Supplementary Information 2

- **Overview**

To compare solutions sets consisting of one or more mitigation measures, we must consider both their capability of reducing UHI (effectiveness) and two important economic criteria: **investment** and **time** (from now on referred as IT). To perform a multi-criteria comparison, we propose an AHP-TOPSIS approach. **First**, we ask experts in the field to evaluate eight UHI-mitigation solutions in terms of **effectiveness** in reducing UHI, **investment** and **time**. **Subsequently,** we exploit the AHP to compare the **measures in pairs** and **give each a score on each metric**. **Subsequently**, all the alternatives are **first ranked according to their efficiency score**; and **then** according to the **IT criteria using the TOPSIS approach**. The first ten most efficient alternatives in reducing UHI are taken and combined with the IT ranking to calculate a final rank (Figure S21).

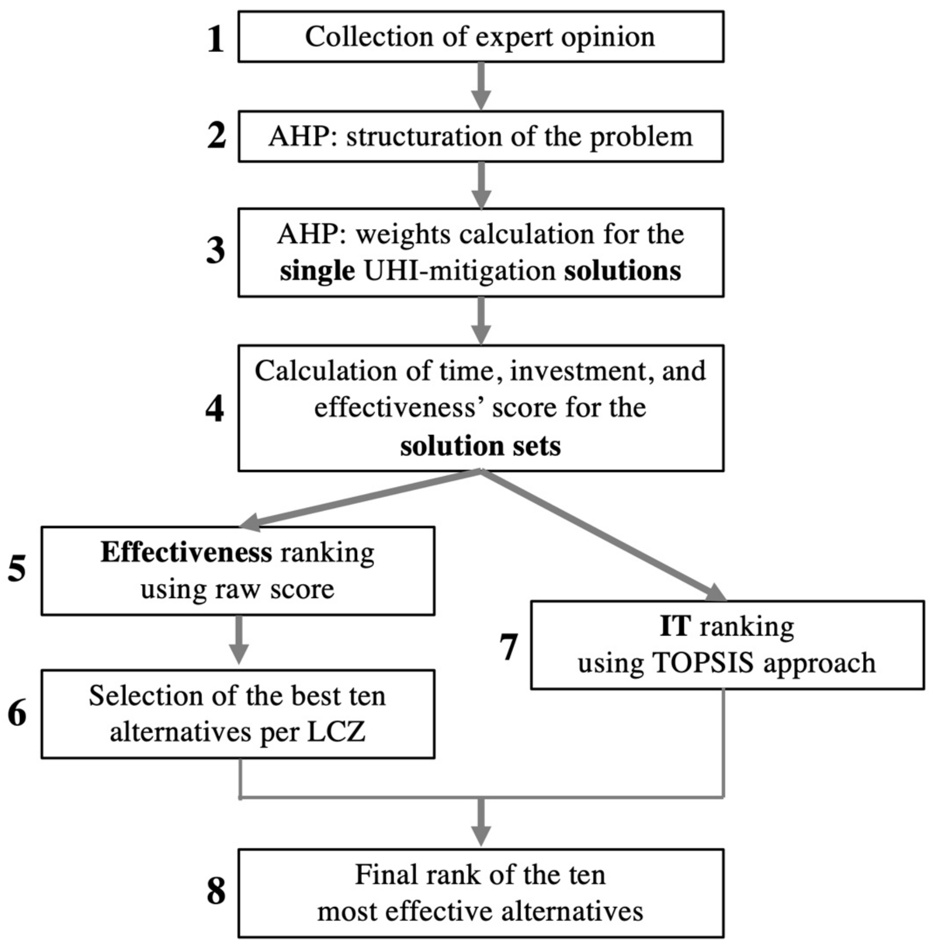

Figure S21 Summary of the methodology

- **AHP Analysis Method**

<u>**Investment, Time and Effectiveness**</u>

To compare solution sets, the following criteria were selected:

- **Investment (I) (N = 1)** takes into account the cost of implementing a mitigation solution.
- **Time (T) (N = 2)** refers to time needed for implementing a mitigation measure from the start to the point when its benefit could be delivered.
- **Effectiveness (E) (N = 3)** represents the potential to mitigate UHI; since it can vary according to the features of the urban fabric, the effectiveness is considered 9 times for 9 different local climate zones (LCZs) (Stewart, 2012).

1. UHI-mitigation solutions

The eight UHI-mitigation solutions considered in this study are as shown in Table S21, marked M = 1 through M = 8. 247 possible sets of multiple solutions are possible with these 8 measures.

Table S21 Summary of criteria and single UHI-mitigation solutions names and notation

N, M	Name	Abbreviation
N=1	Investment	I
N=2	Time	T
N=3	Effectiveness	E
M=1	Green roof	GR
M=2	Green wall	GW
M=3	Reflective roof	RR
M=4	Thermally efficient building	EB
M=5	High efficiency indoor cooling	IC
M=6	Urban forestry	UF
M=7	Evaporative pavements	EP
M=8	Constructed shade	CS

2. AHP

Analytic Hierarchy Processes (AHP) (Saaty, 1980) is a structured technique for organizing and analyzing complex decisions. Starting from a decision problem, the first step is *structuring the problem* to a hierarchical scheme. For this, it is necessary to identify the main AHP objective, the related criteria to achieve it, and the possible alternatives to choose.

