Building and Environment 46 (2011) 1545–1557

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Simulation of the urban climate variations in connection with the transformations of the city of Nantes since the 17th century

Mohamed Benzerzour [a,1], Valéry Masson [b,*], Dominique Groleau [a,2], Aude Lemonsu [b]

[a] CERMA, UMR1563, Ecole Nationale Supérieure d'Architecture de Nantes, Nantes, 6 quai F. Mitterrand, BP16202, 44262 Nantes, France
[b] CNRM/GAME, Météo-France/CNRS, 42 av Coriolis, 31057 Toulouse Cedex, France

ARTICLE INFO

Article history:
Received 19 August 2010
Received in revised form
7 January 2011
Accepted 12 January 2011

Keywords:
Urban planning
Historical analysis
City transformation
Urban microclimate
Numerical modelling

ABSTRACT

The paper seeks to quantify the effect of urban politics on the microclimate of the city of Nantes (France), in particular those initiated by the sanitarians in the mid-19th century to find a remedy for the insalubrity that had been developing with urban densification since the late 17th century. Intensive historical research was first carried out in order to define and date the major transformations undergone by the city, its structure (densification, then widening of the streets, filling of water courses), the lifestyle habits (heating) or the building practices (appearance of stone and paving, higher buildings, insulation). This led to the definition of 5 characteristic states of the city, in 1680, 1756, 1835, 1880 and 1945.

A numerical modelling approach is then used to simulate the urban microclimate of Nantes for these 5 states. The historical information (plans, illustrations) is incorporated into a Geographic Information System in order to determine the general characteristics of the city at the different dates. These are then used to initialize the TEB model which simulates urban energy behaviour and microclimate. While air temperature increases regularly and evaporation decreases (as expected) with greater amount of mineral surfaces, the evolution of humidity is more surprising. Air humidity first increases until the 1850s due to narrower streets. Then it decreases further with the sanitarian transformations which allow the streets to become ventilated and dry. This study gives a good indication of how town-planning actions can, in the long term, influence the urban climate.

1. Introduction

The present context of climate change ([1] IPCC, 2007) combined with the growth of the world's urban population is leading us to take various environmental dimensions into consideration in the design or improvement of cities in order to attenuate global warming (by reducing greenhouse gas emissions) and adapt to the warming to come (thus limiting the possible health and economic consequences). The new "eco-cities" are an example of town planning intended to respond to environmental challenges, e.g. by the use of renewable energies, improvement of transport systems to reduce emissions. However, these eco-cities are home to a very small proportion of the population. The main challenge is to succeed in carrying out town-planning improvements on a large scale in existing cities. For instance, in the study for the "Grand Pari de l'agglomération parisienne" (http://www.legrandparis.culture.gouv.fr/), an urban planning strategy for Paris and its suburbs showed that large-scale modifications, if well targeted (30% increase in forests in a radius of 50 km around Paris, lightening of surfaces in periurban areas), could reduce the urban heat island in the centre of Paris by 2–3 °C during heatwaves ([2] Lion et al., 2009). Such urban transformations may take a very long time; structural changes in cities tend to spread over long periods ([3] Goldstein and Moses, 1973). In Europe, it took centuries to reach the structure of present-day cities ([4] Grazi and van den Bergh, 2008) and a building has a lifetime varying from 50 to over 100 years ([5] Balaras et al., 2007).

Historical studies have shown that these environmental and climate concerns were present in town planning of the past ([6] Péneau, 1998, [7] Guillerme, 1990, [8] Etlin, 1977). As we shall see, priorities in terms of the urban environment were not the same as they are today, as even people's perception of the quality of the urban microclimate was different ([9] Corbin, 1986), but they came close sometimes, such as during the sanitarian planning of the 19th century.

At that time, the city of Nantes, like most French towns, possessed very unhealthy urban spaces and dwellings inherited from its past development. In 1852, the members of the unhealthy dwellings commission ([10] Cherot et al., 1852) declared 24% of the homes in

* Corresponding author. Tel.: +33 5 61 07 94 64; fax: +33 5 61 07 96 26.
E-mail addresses: mohamed.benzerzour@franck-boutte.com (M. Benzerzour), valery.masson@meteo.fr (V. Masson), d.groleau@free.fr (D. Groleau), aude.lemonsu@meteo.fr (A. Lemonsu).
[1] Present address: Agence Franck Boutté Consultants, 43 BIS, rue d'Hautpoul 75019 Paris, France.
[2] Retired.

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doi:10.1016/j.buildenv.2011.01.014

