1. Tr-Island - Combating Urban Heat Islands in the City Centre in Hanover

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Abstract

As part of the HeKris research and exchange, this paper presents a creative proposal in dealing with the issue of urban heat islands in the city centre of Hannover. The area in question is essentially fragmented due to heat island effects making some streets and connecting roads unbearable to walk through. By utilising the old tram infrastructure on Prinzenstraße and Schiffgraben, the project unifies the area and creates a more attractive public realm network. The introduction of vegetation and water elements in urban areas was found beneficial to reduce the heat island effect significantly. The paper further emphasises the importance of a comprehensive urban governance-oriented implementation process and recommends the introduction of a resilience-focused action programme to achieving sustainable urban development in and around Hanover.

Introduction

European countries need to react to incoming crises caused by the phenomenon of climate change to ensure sustainable urban and regional development. The increasing number of heat waves puts pressure on social and ecological systems and functions (Kershaw 2017: 5-1f). In this context, the concept of urban resilience refers to withstanding threats and stresses. It describes an urban system's ability to act as an intermediate approach by developing proactive adaptation strategies to reduce the levels of vulnerability of cities and regions. (Leichenko 2011: 164)

The city of Hanover faces worsening heat stress and has the potential to develop urban heat islands (UHIs) (Schmidt 2019: oral). UHIs are defined as a phenomenon in which "the urban air temperature is higher than that of the surrounding rural environment" (Kleerekoper et al. 2012: 30). Depending on the time, place and urban characteristics, differences of temperature can vary (ibid.).

The resilience of the city with regard to heat will be the subject to this paper. This research paper outlines a strategy of a triangle-shaped urban network of green infrastructures, enhancing the city centre's urban micro-climate, reducing the occurrence of UHIs. The paper begins with a brief description of the research methodology. Then, the study area is shortly described, and findings are explained in context to the main concept for the area. The urban governance characteristics for implementing the strategy are shortly pointed out before the authors give a short recommendation for implementation. Lastly, the conclusion is drawn.

Methodology

The mental map approach is a method that outlines personal representations of people's internal perceptions with the external world in terms of experiences, values and goals. The construction of individual perceptions and understandings of the world supports an urban planning process strategically by fostering planners and decision-makers understanding and planning for a variety of concerned user groups and stakeholders. (Jones et al. 2011: 46) Hence, the main approach for the design of the research proposal has been to observe what already existed in the area, what could be adapted and what could be where improved to prevent heat islands from occurring. In turn, by working with the existing city fabric and by constructing a

new one, this project carefully deals with the historic buildings and streets prevalent to the area.

In addition to the mental map approach, a review of statistical data, context-related literature and strategic documents of the city of Hanover was carried out to further support the identification of potential UHIs in the study area. An indicator system was developed to evaluate the level of exposure to heat, as depicted in table 1.

STRUCTURAL COMPONENTS	SOCIAL COMPONENTS	GREEN INFRASTRUCTURES
• Density of buildings • Heights of buildings • Main road network for pedestrians, bicycles and motorised traffic • Building materials • Surface structures and materials, evaporation rate • Functional integration of area with bordering areas • Land use • Wind corridors • Perceived air temperature • Albedo	• Share of residents in the area • Number of visitors • Share of employees • Age structure: Share of people aged >65 years • Sensitive infrastructures: hospitals, kindergartens, schools • Exposure to noise pollution • Exposure to air pollution	• Share of green spaces (in-street, facades, rooftops) • Functional integrity of green spaces in the urban space • Share of shade on the streets and pavements

Tab. 1. Indicator System for the Evaluation of Heat Exposure (own depiction)

Trisland – Combatting Hanover's Heat Island

This case study area is located in the central city of Hanover, as depicted in figure 1.

