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Climate Twins for Future – Equivalent Urban Climate as Starting Point towards more Climate-Adapted Cities

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1 ABSTRACT

Climate change-related effects such as heat or drought stress for humans, animals and plants or overstrained infrastructures can be observed especially in urban areas. Since these increasingly problematic situations do not represent individual phenomena, but are embedded in a global system, a search for similar problems in other cities or regions followed by a transfer of solutions have evolved as proven approach in the urban, regional, rural, landscape planning and research discourse. Regarding the urgency of the climate crisis, the approach "Mainly something happens and quickly" could guide spatial development planning within this "learning from" approach. But a greater potential would exist by looking to urban structures, mainly open and green spaces, whose current urban climate point to the future for other cities. These climate forecasts combinded with specific spatial examples are called Climate Twins and are an explanatory path that allows comparisons between urban climates, but diverges on the components of time and place (Rey et al. 2020, Bastin et al. 2019, Rohat et al. 2018 and 2017, Nakageawa et al. 2017, Beniston 2014, Ungar et al. 2011, Peters-Anders et al. 2011, Loibl et al. 2010, Loibl and Peters-Anders 2009, Hallgatte 2009, Kopf et al. 2008, Hallegatte et al. 2007).

The aim of this paper is to put this modeling and climate research based method into an open and green spatial planning context and develop it as part of a more climate-conscious and climate-adapted planning paradigm. By using descriptive and explorative analytical methods, questioning what role climate has played in urban development historically, currently, but especially in the future may help to understand the climatic and planning relevance of “non-built” urban structures. Thus, this paper intends to develop Climate Twins as a research-led planning topic and starting point towards more climate-adapted and sustainable cities.

Keywords: Equivalent urban climate, Climate-Adatped, Urban Landscape, Climate Change Adaptation, Climate Twins

2 FUTURE HOT URBAN CLIMATE – NO SHORT-TERM SUMMER FUN BUT HARD REALITY

When heat waves occur in summer, the media like to draw comparisons with cities or regions where these temperatures are common. In most cases, this conveys a positive image, as it is supposed to create a “vacation mood”. In central Europe this applies mostly to destinations in the Mediterranean region. However, the comparisons should actually be taken seriously and should rather be seen as an outlook for future everyday life. The image of a short-term stay in emotional high spirits in warmer climatic zones, which has clearly different daily structures and behaviour patterns and a clear end date, should be replaced by an image of an adapted and changed everyday life in those warmer climatic zones. In particular, the record temperatures, reached so far in 2022 in some southern European countries (Spain, France, Italy, Slovenia, etc.), with drastic challenges (rationing of drinking water, threat of crop exhaustion in agriculture, forest fires, etc.), should be an urgent appeal to society that this tends to be the reality (DerStandard/APA 2022a and b, DiePresse/APA/DPA 2022, Zeit Online/DPA 2022). both for the countries addressed, but precisely also for the northern countries that are currently not directly affected.

For this narrative of the transformation of the vacation region into the everyday region, a lot of questions arise. First, what does "climate-equivalent" mean (section 3), what characterises existing urban open and green structures as “climate-adapted” in order to serve as "learning objects" for Climate Twins (section 4) and additionaly, if any, what role has climate played in urban landscape development (section 5).

3 EQUIVALENT URBAN CLIMATE – AN EXPLANATORY PATH OF CLIMATE RESEARCH

Climate forecasting and summarising in urban climate analyses is currently a field of activity in demand, which spatial planning increasingly has to take into account, or even do more intensively. In a specific

literature research on possibilities of climate change adaptations in urban areas, a universal but applicable statement could be found, which offers potential for deepening:

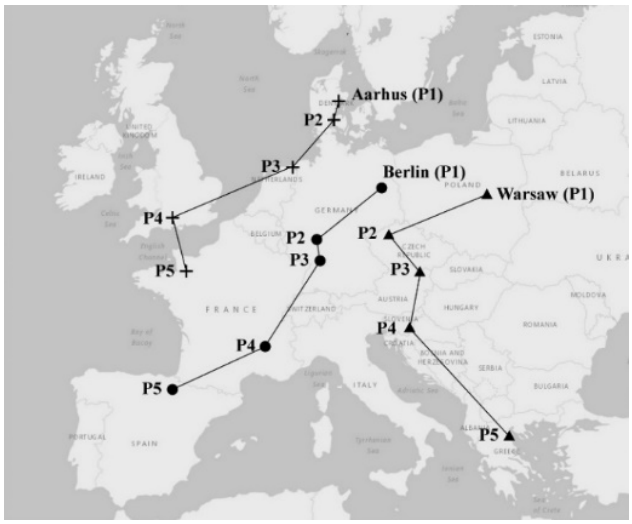
"How urban design can be positively influenced from a climatic perspective, can be seen by looking at building structures in other climates (e.g., shading in narrow alleys, radiation-optimised orientation of buildings)." (Henninger and Weber 2020: 159; translated from German[1])

