Methodology for Selecting Sites and Creating Urban Cool Islands (UCIs) in Cities

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Abstract: Extreme hot weather causes deaths that are largely preventable. Urban Cool Islands (UCIs) offer a landscape architecture solution that can help mitigate mortality brought on by heat waves. UCIs are designated city shelters that provide people, especially at-risk population groups, protection from extreme heat events. The paper illustrates a methodology to identify Urban Cool Island locations for further development. This design-oriented methodology defines key UCI elements of public accessibility, good air circulation, shade and water availability and treats them as flexible values, instead of fixed, pre-existing features in scientific methodologies. This methodology uses free and open-source software and is easily adaptable to mobile phone alert applications. The German city of Leipzig was used to illustrate the application of this framework.

Keywords: Urban Cool Island, hazard response

1 Introduction

Global surface temperatures have been rising at an increasing rate and the trend continues (HRC 2019). Hot weather can be lethal, killing more people every year than any other weather disaster (NWS 2022). In the summer of 2019, large parts of the European Union broke heat records. Paris recorded its highest temperature at 42 °C with fifteen consecutive days over 31 °C (AccuWeather 2019). Across Paris and the rest of France, 1,500 deaths were attributed to the heat wave that year (Guardian 2019). However, this mortality rate was much lower than Europe's 2003 heat wave, which was not as hot and lasted for a shorter duration but left 14,000+ dead in France (WHO 2007).

With longer durations of heat and higher temperatures, why didn't Paris see more fatalities in 2019? What reduced the mortality rate so drastically? The answer is that Paris followed the recommended guidelines listed in the World Health Organization's (WHO) EuroHEAT report (WHO 2007). Paris implemented a plan involving a public awareness alert system (Keramitsogloua 2017), creating community shelters (Cites 2022), opening parks, swimming areas, and greening the city with "islands of freshness" (O'Sullivan 2022).

A key finding of the WHO report is that "the adverse health effects of heat waves are largely preventable" (Hallegatte 2016). Reduced mortality in Paris during the 2019 extreme heat events is a testament to how well Urban Cool Islands (UCIs) and advanced warnings can improve heat health resilience. Paris's islands of freshness are, at their essence, carefully designed urban cool islands that prevent loss of life from extreme heat events. And it is this definition of UCIs that this paper refers to: UCIs are designated city shelters that offer protection from extreme heat events, especially for at-risk population groups. The authors' aim here was to create a framework for identifying sites to create UCIs and making this information available to everyone. The framework's design-oriented landscape architecture methodology provides a simple, step-by-step process. Completing all the steps of the methodology

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acts as a process of elimination before beginning detailed analysis; it saves time and effort by creating a short-list of results to be used by city planners for more complex calculations. The paper focuses on outdoor spaces because they have a secondary effect of improving urban environments (KOWARIK 2016). And while rolling blackouts and power outages often happen during extreme heat, this methodology can easily be expanded to include architectural and air-conditioned spaces as emergency shelters (KENWARD 2014).

2 Methodology

For this study, free or open-source digital applications and tools such as QGIS, OpenStreetMap, and Google Earth were used. The resulting map highlights high-risk mortality areas and their proximity to potential UCIs shelters. The combination of this methodology with a public alert system provides a powerful tool for combating suffering and mortality during extreme heat events.

The steps are simple: Analyse the city for accessible sites with good air flow, then intersect the results for potential UCI locations. Determine at-risk groups' proximity to the areas, calculate occupancy and select the most valuable locations. Adjust the selected locations for water and shade as needed. Make the findings available through a public emergency address system during extreme heat events.