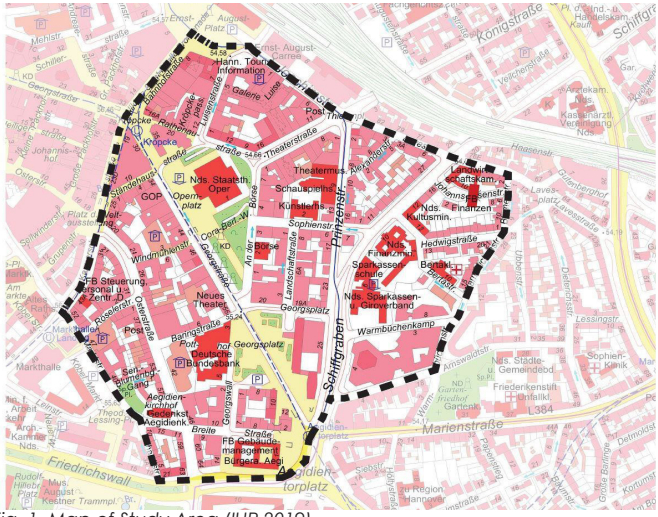

Fig. 1. Map of Study Area (IUP 2019)

In the following section, the analysis results about the location's exposure to heat are presented. Then, the conceptual approach to combat UHIs is explained using a master plan and detail plans of the area. The scientific justification of chosen measures follows before the urban planning process is reflected regarding urban governance.

Analysis results

In the following, analysis results are outlined.

Exposure to Heat

Based on the indicator system and with respect to the three components in table 1, three categories of heat exposure were developed to categorise the analysed area as depicted in table 2.

LEVEL OF EXPOSURE	DESCRIPTION
High	Indication of high pressure on the street. The streets are not or hardly equipped with green infrastructures, cooling materials and infrastructures for buildings, facades and surfaces. A high volume of car traffic leads to significant exposures in terms of air and noise pollution. Heat islands are likely to develop.
Intermediate	Indication of a medium level of pressure on the street. The streets are partly equipped with green infrastructures, cooling materials and infrastructures for buildings, facades and surfaces. Constant car traffic leads to partial exposures in terms of air and noise pollution. Heat island may occur.
Low	Indication of a low level of pressure on the street. The streets are mostly well-equipped with green infrastructures, cooling materials and infrastructures for buildings, facades and surfaces. Low car traffic hardly leads to exposures in terms of air and noise pollution. Heat islands are unlikely to occur.

Tab. 2. Levels of Exposure to Heat (own depiction)

Figure 2 shows the results of the analysis. The red-highlighted streets are perceived as being highly vulnerable to heat stress, whereas the green-coloured ones show hardly exposure. Intermediate pressure is revealed by orange-coloured streets.

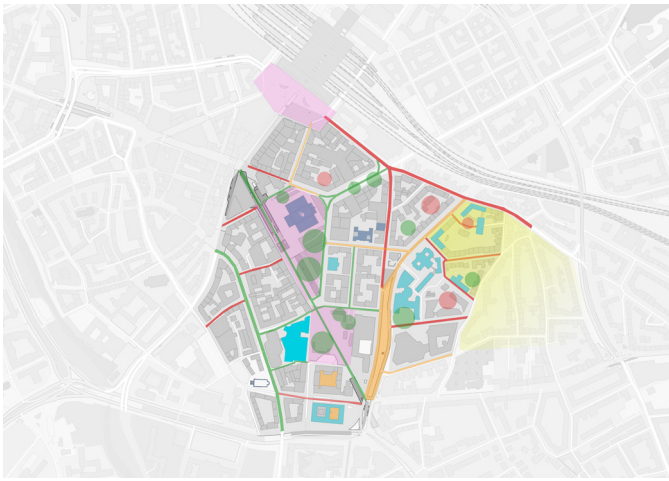

Fig. 2. Analysis Results (own depiction)

Fig. 3. Georgsplatz: Low Exposure to Heat (own depiction)

Fig. 4. Analysis Results (own depiction)

The western area, including the Opernplatz, the Georgsplatz and Theaterstraße, represents well-functioning climate-friendly adaptation measures to heat vulnerability (see Figures 3 and 4). High trees and closely-connected green areas along the alley Georgstraße offer good access to shaded locations. Water elements on Georgsplatz further support a balanced micro-climate and a partly opened surface structure offers possibilities for evaporation. Despite the high density of buildings, the materials are identified as being hardly susceptible to radiation. Nevertheless, the dense concentration of buildings was found to limit air circulation. Only one wind corridor was identified in the Sophienstraße. Despite the wind, a high amount of asphalt, the street's east-west orientation and the lack of greenery were found as strong exposures to sunlight that reflects without hindrance.