This building-related approach of how to plan 'climate-adaptively' seems to be so applicable and helpful that the same demand can be formulated for urban and green spaces – the "non-built" city landscapes. At the same time, it is considered necessary to specify the wording "other climates". At this point, research results by climate researchers on climate-equivalent cities can be used as a basis for spatial adjustments. With a focused view to those cities whose future is depicted in a real setting, may be a promising way to take future climate conditions into account and to act on them at an early stage. In the climate science, research is being conducted under the terms Climate Twins, City Shifting or Climate Analogues.

Climate Twins stands for the "wandering" and "shifting" of cities along climate predictions by data modeling of climate elements (primarily temperature and precipitation). In scientific terms, there is a constant and increasing movement of the isothermal lines that define the large-scale climate zones, putting pressure on current cities and urbanisation. In this regard, the studies aim to identify cities that can be equivalently described in terms of their climatic characteristics through shifts in time and place. This is intended to illustrate where on earth the predicted climate for a particular city can already be found today, thus, can be described as climate-equivalent (Rey et al. 2020, Bastin et al. 2019, Rohat et al. 2018 and 2017, Nakageawa et al. 2017, Beniston 2014, Ungar et al. 2011, Peters-Anders et al. 2011, Loibl et al. 2010, Loibl and Peters-Anders 2009, Hallgatte 2009, Kopf et al. 2008, Hallegatte et al. 2007). A good explanation emerges from one study:

"Twin climate cities are pairs of cities for which it is appropriate to assume that the future climate of a city "A" will be significantly similar to the current climate of another city "B"." (Rohat et al. 2017: 929)

The authors find themselves in consensus that a worldwide "shifting trend" towards the subtropics (around the 20th latitude) is emerging: A southward trend in the northern hemisphere and a northward trend in the southern hemisphere will occur.



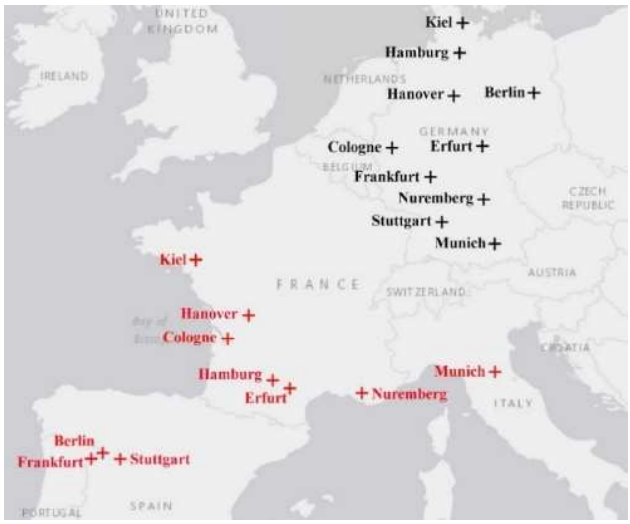


Fig. 1: Climate shift over the European continent for four cities, for the four 30-year shift time periods (Rohat et al. 2018: 438);
Fig. 2: Current location (black) of the main German cities and the location of their future climate (red) (Rohat et al. 2017: 938)

In a global study by Bastin et al. (2019), for 77 percent of cities a different urban climate is assumed than their own urban climate at present. By 2050, spatial climatic hifts can reach up to 1,000 kilometers, or about 20 kilometers annually. To make the data a little more descriptive, examples of Climate Twins are given:

[1] Original quote: „Wie aus klimatischer Sicht positiv auf den Städtebau eingewirkt werden kann, wird durch die Betrachtung der Bebauungsstrukturen in anderen Klimazonen ersichtlich (z.B. Verschattung in engen Gassen, strahlungsoptimierte Ausrichtung der Gebäude)."