2.1 Analyse Accessibility

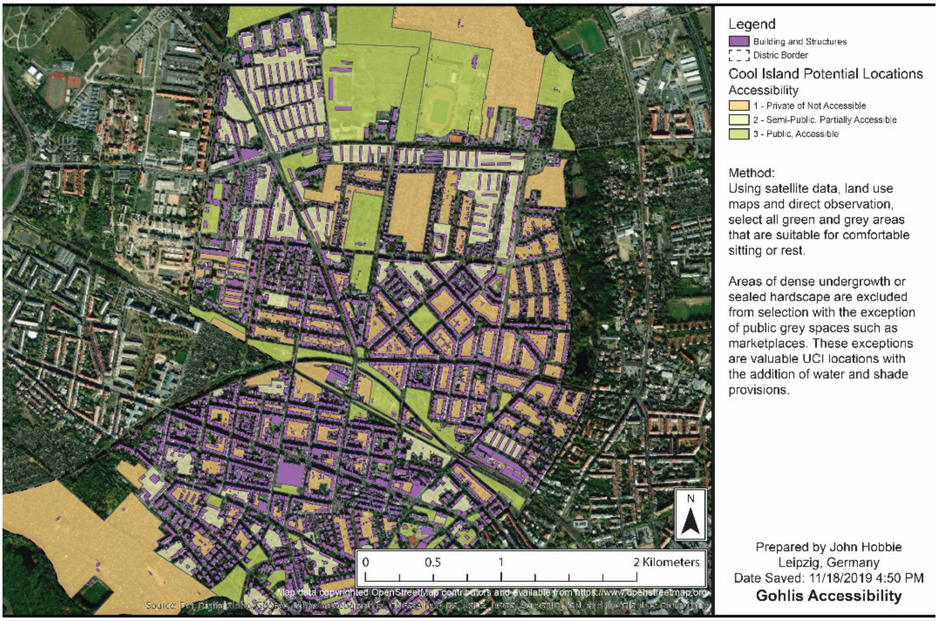

Fig. 1: Analyse the district's accessibility and assign a value; 1 = private or inaccessible, 2 = semi-private and accessible, 3 = public and accessible

The first step is to create a map analysing areas that are accessible to the public and emergency vehicles; both must be able to travel to UCIs easily (Figure 1). Hard and softscapes are acceptable, such as public parks and train stations. This step simply asks if all people; the handicapped, disabled, very young and old, can easily gain access to the UCI. Access also needs to include emergency vehicles, so while forests might be valuable shelters, their distances from emergency personnel can make it ineligible as a UCI.

The value of 1 is assigned to areas that are not accessible. These locations may have characteristics of a UCI, but they are ineligible because they are private or pose obstacles that prevent the average person or emergency vehicles from gaining entry. Semi-public lands are assigned a value of 2 and include such spaces as apartment complexes or sports grounds. These areas might be privately owned but open to the public. For semi-public lands to be a UCI location, permission from the landowners must be obtained prior to creating the UCI. Value 3 spaces are public spaces with no access restrictions areas, including public parks, marketplaces, plazas, or local sports grounds.

2.2 Analyse Air Circulation

Fig. 2: Analyse air circulation and assign a value of 1 = 76% or more enclosed, 2 = 26% − 75% enclosed, and 3 = 25% or less enclosed

Once accessibility is determined, the next step is to locate potential areas with good air circulation. Air circulation is determined by how confined a space is. Like the accessibility evaluation, a 3-point scale is used to rate air circulation of an area. An area that is surrounded by structures by more than 76% of its circumference has a value of 1. Spaces that are surrounded by structures between 26% to 75% have a value of 2. Spaces surrounded by less than 25% or not at all are given a value of 3. There may be cases where vegetation and trees impact air flow. Clearing brush and thinning trees may be needed to allow for accessibility and air circulation. A reference chart to determine valuable spaces by percentage is shown in Figure 2.

To complete the supply identification phase of the methodology, the values assigned to accessibility and air circulation are averaged, producing a single total value for each UCI area. The result is a simple scale of 1 = no, 2 = maybe and 3 = yes, which is easy to understand when working across many different disciplines. This result is the UCI potential site list.

2.3 Determine At-Risk Populations' Proximity to Potential UCI Sites

Identifying demand requires a comparison of who are at-risk and their proximity to potential UCI sites. When considering who are at-risk, studies find a clear correlation between extreme heat and mortality in the elderly, young children, the mentally ill and the sick. In addition, socio-cultural factors also contribute to those who are at-risk. These include people who face social injustice: the poor, the uneducated, and foreigners (Kowarik 2016). For this case study, building/land use data sets were used to locate hospitals, schools, and other at-risk structures, while land value maps were used to determine household income. Germany protects personal privacy so precise data could not be used in this case study, but the land value maps revealed both adequate and lacking areas for UCI sites.

