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ADAPTING EXISTING BUILDINGS TO CLIMATE CHANGE: THERMAL COMFORT IN RELATION TO ARCHITECTURAL TYPOLOGY

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Introduction

Urban heat island (UHI) effect in city center Budapest requires adaptations to the high temperatures through all summer months, which leads to excessive energy consumption, therefore feeds the loop of UHI. In order to break the cycle of energy consumption raising the intensity of UHI effect we must consider thermal comfort as a main factor in our approach to finding solutions. If we propose passive/zero-energy methods that can enhance the thermal comfort within the building envelope, users will rely less on energy consuming adaptation strategies, resulting in less energy consumption, which is one step on the road to adaptation through optimization of existing buildings.

A sustainable and simple optimization opportunity that presents itself in the turn of the century buildings is the court garden. Court garden is an approach, in which we suggest the greening of existing courts of the district VII. Greening court is a suggested nature-based solution (NBS), which benefits biodiversity and supports the delivery of a range of ecosystem services in alliance with the European Commission goals 2024 [1 – European Commission].

Using available ISO standard (ASHARE, 2013) will enable us to utilize the knowledge of thermal design conditions to provide lower air temperature and better air quality through passive ventilation strategies coupled with the greening of courts. It is expected to reach the required thermal comfort zone, which will result in less energy consumption for cooling, thus eventually reducing UHI effect and breaking the cycle.

Climatological findings UHI

The UHI phenomenon increasingly affects the wellbeing of urban residents. Pongrácz et al. (2010) analyzed surface temperatures in nine Central European cities, focusing on UHI intensity using remotely sensed thermal information. The results showed that UHI intensity varied significantly, with monthly average temperature differences between urban and rural areas ranging from 1 °C to 6 °C. By 2014, over half of the global population (54%) lived in cities, a significant increase from 1950 when only 30% lived in urban areas. Currently, 73% of Europe's population is urban, and projections indicate that by 2050, 66% of the global population will live in cities, representing two-thirds of the world's population. Talamon et al. (2016) mark the initial phase of collecting data, references, and databases related to building stock and climate change. This collection will serve as a baseline for the theory of greening courts and will guide the selection of NBS and plants to create carbon sinks within urban environments.

Based on the average outdoor temperatures, residential buildings are designed to accommodate human thermal comfort, the collection and analysis of outdoor temperatures over the years serve as a guide adapting to UHI effect in the city centre of Budapest. Temperature time series of the capital for the period 1901–2012 were analysed by Dian et al. (2020) using daily temperature data from the station data series of five Hungarian cities that are publicly available on the website of the HungaroMet for the period 1901–2019 along with other datasets like CRU TS, E-OBS, and CarpatClim (Johnson & L'Ecuyer, 2018). The study also considered extreme temperatures because they determine the entire range of temperature from where the optimal indoor temperature interval should be maintained.

All data collection and analysis emphasize the importance of extreme daily average temperatures in building energy planning, considering the coldest and warmest days, which are representing 10% of the year, the results show a notable decrease in the range of extremes over time. The coldest days show a warming trend of 1.9 °C per century (Dian et al., 2020), with fewer occurrences of very extreme cold days at the end of the time series. This warming trend has implications for designing heating systems, as it indicates a shift towards milder winters and hotter summers in Budapest.

Through utilizing high resolution grid-cell level data to estimate the mortality burden of UHI, the data of tree coverage show estimated increasing tree coverage to 30% in European cities, which can prevent 2644 premature deaths, corresponding to 1.84% of all summer deaths. A mean increase in tree coverage of 17.7% is projected to bring about a cooling effect of 0.4 °C across European cities (Lungman et al., 2023).

Architectural data and building typology

Tackling the UHI effect through urban planning and architectural typology depends on factors affecting the cooling of buildings such as layout, building materials, sun exposure and orientation. There are several urban factors impacting energy performance such as land use, traffic and surface cover. It was found (Pierdonato et al., 2021) that the relative deviation grows up to 3.1% if the effects of anthropogenic heat such as producing waste heat rejected from cooling systems are considered that is 20 times higher than the one produced by traffic, increasing external air temperature and feeding the loop of UHI in the city.