“Madrid’s climate in 2050 will be more similar to the current climate in Marrakech than to Madrid’s climate today; London will be more similar to Barcelona, Stockholm to Budapest; Moscow to Sofia; Portland to San Antonio, San Francisco to Lisbon, Tokyo to Changsha, etc.” (Bastin et al. 2019: 7)

Comparatively, Rohat et al. (2018) quantified the southward movement of climatic conditions for European cities at an average of 200 kilometers within 25 years. Possible shifting paths for Aarhus, Berlin, and Warsaw indicate south to southwestern European regions as likely future locations (Figure 1). Rohat et al. (2017) further investigated whether and where climate-equivalent regions and cities exist in Europe. The results show that out of 100 European cities, there is one equivalent region for each of 70 cities and one equivalent city for each of 30 cities. Furthermore, possible Climate Twins could be identified for ten German cities; all are located in a more south-western location in Europe (Figure 2).

Beniston had the same research focus (2014) when he examined the geographical displacements on the European continent in three sections. Displacements of two to 14 kilometers per year can be assumed. These are expected to be more intense in continental and eastern European regions than in maritime regions.

Loibl and Peters-Anders (2009), Loibl et al. (2010), Peters-Anders et al. (2011) and Ungar et al. (2011) specifically developed a web-based tool to determine how to narrow down possible climate equivalent regions. With an example of a Czech city they illustrated the wide range of results and showed how difficult it is to define one or a few representative Climate Twins. For doing so, an adjustment of indicators and thresholds is necessary. This difficulty is the argument for the authors to use Climate Twins more as a digital communication tool to show generally the climatic shift of urban climates and to gain attention from the public and spatial planners too:

„Until now no satisfying validation method or data could be found to compare the Climate Twin results with. Therefore the fictive line between ‚good‘ and ‚bad‘ results can only be drawn subjectively by visual interpretations of result maps while variing the thresholds.“ (Ungar et al. 2011: 433)

Another example that pushes the visual representation of Climate Twins is the "Global Map: Shifting Cities" by Climate Central and World Meteorological Organization (WMO) (Figure 3). The map represents where selected cities have their climate equivalent "partners" around the world. In addition, the development path is shown under the assumption of a moderate emissions scenario (basis: targets of the international Paris Agreement of 2015), which would result in a less pronounced shift in the geographical location of all cities.

Based on these results, the Helmholtz Center for Environmental Research (ESKP - Earth System Knowledge Platform) also drews attention to the need for cities to adapt (Kandarr 2018). As examples, the authors picked out Berlin, which in the future will have the peak summer temperatures of Bucharest, up to 28.1°C. Also mentioned is Madrid, which is expected to have conditions like todays Erbil, Iraq, with a maximum temperature of 36.4°C. And in Riad, the mercury will be able to rise another 6°C in summer, up to 48°C (Figure 4).

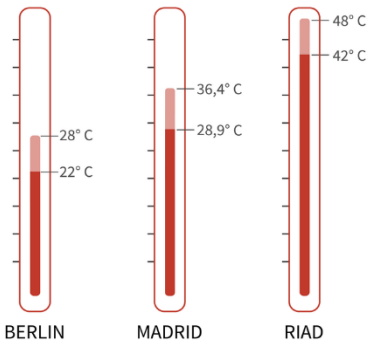


Fig. 3: Website “Global Map: Shifting Cities” (Climate Central and WMO); Fig. 4: Peek summer temperatures in future for Berlin, Madrid and Riad (Kandarr 2018)

Furthermore, Reusswig (2010) used the comparison in his book article "Berlin = Zaragoza?" to debate the multi-layered consequences of climate change. Reusswig referred to the study by Hallegatte, Hourcade and Ambrosi (2007) - numerous references of subsequent studies can also be attributed to this study. Using two models (CNRM ARPEGE, HadRm3H), the shifts in urban climatic conditions by 2100 in Europe were

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calculated and visualised (Figure 5). For example, Vienna would find itself around Venice or Albacete in central Spain.

