pertinent research frame in this local climate concerning urban form typology and morphological indicators.

3.3.1 Corresponding research of local climate

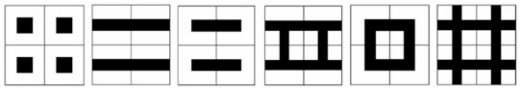
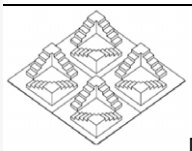
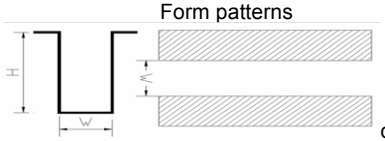
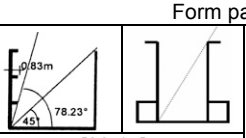
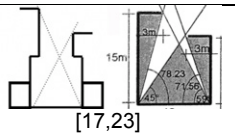
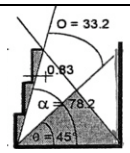
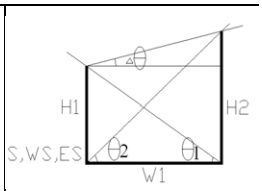
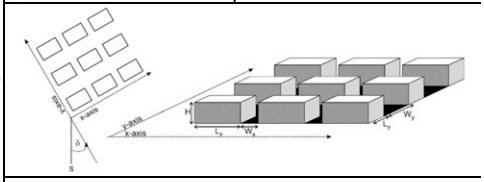
Because climatic urban design is the synthetical consideration of urban climate, we need to respect the research for all the physical parameters and various aims (comfort, energy efficiency etc). To simplify the problematic, we start from the analysis of urban forms' performances on physical parameters such as solar radiation, heat, air temperature, wind, humidity etc. and integrate the complex aims later. Meanwhile hot-summer and cold-winter area shows a representative special climate that summer and winter conditions are totally opposite [18]. The climate conditions that we want to ameliorate are contradictory in summer and winter, day and night. As a result, we need to study the climatic performance of the urban form cases in summer and winter, day and night respectively and comparatively.

3.3.2 Corresponding research of urban forms

Based on the review of previous studies on urban forms, we propose a research frame firstly with the basic urban form patterns and morphological indicators; then we provide the derived direction (with preventative cases) to develop urban form patterns and morphological indicators corresponding to the local climate. From the view of urban scale, we classify the research scales with generic built form, street and urban district.

The general research frame is summarized in the following table (Table 1).

Table 1: Corresponding research frame of urban forms

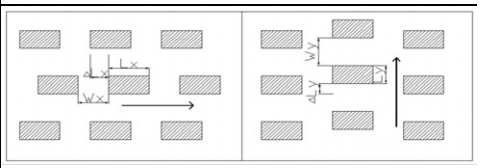
<table>
<tr><th colspan="4">Generic built form</th></tr>
<tr><td rowspan="3">Basic reference</td><td colspan="3">Form patterns</td></tr>
<tr><td colspan="3">  [15]</td></tr>
<tr><td colspan="3">Morphological indicators
Plot ratio, site coverage, ratio of passive to non-passive floor area, sky view factor, ratio of total surface area to volume</td></tr>
<tr><td rowspan="3">Derived direction</td><td colspan="3">Form patterns</td></tr>
<tr><td>  [16]</td><td colspan="2">  [22]</td></tr>
<tr><td colspan="3">Develop with building height variation like the cases; with the concept of solar envelop and to maximize solar available in winter.</td></tr>
<tr><th colspan="4">Street</th></tr>
<tr><td rowspan="3">Basic reference</td><td colspan="3">Form patterns</td></tr>
<tr><td colspan="3">  canyon</td></tr>
<tr><td colspan="3">Morphological indicators
H/W, street orientation</td></tr>
<tr><td rowspan="6">Derived direction</td><td colspan="3">Form patterns</td></tr>
<tr><td>  [23,17]</td><td colspan="2">  [17,23]</td></tr>
<tr><td>Develop with overhanging facade and gallery for shading and cooling in summer.</td><td colspan="2">Develop with overhanging form and height difference of both sides for shading in summer and solar access in winter.</td></tr>
<tr><td colspan="3">Morphological indicators</td></tr>
<tr><td>  [23]
Openness to sky α: to quantify overhanging concerning shading:</td><td colspan="2"> 
H_1/W, H_2/W; spacing angle θ_1, θ_2, spacing angle difference $\Delta\theta$: to quantify height difference of street both sides linking with solar access.</td></tr>
<tr><td>Envelope ratio: GA/(GA+WA), GA-the total open ground area, WA-the total area of bordering walls: concerning cooling effect. [24]</td><td colspan="2"></td></tr>
<tr><th colspan="4">Urban district</th></tr>
<tr><td rowspan="3">Basic reference</td><td rowspan="3">Regular arrangement</td><td colspan="2">Form patterns</td></tr>
<tr><td colspan="2">  </td></tr>
<tr><td colspan="2">Morphological indicators
Floor space index FSI, grid azimuth δ, number of floors n,base block dimension L=Ly, building</td></tr>
</table>