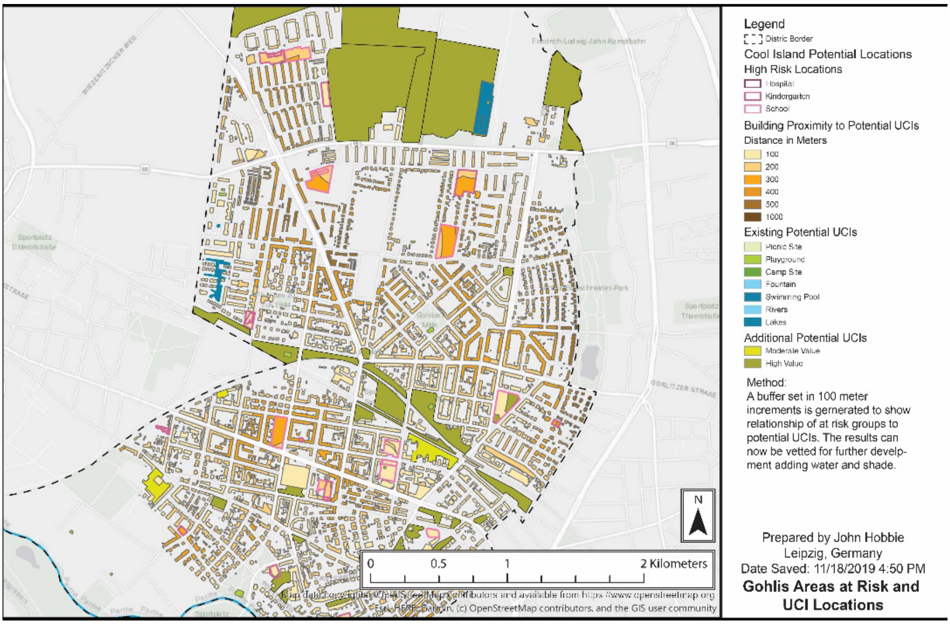

Fig. 3: Determine UCI proximity to at-risk groups using 100-meter increments

While UCIs accommodate everyone in a community, they must cater to those who need them the most. Two basic demographic population categories to be considered are age and income. In this step of the methodology, no values are assigned. Instead, different demographic groups are assessed based on the distance they can safely travel. A buffer of 100-meter increments is used to estimate these distances (Figure 3). For instance, the very young and the very old may have great difficulty walking a kilometer, but other groups will have no problem. More precise distance measurements can be calculated in various ways, but for the sake of easily identifying risk and proximity, a buffer is sufficient to inform city planners and healthcare professionals where additional focus and attention should be applied.

2.4 Determine Capacity

It is also important to calculate UCI occupant capacity. The calculation answers the question: is the UCI large enough to serve its community? This capacity is an estimate of the number of people that can be helped using a standard of one person per 4 square meters. This number is based upon emergency Temporary Hospitals (THs) assessment, giving each person room to lay or sit comfortably while allowing for stretcher clearance and emergency egress (CAMPOS 2022).

To calculate occupancy, a three-meter buffer is applied to all potential UCI sites. This allows a tolerance for hedges, bushes, gates, and comfortable distances from roadsides and any other obstruction that would prevent a person from sitting and resting. The 3-meter buffer is not a fixed distance and can be based on cultural preference.

Next, all spaces less than 10 meters square are eliminated. This 10-meter distance is Leipzig's observed standard area needed to plant a shade tree (*Tilia cordata*). In most cases, a space that cannot accommodate a full-grown tree is not suitable for a UCI. Small spaces that might qualify would include hardscape areas such as public markets and train stations.