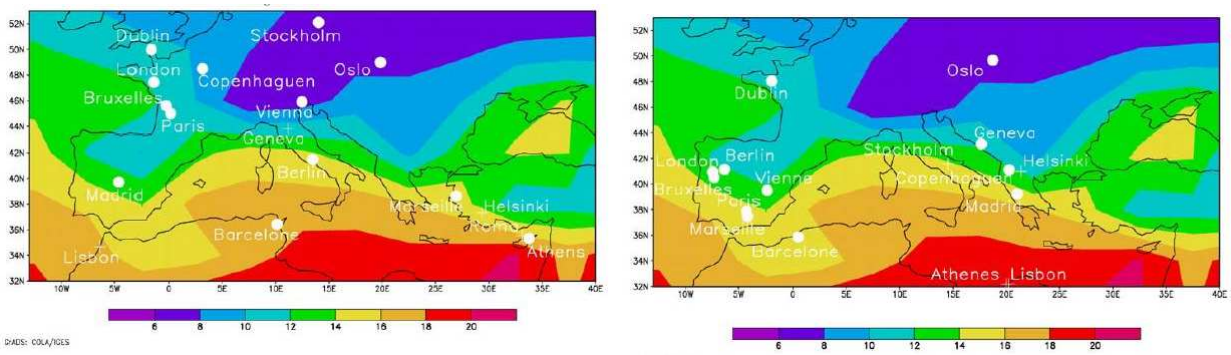

Fig. 5: Map of climate relocations of 17 European cities: Each city is plotted at the location of its “acceptable analogue”; left: ARPEGE-Climat model, right: HadRM3H model (Hallegatte et al. 2007: 50f)

Hallegatte et al. (2007) concluded that by comparing cities in different but realistic climatic regions, solutions for climate-adapted infrastructures, building architecture and street formations can be found. This statement addresses directly spatial planners and thus also forms the basis for this research work. Although this is a 15-year-old and unmistakable statement, planning oriented to Climate Twins is nevertheless largely unknown or considered novel.

Two years later, in 2009, Hallegatte specified the results:

“[...] a building built now to last 80 years would have to face over its lifetime, the climate of Paris [...; and the] climate of Cordoba. For an architect, it is not more difficult (nor more expensive) to design a building adapted to the climate of Cordoba than to the climate of Paris. But it may be more difficult (and more expensive) to design a building adapted to both [...].” (Hallegatte 2009: 241)

Hallegatte along with Kopf and Ha-Duong (2008), also researched to City Analogues to interpret climate change scenarios for cities. The authors investigated implied uncertainties and used the example of twelve European cities to show the limitations of the method, such as the exact location of a "best" or "good" climate-equivalent region or city. This research issue is also the reason why the scientific evidence for spatial planning is wavering. But at the same time, the clear trend towards a warm, mediterranean climate clearly shows that the previous, or let’s call it “domestic”, climatic conditions of the individual cities are no longer sustainable in order to maintain the quality of life and keep possible damage to residents' health as low as possible.

This excerpt of a literature review on equivalent climate locations clearly shows the relevance of climate studies for spatial planning. Through modeling and spatialisation, it shows in a further way the effects of climate change and formulates the need for action. Even if there are uncertainties due to the data basis (climate is more diverse and complex than can be described by just two elements) as well as the different methodological approaches, this creates an extremely exciting and relevant field of spatial planning activity: climate change adaptation of the urban body and fabric inspired by Climate Twins as contribution to qualifying existing adaptation solutions and to strengthen a more serious climate-oriented planning paradigm.

4 CLIMATE-ADAPTED URBAN STRUCTURES – WHAT DOES IT MEAN?

So far the impression might have arisen that Climate Twins and their urban structures are understood directely as ideally adapted to the climate. But, first, the “simple” fact is that increasing climate change is challenging all cities worldwide more and more and pushing them to their limits. Secondly, active research activities searching and investigating solutions for climate change adaptation and mitigation can clearly negate this point. Moreover, the constant natural change of the climate has as a consequence that a city can never be planned as “finished” and designated as finally “climate-adapted”.

Despite this initial “rejection” of a definition of climate-adapted urban structures, there are nevertheless numerous examples of what ‘climate-adapted’ means. Thus, a lot of research projects have emerged in recent years that are dedicated to this question and are looking for solutions on how to implement them.

A first reference is provided by Laue (2019) with "Klimagerechte Landschaftsarchitektur"/"Climate-friendly landscape architecture". Laue goes into detail about the different planning principles of the global climate zones (Figure 6, 7).