The district VII of Budapest is defined by Király Street, Erzsébet Boulevard, Rákóczi Street, and Károly Boulevard (*Figure 1*). This area, known as Belső-Erzsébetváros (Inner-Elizabethtown), was once agricultural until the 17th century, but now houses, 473 buildings across 0.6 km². Typology shown in *Figure 2*. With a population density of 25,899 persons per km², it is Budapest's most densely populated district. Its development dates back to the 18th century, spurred by Pest's expanding population beyond medieval walls, the area witnessed a construction boom between 1885 and 1915, characterized by multi-story apartment buildings. The 1930s saw ambitious projects like Madách Sugárút (Madách Avenue) aimed at urban transformation, interrupted by World War II. Post-war renovations occurred, but limited new constructions followed due to financial constraints. Renovation efforts resumed in the 1980s, though halted due to financial reasons after renewing three blocks in 1988. Recently, Madách Avenue, now Madách Promenade, has seen contemporary-style interventions in its original fabric (Sugár et al., 2019).

Nature-based solutions

The approach to greening courts is through using NBS as an adaptation strategy for extreme heat and heat stress in the city centre through greening courtyards, both vertically and horizontally creating green volumes that impact and significantly reduce heat, enhance the air quality by functioning as carbon sinks. The use of courtyards in the turn of the century buildings is a chance to mitigate to UHI effect through incorporating the natural environment into the built environment, it would participate in rainwater management through providing the natural surfaces as land cover to absorb rainwater. All these can lead to reduction in the use of cooling devices, and so reducing UHI effect in the city centre.

NBS can thus deliver services such as erosion control, drought and flood prevention, carbon sequestration, cooling, and wildfire prevention. Scientific evidence for these multiple benefits and practical know-how are rapidly expanding in Europe, supported by EU Horizon 2020 and Horizon Europe funded research projects [2 – Climate adapt].

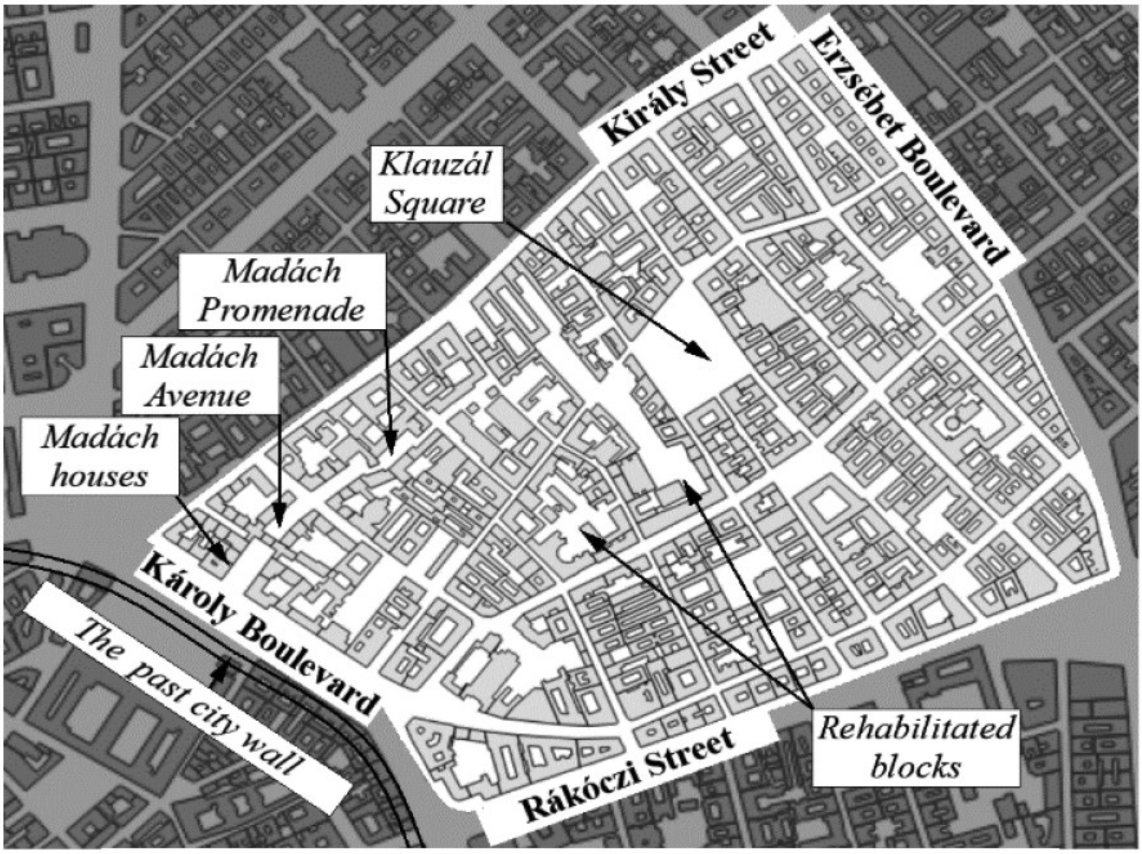

Figure 1: Target area in the district VII of Budapest.