Finally, sealed areas are calculated. Sealed land is determined by buffering the appropriate width of all paths, sidewalks, and roads in the area. Sealed land is also subtracted from the usable space in UCI analysis. Zentrum, a sample area for this study, is almost entirely sealed. That does not disqualify it as a UCI, but it does mean the temperature reduction provided by shade will never match that of a green space. The final formula is for calculating UCI occupancy is:

Occupancy = (Area of potential site) − (3-meter Comfort Buffer) − (all areas ≤10 meters squared) − (% of Sealed area) divided by 4 (people)

The UCI occupancy can now be compared with a city's population and at-risk needs, creating a list of valuable UCI locations.

2.5 Adjust for Shade

Shade is a requirement for a UCI. However, good shade coverage at midday is not always an existing feature. Therefore, shade is not factored into the UCI value at first. Unlike accessibility, air circulation or proximity, shade can be added or removed later. Trees can be planted in a green park with little shade. Marketplaces with 100% sealed grey space are unacceptable for a permanent UCI, but temporary tents or awnings can transform them into valuable emergency shelters. Therefore, once areas of risk and their proximity to preferred UCIs are identified, shade can be provided to create a safe area.

There are two basic approaches to shade. Green Solutions include planting trees for shade, increasing permeable materials for pathways and hardscapes, and maintaining wooded areas to keep ground cover from overtaking suitable areas. Clearing overgrown areas around natural water features such as riverbanks, lakes and canals allows people to keep cool by bathing and swimming. Grey Solutions include erecting temporary shade such as tents and awnings. Permanent and temporary water features such as fountains and pool, water misters, and evaporative cooling fans reduce the ambient temperatures at grey landscapes.

2.6 Adjust for Water

Water is essential to a UCI. Water is nearly always available in Leipzig. But if there is no existing water, other sources (e. g., fire hydrants, hoses, misters, etc.) must be made available for potable water and cooling water alike. A supply of potable water is easily accessed if UCIs are in public buildings such as schools or libraries. For parks or marketplaces, emergency services can provide water from fresh-water fire hydrants and water mains. In all cases, water supply needs must be solved on a city-by-city basis.

Water is also used for cooling the ambient temperatures of a space. Water evaporation is a natural form of cooling that works well in environments with moderate to low humidity. There are many products on the market that cool the ambient temperatures of outdoor spaces.

2.7 Create Public Address System

The lack of an alert system was identified as the main preventable cause of mortality in Paris the summer of 2003 (WHO 2007). That is why it is critical to alert the population of pending extreme heat events and guide them to shelter. Many cities already have public address systems in place, or volunteer emergency brigades that can help ensure public awareness and safety. There are also existing free phone apps for extreme heat alerts (EXTREMA 2022).

3 Case Study

Leipzig (Germany) was chosen as an example to apply this methodology. Leipzig is home to nearly 600,000 people. It has the median yearly income of around €40,000. At-risk age groups make up 26.6% of the residents (STADT LEIPZIG 2020). For this case study, three

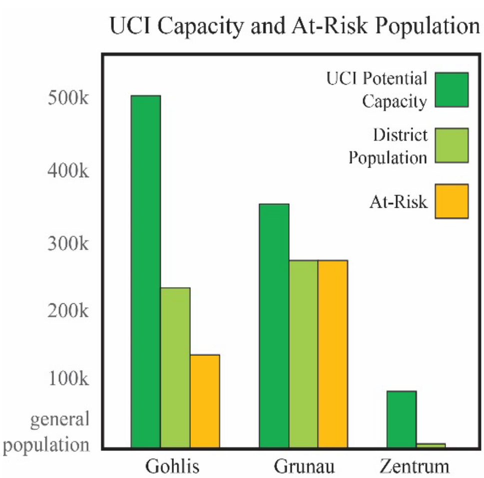

Fig. 4:
This graph shows the total capacity of potential UCIs compared to the districts' populations. The analysis shows that Leipzig has adequate UCI occupancy for the population.

districts were chosen for comparison: Gohlis, Grunau and Zentrum. Each district is distinct in its different income and housing styles. Gohlis tends to be upper middle class, inner city, and a traditional residential style. Grunau is predominantly lower income, locating at the periphery of Leipzig's boundary. It has a combination of single home dwellings and apartment complexes. Zentrum is the city centre with high-value properties and businesses but few residents, and a large, fluctuating, daytime pedestrian population (Figure 4).