depth ratio l=Lx/Ly, directional aspect ratio H/ Wx & H/ Wy, directional street width ratio w= Wx/ Wy. [21]

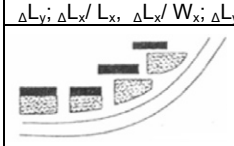
Derived direction

Half-regular arrangement

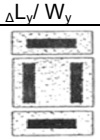
Horizontal



Staggered rows and staggered columns patterns: Directional staggered distance $_{\Delta}L_x$, $_{\Delta}L_y$; $_{\Delta}L_x/ L_x$, $_{\Delta}L_x/ W_x$; $_{\Delta}L_y$, $_{\Delta}L_y/ L_y$, $_{\Delta}L_y/ W_y$

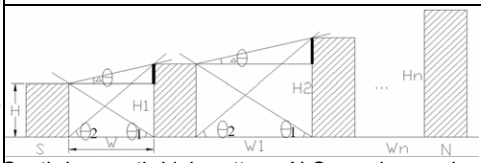


Oblique[18]



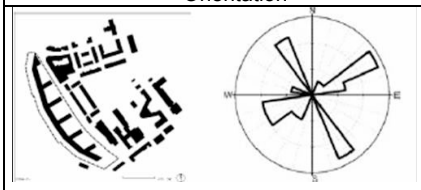
Surrounding[18]

Vertical



South-low north-high pattern: N-S spacing angle difference $_{\Delta}\theta$; $W_n=W\cdot(tg\theta_2/tg\theta_1)^n$, $H_n=H\cdot(tg\theta_2/tg\theta_1)^n$; $_{\Delta}\theta=\theta_2-\theta_1$, $tg_{\Delta}\theta=_{\Delta}H/W$.

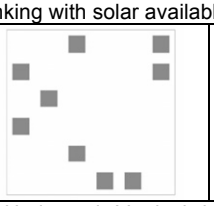
Orientation

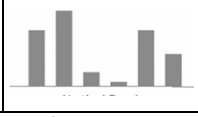


[25]

Orientation rose: showing SVF-weighted facade areas, oriented towards each azimuth sector, linking with solar available. [25]

Irregular





[12]

Horizontal Vertical irregular arrangement is taken as a random form pattern in our study.

The parts of derived direction in the research frame are not exhaustive, but to give concepts and ideas to develop urban form patterns and morphological indicators in research. Combining different form elements and climate aims, we can derive diverse research plans, therefore numbers of research works need to be done in hot-summer and code-winter area.