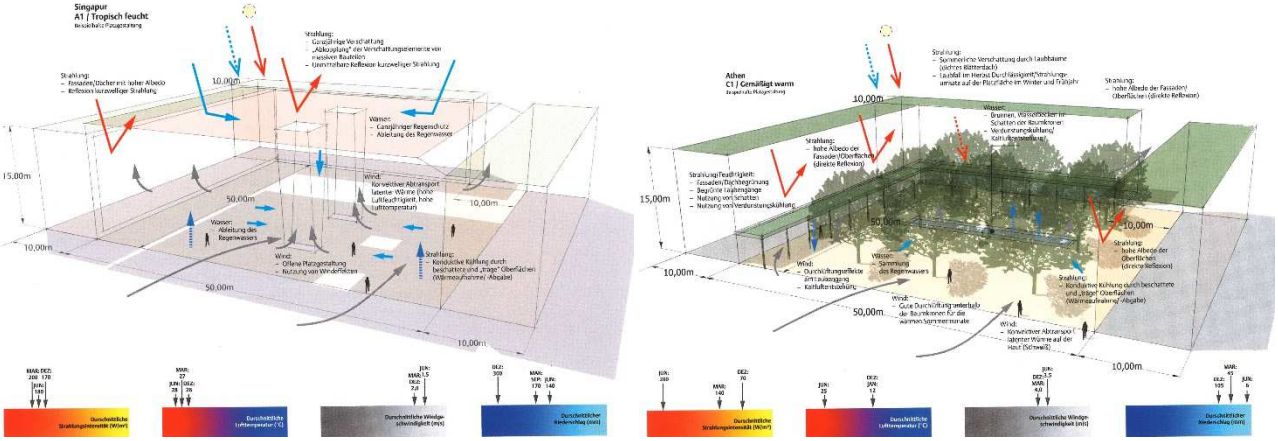

Fig. 6: Exemplary square design in Singapore in a tropical humid climate (Laue 2019: 75); Fig. 7: Exemplary square design in Athens in a warm temperate climate (Laue 2019: 95)

With these considerations, Laue describes intended target states, which can subsequently be described as "climate-adapted" and are consequently recommended for Climate Twins. However, this planning-strategic view touches only the theory. The practical component, the real, existing open spaces and green structures in the cities is a different one and would also require methodologically more application-oriented methods (on-site visits, photo documentations, spatial analyses, etc.).

Remaining in this level of analysis, a closer look shows a partly much less pronounced difference in planning principles between the different climate zones. Figure 8 shows that, for example, the strategy "shading of the open space" is recommended for eigth climate types, from tropical humid, dry and hot, warm temperate till continental with regard to the prevention of radiative transfer.