Contrastingly, it was found that the eastern part of the study area is mostly affected by exposure to heat. A lack of greening on street, such as trees, and a high density of high-rise buildings with reflective facades, partly of glass, were revealed. This finding is accompanied by the low quality of stay due to the lack of a dedicated public gathering area equipped with shade and seating furniture. The majority of streets is asphalted, which further reflects heat and leaves hardly any possibility for evaporation. Additionally, the area is disconnected to the functional integrity of the main city centre. This separation is enforced by the streets Schiffgraben and Prinzenstraße that prioritise car traffic on multiple lanes. Especially on Schiffgraben, high motorised traffic volumes are recognised. Further, disused tram tracks lower the urban design along Prinzenstraße and Schiffgraben.

Fig. 5. Prinzenstraße with disused tram tracks (highlighted in green) (own depiction)

Fig. 6. Asphalted street highly exposed to heat (own depiction)

Based on these findings, the clear divide within the study area is revealed as depicted in Figure 2. Despite a lack of qualitative and quantitative research methods, it could be proven that the occurrence of UHI varies regarding the urban structure. Micro-urban heat islands were identified in a few streets, public parking lots and public inner courtyards based on perceived changes of local temperatures occurring from a lack of wind and vegetation elements.

Use of Area

The whole area is characterised by three main types of usage that are mixed areas, green areas and residential areas (Landeshauptstadt Hannover 2019: www) as outlined in Figure 7. These usages were further analysed and divided by their functionality. The western part of the area is the dedicated core shopping area. It is interrupted by two green areas at Georgsplatz and Opernplatz that provide healthy gathering places. A small part of the area with high importance in the urban context is dedicated to cultural usage at Opernplatz and partly Prinzenstraße: Key cultural points of attraction, i.e. the Hanover state opera and the state theatre. Furthermore, the functionalities in the centre and centre-east are identified as the financial and administration district. A small part in the east is dedicated to residential use which enhances the possibility to expand over the study area's border. According to the land-use plan of Hanover, one hospice was identified as being located in the eastern area. (Landeshauptstadt Hannover 2019: www) However, it could not be clearly identified whether the institution is vacant. Therefore, this kind of usage is not considered in the following.

User Groups

Based on the zoning and the functional analysis of the study area, three main user groups were identified as being exposed to urban heat stress.

- Visitors to the city of Hanover for the purpose of tourism and shopping
- Employees from surrounding shops, financial businesses, insurance companies, banks and administrations
- Residents living in the north-east of the study area

It is clearly discernible that these user groups follow differing interests with respect to them staying and spending time at locations in the area. While visitors are expected to remain outdoors for longer intervals, employees are likely to gather at these places for shorter intervals, e.g. during their daily lunch break. Moreover, the periods of usage differ significantly from each other. While residents are expected to mainly visit these areas in the late afternoon and evening hours during the

week, visitors would rather use the place during the daytime. Employees, however, are expected to use the place during for lunchtime activities around noon. The diversity of user groups points out several demands on public spaces. This makes it clear that new adaptation measures for climate resilience must show beneficial cooling effects on both the inside and outside of buildings.

Figure 7 summarises the findings concerning the functional separation of the area and the main types of land use. The arrows show potential flows of pedestrian ways to reach the closest green public places of stay. The distance to green areas and streets can reach up to 600 metres which emphasises the urgent need for action.

Conceptual design

The following concept consists of a master plan that is followed by a three-stage detailed plan.

Masterplan

The masterplan outlines the core strategy of developing a heat-resilient area in a central part of the city of Hanover. The plan focuses on the more vulnerable eastern area as identified in the analysis; adequately described by the name of the proposal, Tr-Islands referring to the train-tracks and the triangle-shaped as the main unifying component in the design of the masterplan. Three core priorities in three-time frames of implementation are set:

TIME FRAME	PRIORITY
Long-term	Enhancing urban resilience towards adapting to heat stress by the creation of a green network system.
Medium-term	Increasing the urban quality of stay regarding the user groups differing demand by re-using abandoned tram tracks as a complementing network axis.
Short-term	Creation of an expanded pedestrian network to central places of stay from the Eastern part of the planning area by implementing heat-avoiding and resisting guiding elements.