4 Design Guidelines Expression Forms at the End of the Mode

4.1 Position of design guidelines

For urban climate adaptability in urban design, it is impossible to request all the urban designers to firmly control urban climatology. Moreover totally depending on simulation for climatic design also means a disaster for urban designers. It may deny most of the initiative of urban designer and let them become passive in climatic design.

Design guidelines can translate the research results and regulations into general design languages. They can help designers to better recognize urban climate and allow them become more active and effective in climatic design. Moreover it provides to designers enough space to play in the conceiving at the draft design stage. Therefore draft design stage can be well launched without or before simulation work. Thus simulation is placed as a work after the draft design stage, used to improve or validate the draft plans and to aid design more precisely and efficiently facing climatic impacts.

No matter how well an urban designers control the knowledge of urban climatology, his experience is always limited. Urban design guidelines for climate adaptability are a place to organize all the useful design experiences and research results. The work that we have proposed for the guidelines formulation is a mode allowing more extensive communication and cooperation of all the urban designers and climatologists. Moreover it can be validated and improved in the feedback of urban project practice.

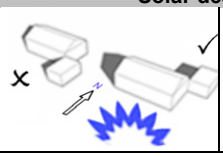
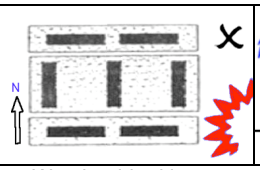
Serving for urban designers and architects, the climatic urban design guidelines need to be expressed in the form that designers prefer and can be well understood. For example in the form of sketches of conceptual design [12]. Here we focus on the proposition mainly concerning the regulation and characteristics of urban forms that are adapted to the local climate, and we need to explore the operable expression forms for the proposed urban forms.

We turn back to the case study of Sixin Project in hot-summer and cold-winter area and discuss how to express urban design guidelines based on urban form typology and morphological indicators.

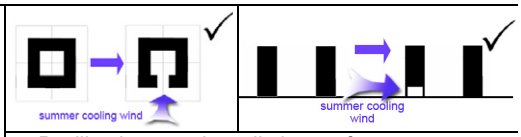
4.2 Qualitative expression forms of design guidelines

It proposes to use good urban form patterns that adapt the local climate and to avoid bad urban form patterns. We show the studies in table 2.

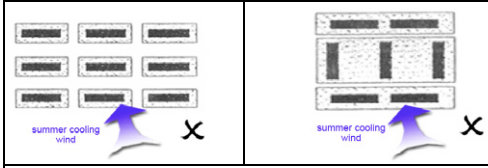
Table 2: Examples of the qualitative expression forms

Solar design	
Generic form	 ▪ For solar access in winter, open side of generic built form tries the most to face to south. [26]
District	 ▪ We should mitigate west and east solar radiation on facades in summer and gain more solar radiation in winter, surrounding pattern make more facades oriented east and west, it is better to be avoided (left fig above). [18,27] ▪ We should avoid the south-high north-low pattern, it disturbs seriously solar access in winter(right fig above)[27]
Ventilation design	

Generic form

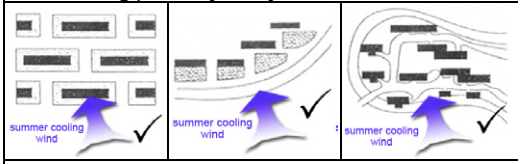


▪ Pavilion has good ventilation performance;
▪ Court could be improved for better ventilation - open one side facing to the dominant orientation of summer cool wind;
▪ Slab could be improved for better ventilation - modify to piloti slab. [27]

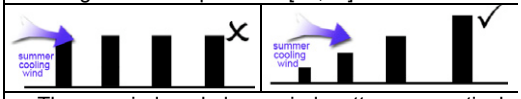


▪ Parallel columns and rows, surrounding pattern are disadvantageous for natural ventilation in summer that we'd better avoid, especially surrounding pattern.[18,27]

District



▪ Staggered rows, oblique rows and free style have better ventilation in summer than the two patterns above; it is more desirable to arrange building with these patterns. [18,27]