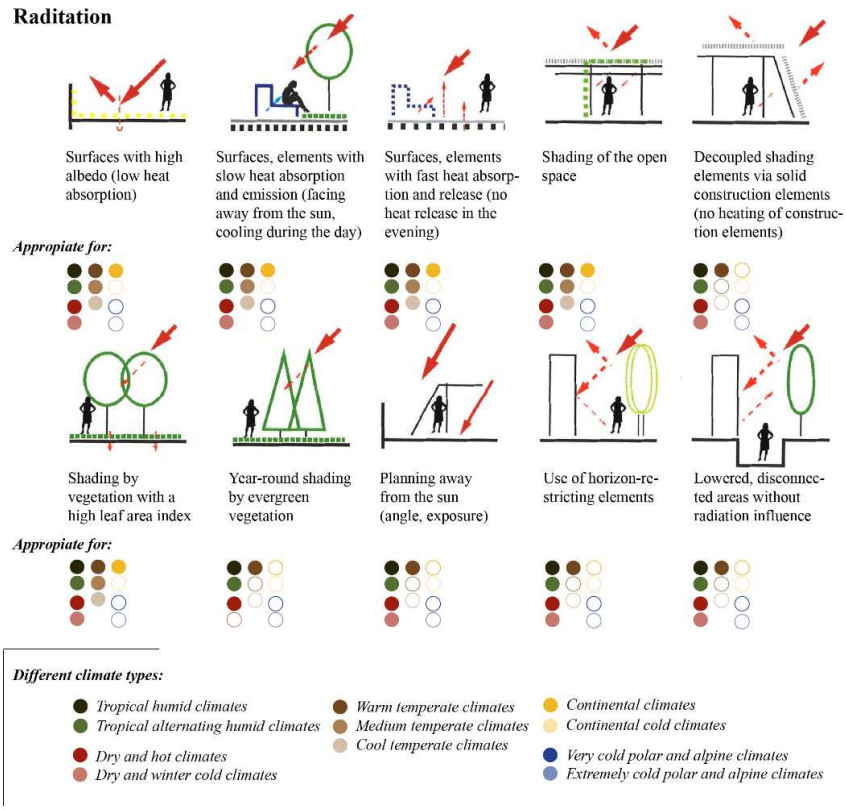

Fig. 8: Climate-adapted open spaces structures with cooling as the primary planning strategy – focus radiation, applicable to multiple climate zones (Laue 2019: 133; translated from German)

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Nearly the same applies for water-specific recommendations like vegetative surfaces to foster an evaporative circulation or water-storing surfaces and substrates. Differentely to radiation, sites within a tropical humid climate should use these guidelines less (Figure 9).

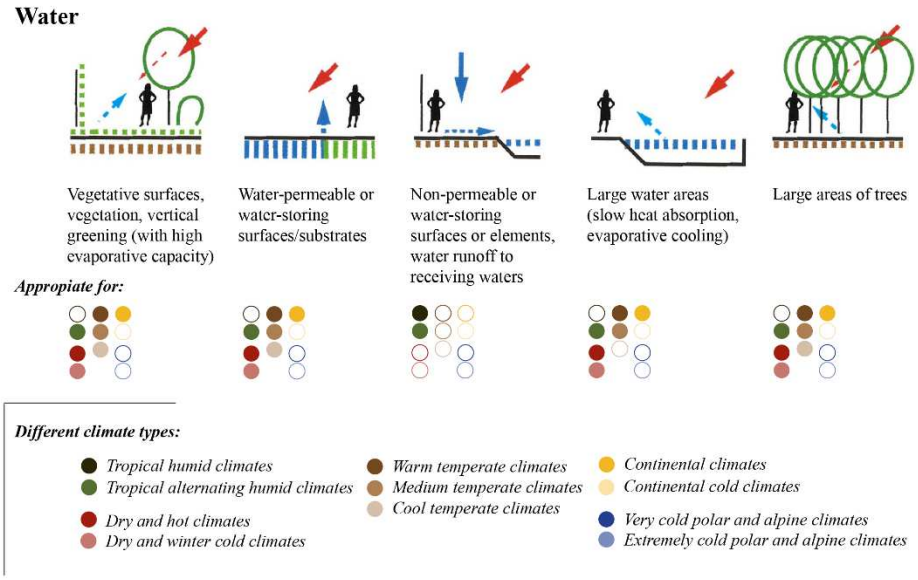

Fig. 9: Climate-adapted open spaces structures with cooling as the primary planning strategy, focus water, applicable to multiple climate zones (Laue 2019: 133; translated from German)

This may give the impression that the recommendations to planning and landscape architecture, structured by radiation, water and as well wind, are to be regarded as universal and that no specifics are necessary. This paper would like to counter this. First of all, climate zones are very large spatial unit. Accordingly, descriptions at this zonal, large scale can only remain general. Only through closer examination and spatial focussing will clear differences emerge, which result in significant differences in the quality of life. Furthermore, the overlap and repetition of spatial structures highlight the relevance of each recommendation to the design and shape of urban open and green space. For example, Laue writes about landscape architecture in relation to climate:

“Landscape architecture has a problem compared to architecture: All open spaces are always thermally linked to larger climatic units. […] An understanding of climate in its spatial gradations is therefore indispensable, especially for landscape architecture.” (Laue 2019: 14; translated from German[2])

5 CLIMATE IN A RETROSPECTIVE – ROLE IN URBAN LANDSCAPES

The simple question what climate-adapted means, however, highlightes that it is actually also unclear whether the current appearance of a city can be understood as an expression of climate adaptation at all. City as a spatial convolut and living beings is rather to be understood as a co-existence of difference, whereby a multitude of interests and developments shaped and shape constantely the appearance of a city. In a critical perspective, a further question is, if any, what role have climate played in urban landscape development?