Tab. 3. Core strategy (own depiction)

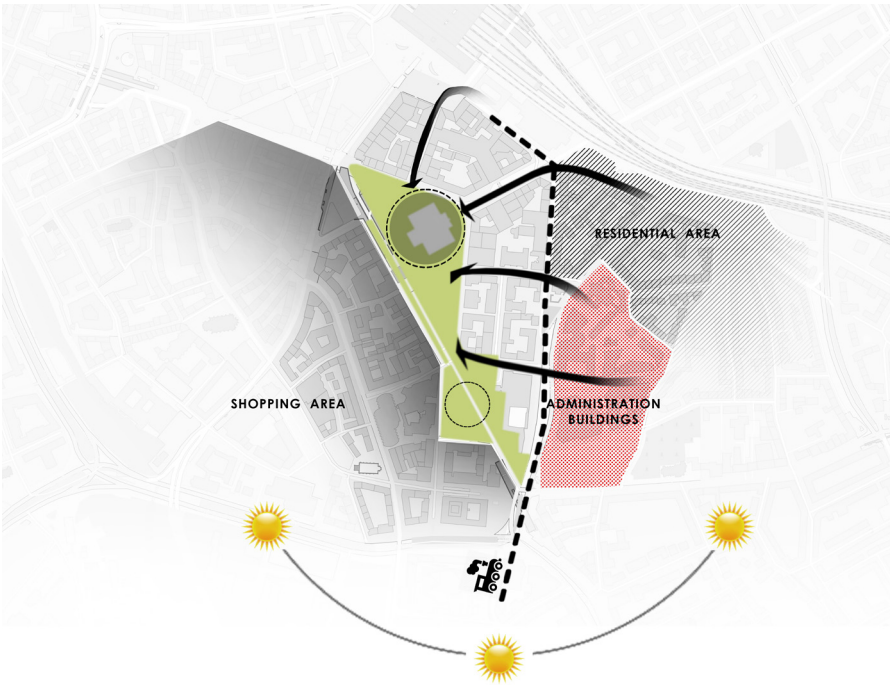

Fig. 7. Brief summary of findings (own depiction)

Figure 8 portrays the masterplan[1].

