

Adding analysis of urban heat island effect in GIS system and applying them in urban planning*

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Abstract: In recent years, the application of GIS in urban planning has attracted the attention of more and more urban planning designers, and a new problem—urban heat island has arose in urban planning. The main aim of the paper is to find ways to connect urban heat environment with GIS system, and to simulate different island effect of different urban planning by using CFD. Then find a reasonable way for ecological urban planning. Of course, we firstly introduce the relation between the City Heat Island Effect and urban planning, then enumerate a practical experiment of Chongqing University. Because of people's requirement of the better living environment and the ecological development of the whole city even the whole globe, we should synthesize and analyze the practical information, which base on the natural factors such as earth surface environment, climate, rainfall amount and wind field, and with these artificial factors such as population, politics and cultures, then design the optimum project of urban planning.

Keywords: city heat island effect; ecological city; GIS; CFD

1. Introduction

It has been known for a long time that urban centers have average temperatures higher than their less developed surrounding. This phenomenon—the urban heat island—was first advanced by Lucke Howard—a chemist of English in 1820 [1]. It has been two hundred years since City Heat Island was concluded. Many experts and scholars have made research of it. Some reasons have been concluded and kinds of means to prevent it have been found. But all of this couldn't get rid of Urban heat island and reduce its intension. So this article brings forward that ecological urban planning is the essential measure to prevent City Heat Island, and its aim is to establish a GIS system of outer physical environment, sequentially make ecological urban planning.

2. The analysis of City heat Island effect and measures of fathering CHIE

City Heat Island Effect (CHIE) is a special climate, which is caused by human behavior.

2.1 the disadvantage of CHIE

The Heat Island affects the small weather in district of every locality and directly or indirectly brings the disadvantage to the resident life.

1) The CHIE makes temperature higher, especially in the south city.

2) The City Heat Island causes a series of health problem. In blazing hot summer, the Heat Island causes the city wet environment worse. At the same time, the water vapor from the earth surface congregates in the sky. This phenomena dues to people getting calenture and eruption. The residents of city island center often have other syndrome such as less appetite, assimilation, abscess and gastroenteritis etc. Further more, it's recorded, 20% of the residents are suffering form neural illness causing by heat island. For example jittery, dysphoria, hypochondria [2].

3) It's said that the higher temperature of city center caused by City Heat Island is useful to the cold area. But Dr Watkins and Dr Kolokotroni concluded that the change of cooling load is bigger than heating load by studying and analyzing the change of cooling load and heating load of London. It's shown in the figure 1. Compared with London Chongqing is very hot, cooling load account for the most. So the change of cooling load must be far bigger than heating load change [3].

2.2 Reasons of city heat island effect

Large numbers of experiments proved that the

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reasons of CHIE are mostly caused by human being. The size of city, the number of individuals, such as inhabitants or housing units per unit of area will effect CHIE.

1) Because the higher density population consumes huge energy, large exhaust gas with much thermal energy was ejected every day. Such as industry discards hot, house heating or air condition and other form thermal source releasing energy. We can plan to reduce the density of the city to construct a ecological city and increase the city-visibility ξ which is given by

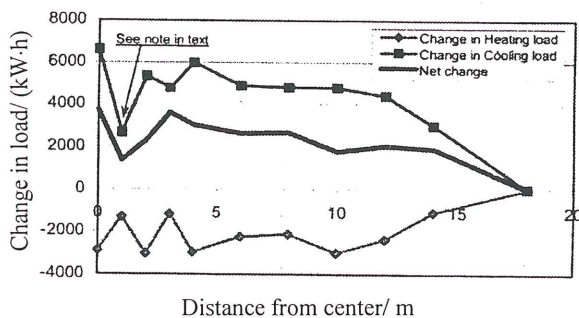


Fig 1. annual heating and cooling load by distance from the center of London

$$\xi = h/d \quad (1)$$

where h is the height of building of roadside, d is the breadth of road.

The buildings are higher; the city heat island effect is more serious. Equally the road is narrower; the CHIE is more serious.

2) The road surfaces such as concrete, bituminous, macadam, blacktop of city have low reflectivity but high thermal capacity. This kind of road surfaces could absorb a great deal of thermal energy, and release less thermal energy, which results in that the intensity of City Heat Island Effect in the evenings is more stronger than in the daytime [5].

3) Trees and grass are very important in reducing CHIE intensity. But in the modern city the greenbelt is smaller and smaller, which prick up the CHIE. Transpiration of leaves can enhance the air humidity, so district climate can be adjusted and improved. The acreage and the distributing of greenbelt are also the emphases of ecological city. Different distributing could have different effect. Withal the size and position of pool is also one of the factors.

4) There is too much Carbon dioxide to release heat. High concentration of Carbon dioxide and smog reduce the radialization from earth to atmosphere. The main

way to control pollution. For instance, Chongqing has done very well in this aspect and gain remarkable achievement. Since 1997 in Chongqing the releasing of exhaust gas has been reduced, the visibility of city has increased, at the same time the temperature at night also becomes low. The mountain cities such as Chongqing need ecological planning and natural ventilation.