Kuttler (2004) points out that urban climatological aspects already have historical “cult status” and were of interest when living conditions in cities declined dramatically:

“The beginnings of urban climatology can be traced back relatively far in time – even to antiquity. First works in this field are attributed to Vitruvius (75 B.C. - 26 B.C.; “Urban Planning and Climatic Conditions”) and Horaz (ca. 24 B.C.; “Air Pollution in Rome”) (compilation in Yoshino 1990/91, Müller 2003). In

[2] Original quote: „Die Landschaftsarchitektur hat im Vergleich zur Architektur ein Problem: Alle Freiräume sind thermisch gesehen immer mit größeren klimatischen Einheiten verknüpft. […] Ein Verständnis für Klima in seinen Raumabstufungen ist also insbesondere für die Landschaftsarchitektur unabdingbar.“

particular, problems of urban planning in connection with climatic and air-hygienic influences were dealt with […].” (Kuttler 2004: 188f; translated from German[3])

The far back presence of climate as a planning issue is also highlighted by Krautheim et al. (2014), who specifically address the relevance of climate as an architectural instrument:

“Climate has been of major influence on architecture for centuries. Orientation, form and materials were, for a long time, the logical consequence of local conditions. This has generated the many differnet traditional styles of architecutre, each with its own regional characteristics and resources. […] Traditional ways of city development correlate with environmental issues, such as the use of solar irradiation, natural ventilation and precipitation, the reduction of emissions […], bringing down the ecological footprint, minimising the energy consumption (etc.), up to the point of introducion complex recycling processes.” (Krautheim et al. 2014: 10)

An example of how natural ventilation harmonizes well with the existing urban and open space structure is the historic city of Korcula in Croatia (Figure 10, 11). Therefore, this example is formulated as

“adapted to the specific geographic, topographic and climatic conditions. The cold and gusty north winter wind (Bora) is being blocked by the street pattern, whereas westerly and easterly summer winds can easily access the urban fabric.” (Krautheim et al. 2014: 65)

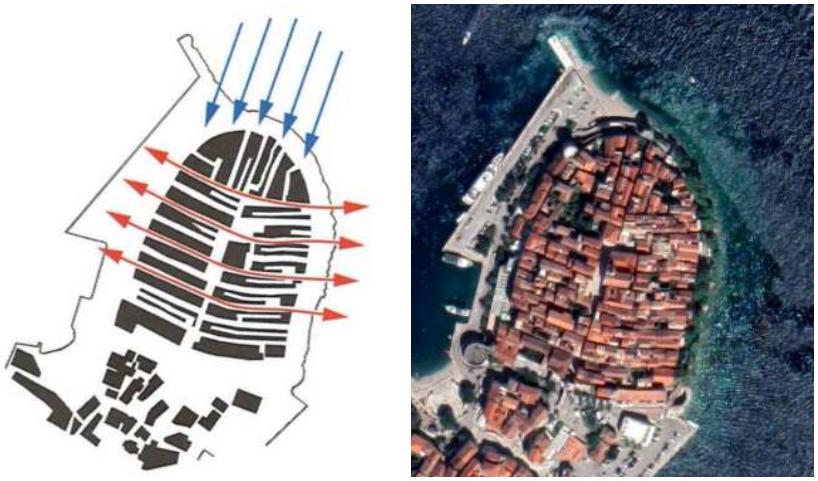

Fig. 10: Historic city of Korcula in connection with wind conditions (Krautheim et al. 2014: 65); Fig. 11: Orthophoto from Korcula (https://www.google.com/maps/)

From today’s (2014) point of view, the authors said that technical and technological progress disregard the orientation towards and planning according to natural and climatic conditions, and that the climate is not considered as a co-designing system element. Furthermore, Reusswig (2014) argues “the consumerist fossil city” has contributed to this since the 1960s:

“Notably since the 1960s a growing number of buildings became typologically identical, irrespective of their geographical location. The same applies to cities. Whereas the majority of medieval cities followed regional and climate specific conditions, many of the so-called ‚new towns‘ generate their own (ir)rational lay-out. Rational principles like optimising an infrastructural network, or irrational designs that create an allegorical image of the city rather than spatially programmed entities, seem to have long superseded a contextural urbanism.” (Krautheim et al. 2014: 10)

Learning from Climate Twins to best arrive at climate-adapted cities also means that looking at existing and historical urban landscape structures involves both parallelising and contextualising (Kurz 2022). Drawing parallels is fundamental, as landscape and vegetation are portraits and also information carriers of the past and present. In a further step, this acquired knowledge can be transferred into new concepts. Therefore, the procedure is the subject of transformation research and includes development steps such as preserving, updating, intervening, intensifying and rethinking.