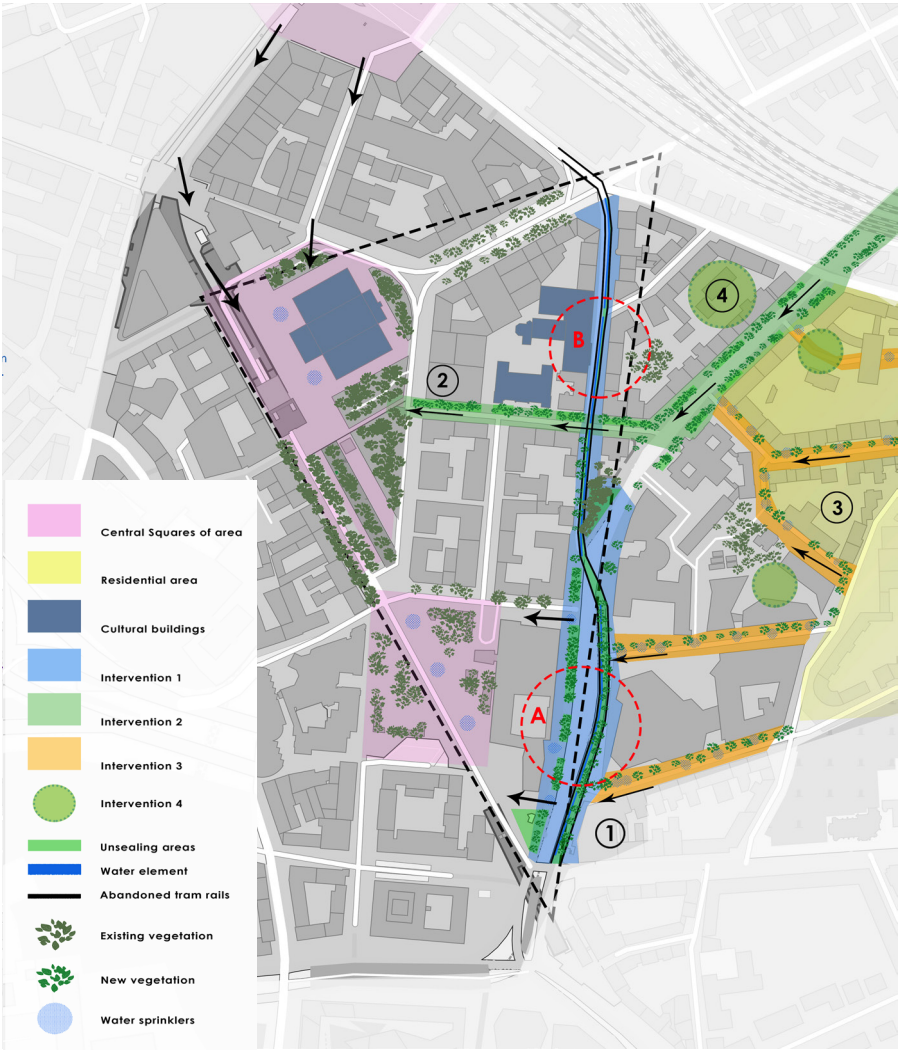

Fig. 8. Tri-Island Masterplan (own depiction)

[1] It should be noted that the paper does not explicitly refer to all measures outlined in the masterplan

Detailed Investigations

Three detail plans point out potential measures for climate resilience adaptation. For each focus area, the precondition is shortly given before the respective approach is explained.

Focus area 1: Schiffgraben south

Preconditions: The regarded section of the street Schiffgraben is characterised by a large cross-section. The road currently includes disused tram tracks with an abandoned tram terminal point Aegidientorplatz. A lack of high trees and greening elements can be identified, leading to a low quality of stay and high levels of potential heat exposure. Similarly, high numbers of passing by cars lead to noise and air pollution.

Approach: While the tram station will be removed, the tram tracks are kept in order to retain the place's former identity. Greening measures are going to be taken for the middle verge on-top and around the tracks. Measures include the planting of high trees for the provision of shade, the planting of grass and seasonal flowers. (see Figures 9 and 10) Additionally, these actions increase the up-take of rainwater and the absorption of CO_2 for counteracting pollutions from e.g. cars. Furthermore, noise emissions can be lowered by the reduction of sealed surface. An additional implementation element is a narrow watercourse along the track, contributing to cooling the area through water evaporation. Plants and tall trees will be planted to the sidewalks and cycle paths along the street, with a steady line of small water fountains, resulting in more favourable heat conditions for pedestrians.

Fig. 9. Installation of Heat Prevention Measures on Schiffgraben (own depiction)

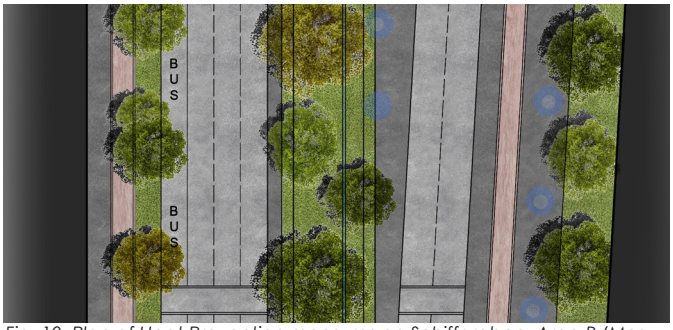

Fig. 10. Plan of Heat Prevention measures on Schiffgraben, Area B (Masterplan) (own depiction)

Focus area 2: Prinzenstraße

Preconditions: Prinzenstraße connects Sophienstraße and Theaterstraße. It is a narrow one-way street, by the northern part of the disused tram tracks in northern and southern direction. The street's importance is highlighted by the presence of the local theatre. Greening elements are missing in the urban structure; hence, the street is perceived as highly vulnerable to heat stress.