5) The skyscrapers are so dense that many deadwater areas and canyon-areas are formed. In these areas, the air hardly flow, which make the temperature increase constantly. Some experts of city planning advise that the shape of buildings should be changed according to the practical situations in different locations, and the relative position of buildings also should be adjusted in different regions. So the thermal diffuse coefficient is defined as followed.

$$\eta = g/(g_1 + g_2) \quad (2)$$

where η is the thermal diffuse coefficient; g is the quantity of heat expelled out of one region everyday, g_1 is the quantity of heat entered into one region everyday, g_2 is the quantity of heat produced in one region everyday.

The quantity of heat entered or produced everyday in every region should be reduced, at the same time the quantity of heat excluded also should be increased. If one side were ignored, the CHIE would be worse.

The above-mentioned measures are all base on the city planning. When we make city planning, the first place is to plan a reasonable disposal of greenbelts, pools, gardens and buildings. Based on this precondition, several things should be done.

First, city-visibility should be improved. The practical way is to widen the roads and lower the buildings. Second, natural ventilation should be enough combined with structural ventilation to get better airflow. This need planner think more about the local climate in the round. Third, city planning is affiliated with GIS (Geographic Information system). This is the ultimate measure to prevent and control CHIE. GIS including kinds of geographic information. We aim to add thermal information to it, and create a Thermal-environment System. Which could make the problem of CHIE will be easier to be solved.

3. The practicality of Phoenics simulation of City Heat Island

3.1 Establishment of Phoenix model

We selected the campus of B District of Chongqing University as the original model. But we didn't take all practical information to the model, only parts of the campus were thought of. In the research, the wind field was the first step of this experiment. The assumable model is Fig. 2.

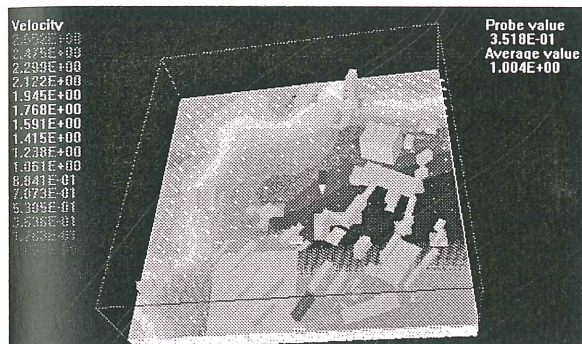


Fig. 2 The model of B District of Chongqing University

Phoenix software is one of CFD software. The mostly equations used in this simulation are these:

The continuity equation is given by

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_j)}{\partial x_j} = 0 \quad (3)$$

where ρ is the density of the calculative air; u is the velocity of inlet air; t is the time.

The momentum equation is given by

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_j)}{\partial x_j} = \frac{\partial}{\partial x_j} \left[\mu \frac{\partial u_i}{\partial x_j} - \overline{\rho u_j \mu_j} \right] - \frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_i} \left[\mu \frac{\partial u_j}{\partial x_i} \right] + \rho g_i \quad (4)$$

where p is the pressure of the air; $\overline{\rho u_j \mu_j}$ is the instantaneous date.

In this simulation, the annual average of velocity is 2.2 m/s. In the figure2, we could see that in someplace the velocity is 2.652 m/s, which is bigger than the average, and in some place the velocity is 0.000465 m/s, which is very small. In the same absolute height places the velocities are different. Because that they have different relative heights. The Phoenix only give simulation picture of the absolute height. So it couldn't fit for mountain city simulation. The aim of our experiment is to contrive a new Phoenix according to mountain city practice.

3.2 Discussion on experiment results

From the experiment we could see density of buildings can effect the natural ventilation. The main aim of this article is to discuss how to establish a city planning system of ecological city. Especially in the mountain city, physiognomy is an important factor in urban planning and it could affect the wind field and the wind velocity. In this model, the wind velocity is descending from 2.652m/s to 0.176m/s, even more some place the wind velocity is almost zero.

4. CHIE combined with GIS

Our ultimate aim is to add the CFD simulation of mountain city to GIS, and apply it to city planning. Today, GIS is very popular in many fields. Even in city planning also begin to apply GIS, but the use of GIS in practical project haven't been maturate. A perfect GIS haven't been formed, especially in thermal environment and city planning. So we try to use CFD to simulate the change of city quality of thermal, and try to find a practical way to solve City Heat Island Effect, then add the result to GIS and get a thermal-GIS for city planning.

5. Conclusions and future work

For the case of City Heat Island Effect, the only way of solving CHIE is to establish a reasonable city planning system, which needs not only thermal research but also GIS study. In this article, we bring a piece of suppose forward, and refer to only a small part experiment. In fact, there are many jobs need to do in order to carry out the plan, such as the thermal and the pressure simulations are our next step. Certainly we still need consider other factors. But in the future we certainly could bring out a perfect ecological urban planning system.

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