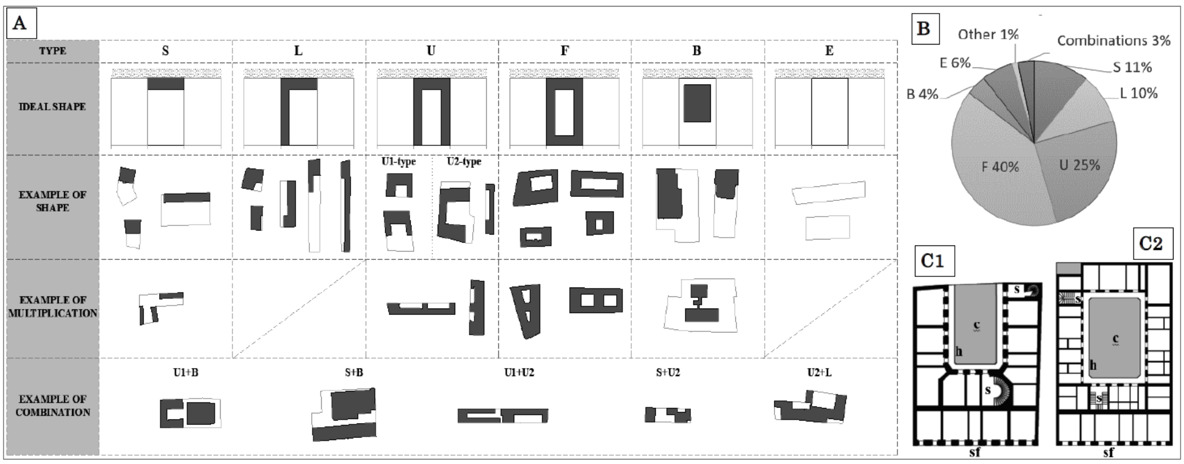

Figure 2: Typology and function. A: the layout of the building stock,
B: the distribution of layout types, C: example layout of the most common U (C1) and F (C2) types (c=courtyard, h=hanging corridor, s=street front façade) (Sugár et al., 2019).

Thermal comfort

Thermal comfort can be defined as the absence of the desire to adjust indoor temperatures through the use of active heating/cooling methods or the change of clothing in order to become relaxed in a space in relation to the feeling of cold/warm.

We intend to work on the microclimate of the building envelope including court area, meaning we intend to control/enhance indoor air quality through controlling the source of air (the court). The aim is to control temperature (air temperature and radiative temperature of surfaces), capture aerosols and airborne particles and contaminants, controlling the source of air in order to create a comfort envelope within the apartments of the building.

Figure 3 simplifies the relationship of environmental factors on the individual thermal comfort, physiological and psychological health (McDowall, 2006). The highlighted boxes represent the environmental factors that will be controlled by our NBS approach.