Approach: It is proposed to implement greening elements between the buildings. A green canopy is suspended above the street level, with vines and climbing plants creating adequate shading without the use of trees. This measure is implemented to address the narrowness of urban space. Furthermore, the space of the tram tracks is used to extend the water element from Schiffgraben, for further cooling. Additionally, the street

Fig. 11. Installation of Heat Prevention Measures on Prinzenstraße (own depiction)

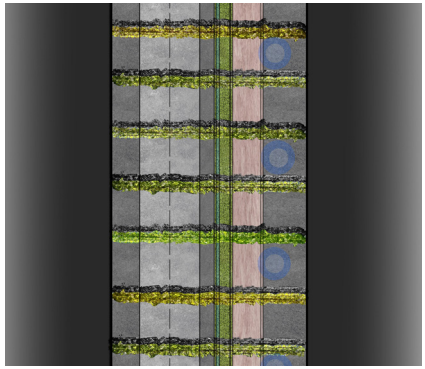

Fig. 12. Plan of the Heat Prevention Measures on Prinzenstraße, Area A (Masterplan) (own depiction)

will be equipped with street furniture to increase the quality of stay for users. The furniture supports spaces dedicated to pubic usage and not for commercial purposes.

Focus Area 3: Streets to the east of Schiffgraben - Creating a Network

Preconditions: See Focus Area 1.

Approach: Along the Schiffgraben road link to Sophienstraße, a combination of tree planting and unsealing surfacing measures should be implemented. This will create more adequate walking conditions for pedestrians and cyclists with reduced street-level temperatures. People are encouraged to actively move westwards the city centre area to benefit from high-quality green spaces of stay. Secondly, the connection between the city centre and the residential area is enhanced by adding more trees for shading. Additionally, spatial markers will guide residents as they move further into the city centre with green sculptures becoming more frequently placed as moving closer. Finally, the creation of additional green pocket spaces, within accessible building courtyards, will improve the spatial quality and the users' values, especially for employees working in the large office buildings.

Justification for chosen measures

Measures to be implemented are chosen based on their scientifically proven capability to provide for environmental and social resilient capacities needed in response to the former analysis. Additionally, the presented approach aligns with the urban development strategy Hannover City 2020+ (Landeshauptstadt Hannover 2011: www).

Whereas the urban built form and the materials are hardly subject to change, water and vegetation were mainly chosen as interventions for reducing the UHI effect (cf. Kleerekoper et al. 2012: 32). According to Kershaw (2017: 4-29), blue and green infrastructure are well suitable for mitigating UHIs.

Vegetation measures can have an average cooling effect up to 4.7°C in urban areas. An environment can be actively cooled by transpiration and evaporation. Additionally, planting high trees

with dense treetops provides for shading surfaces and lowers the absorption of radiation. Vegetation in terms of green public spaces further benefits citizens acceptance and can be implemented at a low cost. (Kleerekoper et al. 2012: 32) Moreover, vegetation serves for potential flood relief by being an ecological, natural and therefore sustainable drainage system. Apart from the “hard” facet of built resilience, “soft” social factors are enhanced by the improved health and well-being of users due to the environmental improvements by aestheticised urban structures. (Kershaw 2017: 4-20)

Street trees

Trees can absorb up to 90% of solar radiation and thus have a positive effect on urban micro-climate. The temperatures under trees reach a cooling effect of up to 15°C compared to the temperature of the environment (Tonneijck et al. n.d.: 13ff). The larger the treetops, the stronger the measurable temperature difference in the built environment. (Kleerekoper et al. 2012: 32; Tonneijck et al. n.d.: 16)

Green spaces

Greened areas generate cooling as they are suitable for rainwater retention, which then evaporates again (Kershaw 2017: 4-20; Kleerekoper et al. 2012: 32; Tonneijck et al. n.d.: 16). Green street spaces further provide for multifunctional use. Ecosystem services bind air emissions such as CO_2. Equally, social cohesion is strengthened as the quality of stay at public spaces is enhanced by their regulative impact (BFN 2017: 17). The authors emphasise the importance of social capital in the context of a resilient urban environment. The usage of wildflowers or other plants similarly enhances the quality of the urban environment (Tonneijck et al. n.d.: 24).

Water elements

Water functions as a heat buffer by its heat absorption capacity. Especially flowing waters, such as streams, are most suitable for transporting the heat out of the area (Kleerekoper et al. 2012: 33). The biggest cooling effect comes from dispersed waters such as fountains (ibid.).