[3] Original quote: „Die Anfänge der Stadtklimatologie lassen sich zeitlich relativ weit - sogar bis ins Altertum - zurückverfolgen. Erste Arbeiten auf diesem Gebiet werden Vitruvius (75 v.Chr. - 26 v.Chr.; 'Stadtplanung und Klimabedingungen') und Horaz (ca. 24 v.Chr.; 'Luftverschmutzung in Rom') zugeschrieben (Zusammenstellung bei Yoshino 1990/91, Müller 2003). Dabei wurden insbesondere Probleme der Stadtplanung in Zusammenhang mit den klimatischen und lufthygienischen Einflüssen behandelt […].“

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Keeping the question raised and also Kurz's (2022) notion of parallelisation and contextualisation, Rathore (2021) summed up her thoughts on this topic in her article "The City Adapted". She explains adaptation as an expression of three components: Preservation, reinvention and association.

"'Preservation' […] is a conscious attempt to attach value to architectural remnants belonging to different historical eras. […] Furthermore, the preservation of ecological interventions that date back to the city's inception, such as the interconnected systems of lakes in Udaipur, acts as a reminder of a pre-colonial existence; of capacities, skills and resources that can only have been the basis of a formalised settlement." (Rathore 2021: 56)

Regarding reinvention and assosciation, the author particularly addresses the cultural significance of existing urban landscapes as central components for adaptation. In this context, Paul Oliver (1999/2006) explored intensively in his "Encyclopedia of Vernacular Architecture of the World" the contradictions between these two "logics" or "rationalities" guiding design. "Vernacular" describes a category of architecture based on local needs, construction materials and reflecting local traditions. Through this explanation, "vernacular" can also be included in the set of definitions of "climate-adapted", albeit in a cultural-historical focus and less in a spatial planning understanding.

Also of interest is the contribution by Koohestanian (2021), who is researching on climate adaptation in cities through the use of a global approach with local solutions as part of the Fraunhofer Institute's Morgenstadt Global Smart Cities Initiative (MGI). He writes about Kochi (India, Kerala), one of the three pilot cities, where climate risks in the form of floods, storms and heatwaves are becoming increasingly problematic. By analysing the existing spatial structures, the researchers found that a complex network of rivers, tidal creeks and backwaters dating back to colonial times is present. With the supportive use of native vegetation (magroves) and wetland, this infrastructure offers the possibility to build a natural drainage system that protects the city from flooding events. This measure also has a direct effect on the necessary reduction of urban heat islands. It is interesting to note that the term "climate-adapted" is not used here, but the approach of recognising, understanding and further developing the use of existing natural and built structures is a clear expression of climate-adaptive planning.

The short excursion into the literature concerning the historical role or relevance of climate in the current appearance of urban landscapes shows multifaceted interpretations of climate-adapted cities and, additionally how important their cultural aspects are. At the same time, dealing with Climate Twins shows the urgency to think more intensively about the natural laws of climate in the planning and design of urban fabrics, both now and in the future.

6 CONCLUSION

Climate Twins as an additional topic of urban climate change adaptation raises a lot of questions but also challenges. The importance of up-to-date climate data and climate studies as a basis for climate-oriented spatial planning is highlighted, as well as the relevance and methodological challenge of comparative research. The central research object "existing urban structures" as learning objects are manifold, diverse and historically complexly interwoven. Thus detailed spatial analyses has to accompany research and planning in order to understand the local context and to translate it in transferable concepts for climate adaptation.

Learning from existing open and green space structures in equivalent climate zones can also broaden other exciting and current topics such as architecture, landscape architecture, urban planning, energy supply, but also the cultural significance of urban space. Additionally, describing the future urban climatic conditions with the help of climate-equivalent situations can possibly assist to move from the vacation image described initially to an everyday image and show the urgency of action against climate change.

Accordingly, Climate Twins can be considered as an interesting and promising starting point towards more climate-adapted cities and can also be described as an urgent field of research. Climate-equivalent orientated research may help spatial planners, urban designers and architects to move forward on the question: which urban structures and uses will face greater constraints under changing climatic conditions and how can they be adapted, inspired by their climatic twin?

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