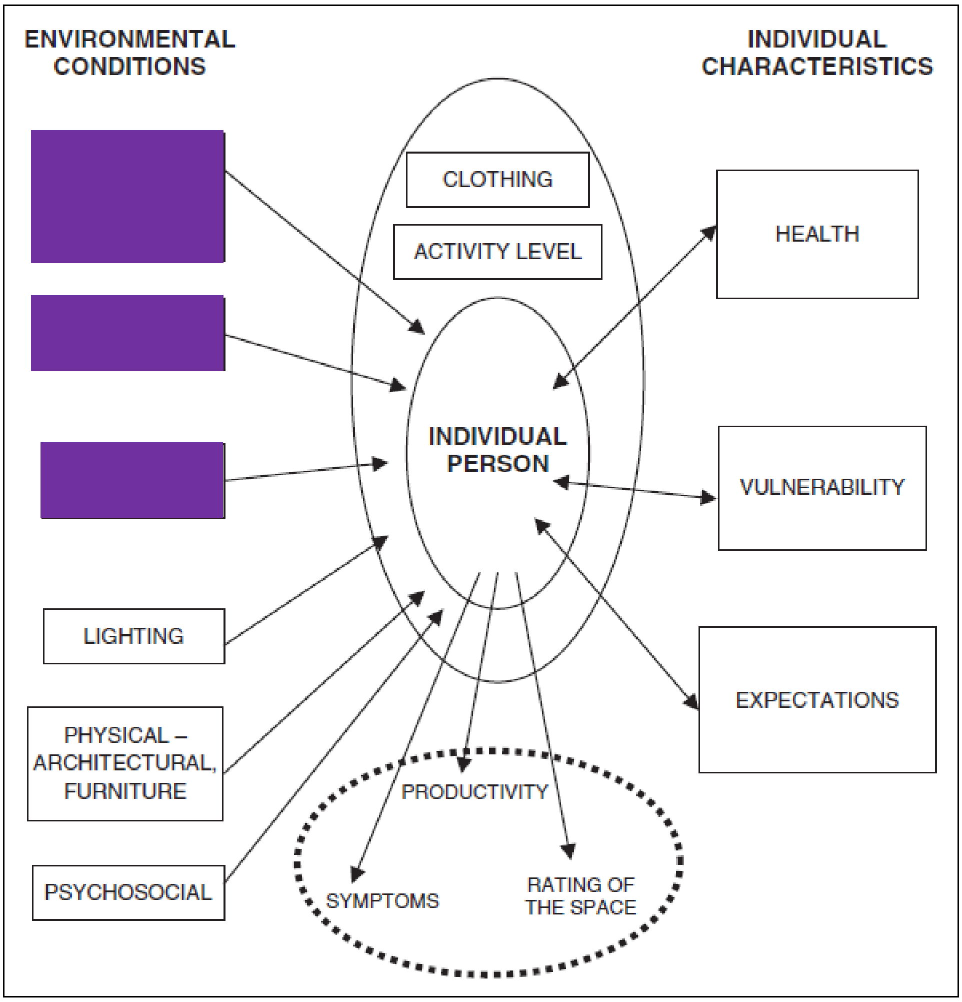

Figure 3: Personal Environment Model
(adapted from the construct of comfort (McDowall, 2006)).

Thermal comfort is essential for occupant well-being and productivity, making it vital to adopt sustainable methods that minimize environmental impact. Effective strategies include passive design techniques, such as natural ventilation and building orientation, which reduce reliance on mechanical heating and cooling systems.

Incorporating renewable energy sources, like solar power, enhances energy efficiency while supporting thermal comfort. Additionally, using sustainable materials – such as high-insulation windows and green roofs – can help maintain ideal indoor temperatures. By focusing on these sustainable methods, we can create comfortable living environments that also promote ecological responsibility and energy conservation.

Sustainable methods to enhance thermal comfort

- Passive cooling techniques: Utilizing natural ventilation and shading can help maintain comfortable indoor temperatures without the need to operate mechanical systems (Chow, 2024). The approach in our work is relying on enhancing the court air quality (micro-climate) and through passive ventilation methods enhancing the indoor temperature and air quality accordingly. Passive cooling approach reduces energy consumption and elevates comfort by allowing fresh air to circulate naturally.
- Use of renewable energy: Implementing renewable energy sources, such as solar panels, this not only supports passive systems and promotes thermal comfort but also minimizes the environmental impact associated with traditional energy sources, renewable energy in the court could be focused on the reuse of rainwater for irrigation or cooling purposes.
- Building orientation and design: Designing buildings to take advantage of natural light and prevailing winds can significantly improve thermal comfort. Proper orientation can reduce heat gain in warmer months and enhance natural heating in cooler months, although in the case of the district VII of Budapest, the orientation is already decided we are able to investigate the result of orienting buildings in one direction through the existing database and come up with conclusions accordingly, utilizing wind flow through aerodynamics science of passive cooling will take part in the analysis of courts.
- Insulation and materials: Using high-quality insulation and thermal mass materials can help regulate indoor temperatures. These materials absorb heat during the day and release it at night. Analysing surfaces covering the court (floor-walls and glass covered areas such as windows) will give us insights on heat absorption, reflected heat, heat radiation and heat retention and release through the day/night cycle, using these insights we will suggest materials that are contributing to a preferred stable thermal environment.
- Landscaping: (Chow, 2024) Incorporating greenery around buildings can provide shade and reduce heat absorption, contributing to a cooler microclimate. This can enhance the overall thermal comfort of the building occupants; in our study we intend to introduce the greening within the building due to the availability of space within the court.

These sustainable methods are essential for achieving thermal comfort while addressing the challenges posed by UHI in Budapest and the increasing demand for energy-efficient solutions.

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