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URBAN CLIMATOLOGY AND APPLICATIONS

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Abstract: The city development of Germany follows three main directions, which are influenced by the demographical development. Conversion of industrial, military and non used train track areas to housing and service centres, the economical concentration and more densely built up inner cities are named as new urbanity. Climatologically speaking this development leads to an increase of heat island, air pollution and a reduced ventilation of the cities. At the example of Kassel it can be seen that this development has positive and negative factors. Urban climate studies can be used to support ideas of architects and planners without destroying thermal and air quality comfort. Especially the importance of open spaces and the thermal conditions there are taken as example to create a climatologically approved urban design. From the definition of an ideal urban climate the different planning levels and climatic scales are combined.

Key words: urban climate, town planning, climate maps.

Аннотация: Под влиянием демографического роста, развитие городов Германии происходит в трех основных направлениях: перепланировка промышленных зон, территорий военных объектов и неиспользуемых железнодорожных путей в районы жилой застройки и центры обслуживания; экономическая концентрация; уплотнение городской застройки. Этот процесс назван новой урбанизацией. Климатологи утверждают, что он приводит к увеличению городского острова тепла, росту загрязнения воздуха, уменьшению вентиляции городских территорий. На примере Кассела видно, что такое развитие имеет как положительные, так и отрицательные стороны. Для улучшения термического режима города и качества воздуха архитекторам и планировщикам необходимо учитывать при разработке проектов данные исследований городского климата. Особенно важно учитывать температурные параметры открытых пространств, используемых для улучшения климатических условий городской среды. Для определения оптимальных климатических условий на различных стадиях проектировки необходимо использовать данные климатических исследований соответствующих уровней детализации.

Ключевые слова: городской климат, градостроительство, климатические карты.

1. INTRODUCTION

In Germany one can observe different developments. One is that inner cities gets more densely built up areas with spare vegetation and less open spaces; the second one is the conversation non used open areas like military fields, large old factories and railway tracks into building sites. This new urban development leads to an increasing roughness with reduced ventilation and higher air pollution and also to an increased heat island situation with thermal stress conditions. Urban climate studies have to meet these subjects in order to give help for urban planners and architects. The basic knowledge about urban climate has to be evaluated and transferred to planning practice and to answer their urgent questions.

But there is also a third aspect, which tend to be the opposite and occurs mainly in eastern Germany. Due to loss of people and industry there the population decreases and many houses and factories were destroyed. Here new areas become free and can be climatologically used for ventilation and for an improvement of the open space climate.

In all these developments it is important that urban climate studies help to bring the thermal and air pollution aspects into discussion and not to see an open pace as a potential area for buildings. For this urban climate investigations have to meet the urgent questions of planners. Which areas may be free for development, is there a limit in density of buildings, which gaps have to be maintained. To answer these questions links between climatological and planning scales together with evaluation criteria are needed. The linkage between scales and levels of urban climate and planning aims shows on figure 1. Moreover it is shown that urban climate only can work with an areal infor-

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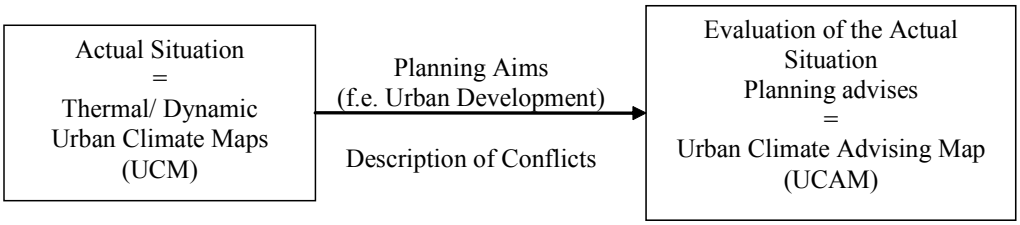


Figure 1. Linkage between scales and levels of urban climate and planning aims

mation set, which combines planning trends, thermal comfort and air pollution.

Finally coming to very concrete proposals, mainly what is of concern for the behaviour of people, interviews showed the important role of microclimate in the neighbourhoods. The more densely built up cities in the mid latitude climates create an optimum of thermal comfort conditions in short walking distances, which is judged as positive, while ventilation is rather seen as negative (Katzschner 2004). The objective here is to discuss in which circumstances this situation can be accepted and when the situation turns to negative in warmer climates. Warm climates therefore need generally wider gaps, while in moderate climate density can be even increased in some situations.

In principle any urban climatic research end in proposals for urban development. This is done by a simple comparison between the analysis of an actual situation with the proposed plans and end in a recommendation. Analyses can be done with models or measurements.