Non-consumption areas / Street furniture

Non-consumption areas can animate people to socially interact (Tonneijck et al. n.d.: 28). This contributes to building social capital and thus social resilience as they provide inclusive areas. Likewise, street furniture in various spaces offers the possibility to participate in public life. Especially elderly and weaker people benefit from such infrastructures as these offer rest places and public realm. Therefore, sufficient and well-designed infrastructures in urban places can help people to build social capacities and to encourage social exchange.

Green Network

Apart from urban heat prevention and adaptation measures, the creation of a green network shall provide for enhanced levels of social resilience. On the one hand, a network of green infrastructures enables balancing and synergising heterogeneous user demands by providing for multifunctionalities of space (BFN 2017: 14). The incorporation of the crucial resilience elements, diversity and redundancy, is supported as the urban land-use patterns serve for various social, ecological, economic functions (Sharifi & Yamagata 2018: 19). On the other hand, a network consisting of greened pathways offers a basis for sustainable mobility, as movements of people are facilitated by well-designed pedestrian paths and areas (Olazabal et al. 2018: 200; BFN 2017: 13). Eventually, mixed-use neighbourhoods and walkability "provide more opportunities for strengthening social networks and enhancing social interactions among neighbours, thereby enhancing social capital and sense of attachment to the community" (Carpenter 2015 in Sharifi & Yamagata 2018: 18). (BFN 2017: 13; Sharifi & Yamagata 2018: 18f). "The creation of an urban green network benefits that urban heat island effects as it accumulates from the sum effect of all development [so that] great variations may be evident in small areas and these have immediate impacts on residents' health and energy demands." (Stangl 2018: 186) Eventually, linking residential and business is essential for enhancing urban resilience (BFN 2017: 13).

The notion of urban governance

The consideration of urban governance in the context of urban planning plays a major role in resilient urban development. Urban governance "refers to how government (local, regional and national) and stakeholders decide how to plan, finance and manage urban areas" (Avis 2016: 4). As it is profoundly politically informed, a process for decision-making should be strategically determined by a variety of institutions and actors (ibid.). Strong structures of cooperation can build up a local or regional system of action (Plöger & Lang 2013: 334; Lukesch et al. 2010: 47). According to the UN-Habitat (2015: 1), urban governance is understood as "the software that enables the urban hardware to function [...]" by making "local institutions able to respond to the citizen's needs" (ibid.). That indicates the need for multi-level governance in order to make decisions on vertical and horizontal levels (UN-Habitat 2015: 1).

The urban development process for implementing heat-resilient urban areas needs to be shaped by these characteristics. To include various competencies which strengthen redundancy (Kühnel 2014: 181; Lukesch 2010: 50f), stakeholders of the private, public and non-governmental sector will have to be included.

The public sector, represented by the City of Hanover, acts as the executive and legislative power. The city's government, but also the regional and state government indicate key roles in terms of political decision-making and establishing legal frameworks. The multi-level approach is highly important as, in the case of heat islands, not only the urban micro-climate needs to be regarded, but further the meso-climate of the Hanover region. Additionally, an integrated approach towards urban planning should take place. It could be beneficial to create a municipal working group with representatives of the city's' different departments and institutions to foster collaboration, knowledge transfer and the effectiveness of urban planning (BFN 2017: 24).

The inclusion of the private sector is particularly important due to various reasons. First, the outlined concept concerns numerous private businesses and companies that are in

the area. Owners and users of the buildings, especially in Prinzenstraße, need to be informed and convinced about the importance and effectiveness of the planned measures as these directly affect the usage of building structures and facades. Them being highly aware of the vulnerability to heat stress can increase their openness and willingness to participation and collaboration.

A further important stakeholder is the ÜSTRA traffic company due to it being responsible for the disused tram tracks that are subject to the re-design of the urban space. Moreover, collaboration with experts from private urban planning companies is useful for a strategic, independent planning process, knowledge transfer between different stakeholders and for quality guarantee (BFN 2017: 24). Public-private partnerships could be a good means for financing construction and maintaining the new functions.