▪ The up-wind and down-wind pattern or vertical random patterns have better nature ventilation performance than vertical uniform pattern. [18,27]

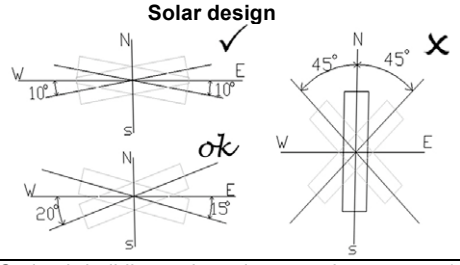
4.3 Quantitative expression forms of design guidelines

It requires not only to restrict building or urban forms for climate adaptability but also to allow design flexibility. We show the studies in table 3.

Table 3: Examples of the quantitative expression forms

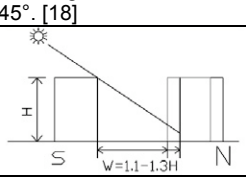
Solar design

Building



▪ Optimal building orientation: south to east 10°-south to west 10°;
▪ Appropriate building orientation: south to east 20° - south to west 15°;
▪ Inadvisable building orientation: north to east 45° - north to west 45°. [18]

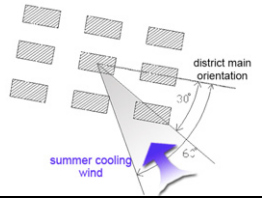
District



▪ To meet the request of enough solar hours, solar distance is requested in winter: 1.1-1.3H (1.3H - 2 solar hours, 1.2 H - 1 solar hour in winter. [18])

Ventilation design

District



▪ The angle between the district main orientation and dominant orientation of summer cool wind are better to be controlled between 30°-60°, meanwhile maintain sufficient streets widths. [10,26].

Overall the suggestions for the expression forms of design guidelines are hoped to be diverse and flexible, and the two expression forms could combine mutually for the formulation work.

5. Discussion and conclusion

5.1 Study from the view of urban forms

Based on the study of Sixin project, we could find that the guidelines mainly concern qualitative work, while it lacks of the quantitative work. We should pay more attention to develop the research that can bring quantitative results.

Moreover, we should be very cautious when understanding and translating the research results. Therefore we can't take directly the results of other researches without considering their particular research context (climate type, site, scale, surface materials etc). For example, the equation of "maximum heat island intensity" (1) concluded by Oke [9].

$$\Delta T_{u-r} = 7.54 - 3.97 \ln(H/W) \quad (1)$$

It showed that the narrow street canyon or the larger H/W, increase the $T_{max.}$. Without carefully considering the particularity of his research, we will wrongly derive that narrow streets are the wrong approach for hot climate as they tend to increase already high temperature. Yet we know that the traditional hot-arid cities are very compact with deep streets and provide cooler time than rural area at the hottest time of a day. This apparent contradiction is due to simplistically understanding the equation. Oke mentioned that the conclusion can just be validated in the climates of American and Europe cases at the urban scale with special surface materials that he assumed.

5.2 Study from broader view

To study from a broader view, we explain at first the factors that urban design needs to be considered synthetically. For climate conditions, it needs to consider all the climatic elements and the opposite conditions such as in summer and winter, day and night. For objectives of climate adaptability, it needs to think about outdoor thermal comfort, building energy efficiency etc. For urban scales, it needs to manage the factors of all scale from a building to urban district. For strategies, it needs to integrate all the aspects of urban forms, surface materials, architectural strategies etc. Comparing with urban design, a research plan of urban climatology normally studies only one point or one aspect. There are also good examples exploring the researches with diverse problematics [7,9,16]. Therefore we

encourage the research to consider more complicated factors such as: multi-climatic elements, opposite climate conditions, multi-objectives, multi-scales, multi-strategies etc. That means we need a broader and diverse cooperation between urban climatology and urban design.

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