2. URBAN DEVELOPMENT CONCEPTS RELEVANT TO URBAN CLIMATE

Urban development plans and concepts like a master plan have some more principle aims, which later on get a spatial implementation like:

1) development of inner cities with living, working and shopping together with a reorganisation of the city and the suburban structure;

2) development of an improvement of the living situation (the social city);

3) regaining of open spaces through pull down of buildings and a convert of land use (the renewal of cities);

4) service centres in the inner city like hospitals, administrations or service companies;

5) development of the infrastructure including traffic;

6) near by recreation (development of green spaces);

7) development of cultural consciousness;

8) health problems.

For further planning discussions concepts have to be brought into connection to the urban climate aspects. To which extent do dense building sites effect heat island and thermal conditions of the open spaces and what potentials does the concept have to improve thermal conditions and air mass exchange for example along roads and parks.

The punctual developments, which are conversion areas from military places to service centres and from not longer used industrial places to residential buildings, are dealt and urban climatically evaluated in chapter 4.2 on a microclimatic level.

Before discussing some conflicts between planning and urban climate it is important to see the interactions between climate and use of spaces. Investigations with interviews from previous studies [1] showed very clearly the need of certain microclimates in neighbourhoods. At the example of Kassel the ideal thermal conditions could be derived as follows:

1) the use open spaces is more frequent in the centre of the heat island and increases with high values of the thermal indices;

2) street are seen as comfortable for pedestrians if thy have the choice between sun and shadow;

3) ventilation areas have to be judged in the frame of the city as such and should be classifies as important yes or no.

Otherwise there will be no influence on planning.

The definition of urban climate by the World Meteorological Organisation is the change of meteorological conditions which is caused through the built up areas combined with the antropogeneous air particles. But this means that the urban climate is connected to all weather situations and does not occur during special conditions. Urban climate is defined also as a mesoclimate with at least 5 km wideness. Through the densly built up ares in principle a disturbance of air flow is seen, which has a vertical dimension of ca. 1000m. The disturbance can be listed as follows:

1) the city is a barrier against the regional winds;

2) the city has an inhomogeneous higher surface roughnes;

3) the city creates compared to the surrounding areas, a heat island, which is depending from surface conditions and the amount of buildings;

4) cites have a high discomfort through a change in the radation balance;

5) the city has to be considered as air polluting system.

Therefore a city has its own meteorological system on a mesoscale level, which can be clearly separated from the surroundings. Within these systems different microclimates exists. Especially the Urban Canopy Layer (UCL), this is the atmosphere between surface and mean roof height. Here the described changes in climate have their maximum.

3. URBAN CLIMATE AND PLANNING

In urban climate studies different aspects have to be considered, as they directly influence urban planning and effect the health conditions. The definition of these complexes are derived from the interaction processes between climate and man. To study risks.

1) Air pollution complex.Under this aspect mainly the ventilation and the local circulation systems have to be judged. This is to avoid high concentration of air particles in different areas. The meteorological parameters used are wind and turbulences.

2) Thermal complex (thermal comfort conditions).Here the thermal comfort conditions in form of heat stress is described. This is a complex function out of the meteorological parameters of wind, radiation, air temperature and humidity. Different indices can be calculated.

3) Architecture and building design.Heat balance of buildings are depending on wind speed, this changes the k-factor (heat transfer) of houses.

4) Energy saving aspects.Natural ventilation and air exchange in the buildings is considered in the context of urban climate situation.

5) Global climate change.The global warming effect will create a even higher heat load in cities, therefore heatwaves will have different effect depending on city densities.

As described above it is important to develop a working scheme in order to have a actual description of the urban climate circumstances, an evaluation of that an a derived urban climate advisory map.

This can be done on different levels, which are dependent from architectural or planning aims. For all theses levels criteria for planning has to be found in order to be able for implementations. Criteria can be the improvement the ventilation situation (airpaths, local circulation systems) or the reduction of the heat island by the heat storage capacities and more green in open spaces.

The definition of the ideal urban climate considers the areas and time concept as important evaluation criterion: The «ideal urban climate» is an atmospheric situation within the UCL with a high variation in time and space to develop inhomogeneous thermal conditions for man within a distance of 150 m. It should be free from air pollution and thermal stress by means of more shadow and ventilation (tropical areas) or wind protection (moderate and cold climates) [4].

Evans and others have already developed some proposals for architects and planners on how to achieve this situation on a micro scale level. These general proposals have to be devoted to concrete urban places as seen before:

Table 1

Proposals for architects and planners

Planning possibilities	thermal effect
Width of streets	using shadow and sun in a daily and annual variation
Pergolas and arcades	sun protection in summer, using winter radiation
Vegetation	sun and wind protection, long wave radiation
Colours	reflection and daylight
Materials	heat storage, dust

4. METHOD

The principle underlying methodology is an areal evaluation of urban climate conditions. This is based on land use from digital grid data sets together with topographical data in 200 m grids. The meteorological input parameters were mean air temperatures and humidity, wind speed and wind directions from near by meteorological stations or from recorded data in existing analysis like in the Environmental Atlas Hessen and measured data.