The non-governmental sector is embodied by residents of the city of Hanover, citizen organisations and other action groups. Their early inclusion not only in the decision-making process but also in the urban design process is crucial to balance their demands and interests by dialogue mechanisms (BFN 2017: 14; UN-Habitat 2015: 1). Local knowledge is necessarily offering the intermediary between stakeholders to plan for uncertainties (Kim & Lim 2016: 6; Klein et al. 2017: 35). Additionally, the involvement of citizens at different planning stages fosters public acceptance for interventions (Greenspace 2005 in Kleerekoper et al. 2012: 32). Moreover, the authors expect that the integration of residents increases the participants' internal capacities to act, understand and be responsible for their environment and its vulnerabilities. Such a process equally supports the creation of social capital by interacting with a variety of stakeholders in an integrated way. Eventually, the first step towards social resilience can be taken by broad participatory measures in a bottom-up approach. The actual urban planning process should go beyond formal instruments to achieve common targets (BFN 2017: 24).

Apart from the urban planning process, the latter maintenance of the implemented green infrastructures should be considered as a mutual task between various actors. Here again, a strong collaboration between the responsible departments such as urban planning, environmental and landscape departments can facilitate these tasks. A successful planning process may also encourage other actors such as citizens or private companies to take responsibility for the implemented measures. Urban gardening in public space could indicate one solution, supported by companies' activities for corporate social responsibility. The development of social capital by such offers must neither be underestimated nor be undermined.

Recommendation

The above-presented concept already indicates that urban resilience can only be implemented using an integrated development approach. However, the authors found that the city of Hanover does not yet provide an optimal-sized strategy for managing climate resilience in an urban context. As there is not a one-size model of implementation, the authors recommend the introduction of a resilience concept into the city and regional policies and guidelines for promoting coping with transformation proactively. The necessity for a comprehensive resilience strategy is emphasised in the light that the recognition of resilience contributes to long-term urban sustainability. Despite the current incentives for green roofs (Landeshauptstadt Hannover 2019: www), it is recommended to foster the implementation of greening measures on facades. Stronger limitations for the use of radiating building materials on facades are needed regarding the decrease of urban air temperatures. Enhancing urban resilience in terms of upgrading the urban structure may be one step. Nevertheless, the social component must not be forgotten as outlining policy proposals only may be too weak. Therefore, it is recommended to also focus on enabling locals' social capacities of coping and adapting. It is highly important to foster the creation of social capital by providing opportunities for the inhabitants of the city to gather and exchange. By doing so, awareness for urban stress rises and responsibility for transformation towards urban resilience. Innovative changes towards resiliency can only arise from local governments ability to design comprehensive resilience policies with the influence of numerous stakeholders.

Moreover, a quantitative and qualitative monitoring system is needed for measuring the effectiveness of the proposed measures. As part of that, the authors propose the development of a smartphone application for informing people about stresses and risks and offering a possibility to a reliable exchange with public authorities. By that, useful information can be collected contributing to an efficient information base - for actors and concerned citizens or visitors. The limiting accessibility of a smartphone app could possibly be overcome by installing information and interaction monitors at public spaces. Despite high costs for implementation and maintenance, the authors stress the importance of such a system.

Conclusion

This research paper presents itself as a pro-active approach to making a district more resilient against the coming challenges of heat islands. As with the main issue of dealing with the specific area of Opernplatz and the surrounding streets and quarters, the results of climate change will make this well-built city area less and less productive.
Within the analysis, the area is shown to be distinct for the emergence of urban heat islands which requires a scaled approach to addressing these issues. The masterplan proposal outlines a direct result of the analysis, connecting the main travel hubs, i.e. Kröpcke, Hauptbahnhof and Aegidientorplatz, to the eastern areas of the study site, reducing the need for car travel and greatly improving the quality of street spaces in and around the study area.

Flexibility always characterises an important element of urban resilience. This is put into practice as the areas referred to in the masterplan proposal reflect multifunctional spaces, directly and indirectly, effecting users of the areas. As usability of the spaces is maintained and improved, the areas become valuable to the public and other user groups, greatly improving the social resilience of people.
Moreover, a holistic urban governance process was outlined as key for successful implementations. Lastly, the authors formulated a brief recommendation for the municipality of Hanover, including the need for a monitoring system to measure effectiveness as well as a possible information system for citizens.

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