In all instances, the at-risk population of each district in Leipzig is below the UCI capacity. Germany restricts personal data access, so property value (instead of income) was used to determine the districts' at-risk population sizes (Figure 5).

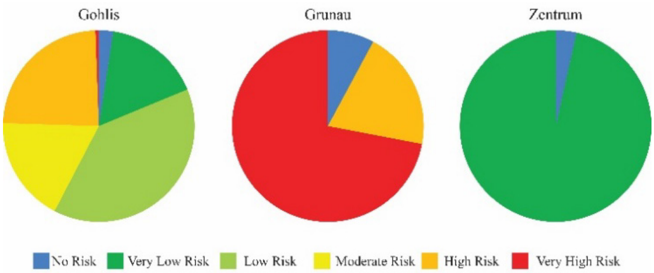

Fig. 5: Land value charts were used to estimate income. This chart shows where the need for shelter is the highest.

Grunau district stands out in terms of need. Approximately 5% of the population lives more than half a kilometer away from a potential site, and most of the population is poor. Using this data, city planners can begin adding shelter for at-risk populations, knowing where to create UCIs, how big they should be, and how much shade and water will be needed to ensure adequate safety (Figure 6).

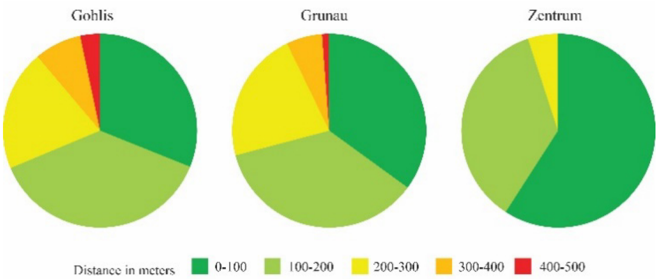

Fig. 6: Even with sufficient supply of UCI locations, some people will be too far from the sites to be beneficial. They will require special attention.

This analysis can be used for more than short term emergency planning. Resulting data can be used to guide changes to zoning plans, determine where best to allocate resources for new public spaces, influence property values, initiate community support measures that guide public investment strategies, and mitigate climate displaced refugees (IOM 2008). Further analyses on wind direction and flow, public transportation proximities, or specific private information for at-risk groups would further enhance the results.

4 Conclusion

Dangerous heat waves are increasing in temperature, frequency, and duration. As power blackouts happen, electrical plants shut down and transportation comes to a halt (KENWARD

2014, WEHRMANN 2019, MUDGE 2019), there is an increasing need for landscape architecture solutions to shelter people from extreme heat events. This methodology provides a framework for putting UCI creation into practice, and it is expected to evolve and adapt to cities' specific needs. It offers a solution to an imminent threat and encourages action, which will provide protection and save lives.

Table 1: Data sets used in this study

Name of Data Sets	Date	Author	Format
ArcGIS Map Service/Canvas/World_Light_Gray_Base	2019	Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS User Community	Raster
ArcGIS Map Service/World_Imagery	2019	Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community	Raster
sachsen-latest-free.shp\gis_osm_buildings_a_free_1.shp	2019	OpenStreetMap contributors	Shapefile
sachsen-latest-free.shp\Leipzig_boundary.shp	2019	OpenStreetMap contributors	Shapefile
Sachsen-latest-free.shp\gis_osm_roads_free_1_Clip	2019	OpenStreetMap contributors	Shapefile
sachsen-latest-free.shp\gis_osm_buildings_a_free_1.shp	2019	OpenStreetMap contributors	Shapefile
Current land values: https://www.boris.sachsen.de/bodenrichtwerte-aktuell-4032.html	2019	Staatsbetrieb Geobasisinformation und Vermessung Sachsen GeoSN	Webpage
Google Earth 3D, Leipzig	2019	Google Earth/Maxar technologies	*.kml

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