In order to use planning aims and combine them with possible changes in urban climate the maps have to be linked to each other so that conflict immediately can be recognized. For example where future build-

ings will effect ventilation and how air pollutions is distributed. The climatic functions then were translated to an evaluation with means for planning.

Through the Geographical Information System (GIS ArcInfo) geographical data and land use data were classified and transformed to urban climate functions like, thermal aspects (i.e. heat and cooling rates), a wind classification with ventilation paths and topographically influenced downhill movements. The building fabric was classified through roughness length and thermal radiation processes.

The following factors were used:

1) land use classifications for thermal and radiation with categories of city structures, industrial areas, gardens and parks, forests, greenland and agricultural areas;

2) topographical and geographical data which influence the local circulation;

3) pattern; ventilation through an analysis of the roughness length.

Evaluation was carried out through a GIS based calculation method, which calculated weighting factors for every grid with a result for thermal and dynamic map. This then was combined to the urban climate function map with an evaluation to the urban climate map for planning use.

Due to this methodology the climate map has two levels: one is dealing with the thermal and the second one with the dynamical aspect. Therefore it is possible to have a classification in the final map, which can differ between the advices for heat island effects and the well ventilated areas or weak ventilated areas for improvement. The method of a GIS based urban climate calculation can be used at all different scales with various grids in order to get answers on different planning levels.

Table 2

Urban climate and planning scales

Administration level	Planning level	Urban climate issue	Climatic scale
city 1:25.000	urban development; master plan	heat island effects; ventilation paths	meso scale
neighbourhood 1: 5.000	urban fabric system	air pollution	meso scale
block 1: 2.000	open space design	thermal comfort	micro scale
single building 1:500	building design	radiation and ventilation effects	micro scale

5. RESULTS

Urban climate and planning on a city level

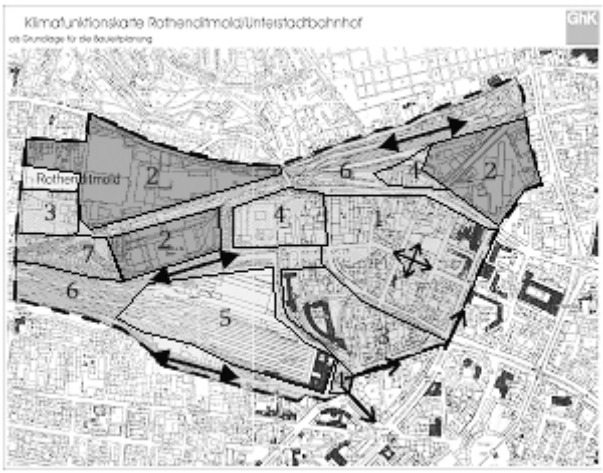
For the city level urban climate analysis of the region are needed. Urban climate investigations followed up by planning proposals. From the urban climate analysis the evaluation takes the climatic characteristic and transfers it to a climatically based evaluation with planning advises. This is done in 8 steps with important ventilation areas, cold air production areas with downwind streams as the most important spaces for air mass exchange up till the red areas which mark the heat island with reduced ventilation. While in the blue and green areas the planning advice is not to extend buildings here, in the yellow areas a more dense building structure is allowed and in the red areas planners should look to the microclimatic conditions of the open spaces.

It is important to mention, that different urban planning levels need different climatic scales. Urban development is devoted to the meso scale f.e. 1.25.000; open space planning with thermal comfort analysis have to be done in a mirco scale level of 1:2.000 or larger, which can be seen in the next chapters.

Urban planning needs qualitative and quantitative spatial results on which they can rely on. GIS calculates grids which later can be transferred to vector data. The results from the investigation areas are shown in a spatial evaluation and a directly devoted planning advice, where the urban climate function is explained with the outcome for planning. The main classifications are: ventilation areas, improvement areas against thermal stress, fresh air production zones and rules for density and heights of buildings.