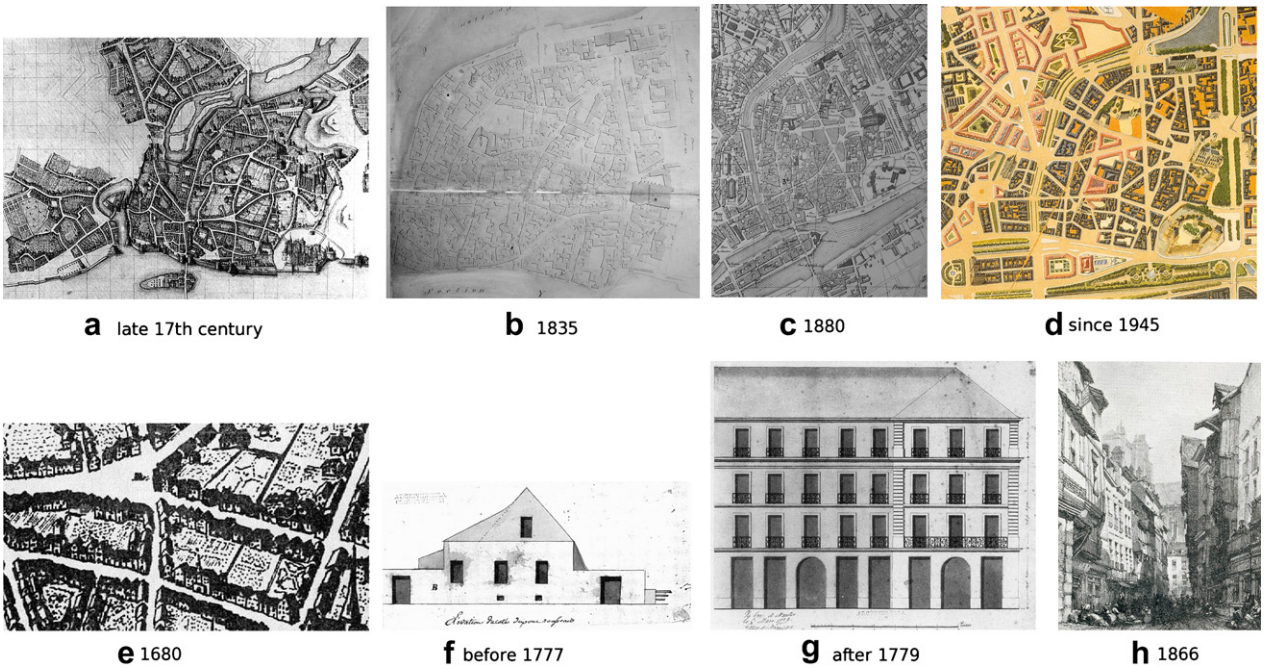

Fig. 1. Plans of the city (top) and drawings (bottom) of Nantes from the 17th century to 1945.

the suburbs and the old centre uninhabitable for reasons of insalubrity. This insalubrity was mainly due to outdoor conditions. " *The insalubrity of the dwellings stems not only from the conditions of existence specific to each one but […] , very often, also from external, permanent causes. The commission has come to recognise that the serious nature of the inside causes of insalubrity are almost always connected with that of the outside causes. It is in the badly ventilated, damp and dirty quarters that hygiene is most neglected in the dwellings. Similarly, this is also where the partial implementation of water systems would be the least effective*" (the original citations in old French are listed in Appendix A1). Given these causes, directly related to the morphology of the urban spaces, individual interventions on dwellings were thus deemed ineffective. Priority should therefore be given to transforming the spaces and structure of the city: *"Openings must be made in the quarters, streets must be widened, houses opened up, paving restored in the streets and the sewers drained"* ([10] Cherot et al., 1852; Appendix A2).

The aim of this study is to explore the impact of long-term town-planning policies on the urban microclimate and to present the interest of numerical approaches for this. It will focus on the example of the city of Nantes (France) for a period of 300 years. The major changes in the city from the 17th century to the present day are analysed using several historical sources presented in Section 2. Five periods corresponding to one or more major changes in terms of urbanization or systems (heating, sewers, etc.) are then identified (late 17th century, 1756, 1835, 1880 and 1945, cf. Section 3) and numerically simulated in order to estimate the potential impact of all these transformations on the urban climate (Section 4). Our conclusions are given in Section 5.

2. Historical analysis of the transformations to the city of Nantes

In this section, we present all the urban transformations that, according to the current understanding of urban climatology, could have led to changes in the urban microclimate. Some of them were set out explicitly to make the air cleaner in urban areas, while others were put forward in response to technical and safety priorities.

2.1. Nantes in the 17th century: the pre-sanitarian city

From the end of the Middle Ages, Nantes drew back within its ramparts (see the 1680 plan of the city in Fig. 1a) for security reasons. This way of life generated unhealthy conditions for population by favoring the stagnation of warm and damp air masses. Such conditions were however compatible with the economic activities, still based on advances in organic chemistry. They were even sought ([11] Olivier de Serres, 1600) because damp air and organic waste stored within the city itself were required for the fabrication of numerous products such as saltpetre (necessary for making gunpowder), textiles, leather and paper.

The southern part of the river Erdre in Nantes was bordered by streets, most of which were the filthiest of the city ([12] Wismes and Gaëtan, 1907, [13] Edouard, 1906). A veritable "open sewer", the river Erdre had a microclimate that set it apart from the rest of the city. This is confirmed by a police order of 30th January 1572 (Nantes Municipal Archives). Dirty activities were concentrated around the Erdre, religious functions taking place in the North-East of the city, in a higher location and a good distance from the unhealthy air of the river ([14] Dubuisson, 1663, [15] Favre, 1977).

These variations in the microclimate were also measured sometimes. In 1852, a great difference in humidity, measured with a hair hygrometer,[3] was observed between the streets and courtyards of the Fosse district (densely built up with cramped urban spaces near the river Loire) and the Delorme district (a fairly wide boulevard). It reached 5–10% ([10] Chérot et al., 1852).

The change from the "stinking city" to the "polluted city" of the industrial era took place slowly, as people became aware of a whole series of questions: *"political and cultural, symbolic and everyday, scientific and technical, economic and environmental"* ([7] Guillerme, 1990). The change in military priorities meant that it was no longer

[3] The length of a human hair increases by 2 to 2.5% when the humidity of the air goes from 0 to 100%. The hair hygrometer was developed into an instrument (a sort of compass) that gave a direct reading of the relative humidity of the air quite simply.