Urban climate and planning on a city quarter level

In the frame of the urban climate situation of Kassel as result in the meso scale one comes to a more micro scale analysis as seen in figure 2 in a scale of 1:5.000 as background information for a master plan. Reason here was the conversion of non used old train tracks and industry into building sites for residential buildings. The area is situated near the city centre and so it would fit to the inner development plan from the overall concept. The old train station is not longer intensively used and areas become free for further building development. The intention was to reorganise an



Legend:

colours classification	PET (^oC) (typical summer day 12 o'clock)	ΔPET(spatial ^oC)	
1 dark red (industry)	warm	42	5
2 red (residential 5 fl)	very warm	39	10
3 brown (residential 3 fl)	warm	35	15
4 yellow (open structured)	moderate	30	6
5 grey (train tracks)	warm, ventilated	34	2
6 blue (vegetation, tracks)	moderate	33	5
7 dark blue (vegetation)	cool	25	2

Figure 2. Urban climate map of the investigation area in a scale of 1:5.000

old train station with new constructions of residential buildings and create open space for recreation. The master plan should also include a detailed urban climate study to evaluate the meso- and microclimate in terms of ventilation and thermal conditions. Within these city structures a climatological inhomogeneous situation occurs with high heat islands effects, air paths and vegetation sites.

Therefore more detailed investigation was carried out with measurement and calculations of thermal index PET in order to make recommendations for the construction of buildings and open spaces, as for any open space planning discussion where the different thermal conditions in an area play an important role. This is can not be done by average values. More important for any planning evaluation is the variation of the thermal conditions in time and space. Here the physiological equivalent temperature PET with a spatial variation was used. Each value then was directed to an urban classification (figure 2).

One can see that highest values PET occurs in the industrial outdoor places without any vegetation. The spatial variety is low. Residential areas can be warm, but it is always possible to choose cooler places there (i.e. backyards and tree shadow).

From these investigations for ventilation a thermal comfort following proposals were derived:

1) the blue areas should be kept free for ventilation;

2) the yellow areas can be built under respect of the air flow as drawn in the map;

3) for the residential areas with a good ventilation and a high variety of thermal comfort zones, no recommendation is given;

4) wide streets with high wind speed need more vegetation against cold stress during autumn to spring;

5) the very small vegetation site has very different thermal comfort conditions, this should be kept.

Urban climate and planning of open spaces

Coming into more details of the open space planning the microclimatic scale should be investigated and evaluated. This can be shown at an open space Hauptbahnhof in Kassel. First step were measurements with parallel interviews. The local spots were thermal comfort never could be reached, while others have a high percentage of thermal comfort throughout a year. The thermal calculation that the non comfort places correspond to cool places while the comfort ones are not the hottest points but fairly warm places. The evaluation criteria climate variability shows in a yearly average the frequency of occurrence of a certain thermal comfort situation.

Application of urban climatology with the cultural concept Kassel

The union of architects and urban planners [5] had developed a concept for an application to become cultural capital. Within this concept they advised different cultural activities in the open spaces of the inner city and towards a park area. As said before the use of open space is also depending from climate, therefore the concept in its spatial pattern has to be considered in the microclimatic varieties. The main concept of a walking line between the important cultural events is situated in the maximum heat island with reduced ventilation. This warm areas are adopted well for cultural activities, while a t the slope situation towards the park high winds occur with cold stress most of the

time therefore this areas are only suitable for walking and not for sitting outside to have coffee etc. These planned activities were background for the PET values, which should be achieved in that typical situation during summer, when open space activities have their highest frequency.

6. CONCLUSIONS

For any urban plan, concept or master plan urban climate maps are important to evaluate thermal comfort for the use of open spaces and ventilation for air pollution problems. One can see that these aspects were separated in different planning levels to which climatic investigations has to be devoted to.

Following the aim of planners to revitalise cities the use of open spaces are in the centre of discussion and here the thermal comfort play an important role. Heat island in this sense can also be seen as positive for mid European cities. Higher varieties of microclimatic situations having the air pollution problem in mind can be good criteria for urban climate. In general it is important to compare the climate pattern with city structures and the use of open spaces at the same levels.

REFERENCES

1. Katzschner L. Analyse der thermischen Komponente des Stadtklimas f?r die Freiraumplanung / L. Katzschner, U. Bosch, M. R?ttgen // UVP Report. - Hamm, 2002. - №. 3.

2. Katzschner L. Beitrag der Stadtklimatologie zu den Zielen einer neuen Urbanit?t / L. Katzschner // UVP Report. - Hamm, 2004. - № 1.

3. Katzschner L. Designing Open Spaces in the urban environment: a bioclimatic approach EU Ruros Project / L. Katzschner // Forschungsvorhaben im 5. Rahmprogramm. Centre for Renewable Energy Sources. - Greece, 2004.

4. Mayer H. Die humanbiometeorologische Bewertung des Stadtklimas / H. Mayer // VDI-Reihe Umweltmeteorologie. - D?sseldorf, 1990. - Bd. 15.

5. Karte des Konzepts einer Innenstadtentwicklung Kassel (SRL Vereinigung der Stadt und Regionalplaner Kassel). - SRL Kassel, 2003.

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