Our goal was to identify the best alternatives in mitigating UHI and, among them, the most economical ones. We identified two considerations: the **economic feasibility** and the **UHI-mitigation efficacy**. Then, three criteria (i.e., Investment, Time, Effectiveness) were selected to quantify those considerations.

The second AHP step is *weight evaluation* to obtain weights to rank both the importance of the criteria according to the objective and the importance of the alternatives for each criterion. Weight evaluation involves pairwise comparisons done by exploiting 11 *n* x *n judgment matrices*: matrix one compares the importance of the economic criteria of investment and time; matrix two and three compare the eight different measures in relation to investment and time, respectively. The other matrices compare the eight-individual solution (n = 8) according to the effectiveness in the 9 LCZs, one matrix per LCZ (Figure S22).

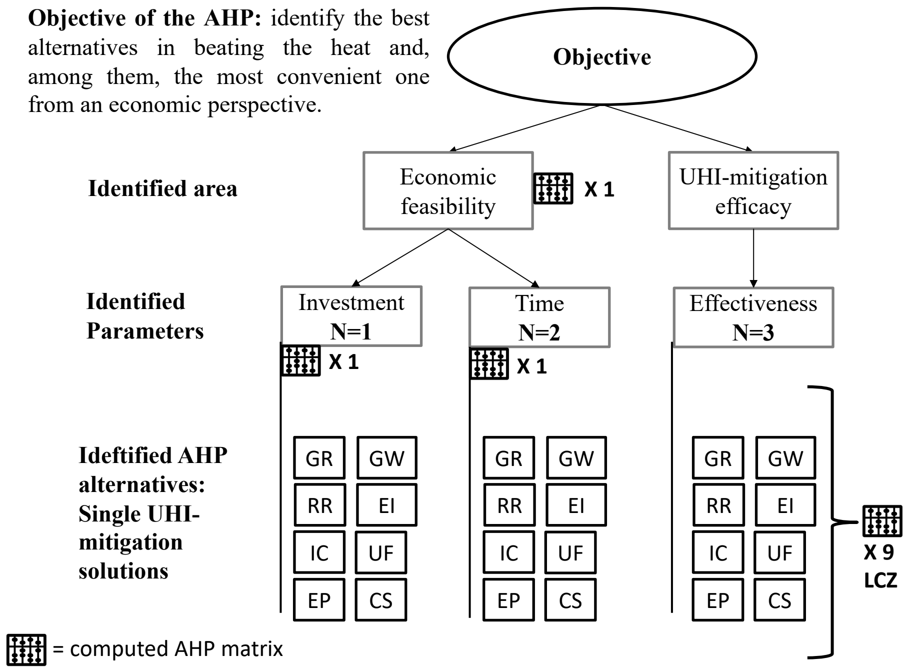

Figure S22 Structure of the AHP problem

Matrix A is an example of an $n \times n$ *judgment matrix.*

$$A = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n,1} & a_{n,2} & \cdots & a_{n,n} \end{pmatrix} \tag{1}$$

Each element of the upper diagonal a_{ij} is generated by comparing the i-th with the j-th alternative n (i.e., individual UHI-mitigation solution) on a scale shown in Table S22. The scale is composed of verbal scales associated with numerical values. The lower diagonal of the matrix contains the reciprocal values of the upper diagonal. The diagonal elements equal one since the same criteria (or solution) is compared

Table S22 Saaty's verbal scale

a_{ij}	Verbal scale
1	The two criteria are **equally important to** quantify the merit of the solution in being part of a solution set
3	One criterion **is slightly more important** than the other to quantify the merit of the solution in being part of a solution set
5	One criterion is **strongly more important** than the other to quantify the merit of the solution in being part of a solution set
7	One criterion is **very strongly more important** than the other to quantify the merit of the solution in being part of a solution set
9	One criterion is **extremely more important** than the other to quantify the merit of the solution in being part of a solution set
values of 2,4,6,8 can be used as intermediate values	

The weight of each alternative is calculated from A as follows:

A *decision matrix* (B) is defined, whose elements are obtained by dividing the corresponding element of A by the sum of its column (Eq. 2-3)

$$B = \begin{pmatrix} b_{1,1} & b_{1,2} & \dots & b_{1,n} \\ b_{2,1} & b_{2,2} & \dots & b_{2,n} \\ \dots & \dots & \dots & \dots \\ b_{n,1} & b_{n,2} & \dots & b_{n,n} \end{pmatrix} \tag{2}$$

$$B_{i,j} = \frac{A_{i,j}}{\sum_{k=1}^{n} A_{k,j}} \tag{3}$$

The weights are obtained by averaging the row of the decision matrix *B* (Olson, 1996) and normalizing them to one by dividing each one by the highest weight (Eq 4-5).

$$w_i = \frac{\sum_{k=1}^{n} B_{i,k}}{n} \tag{4}$$

$$\overline{w_i} = {}^{w_i}/_{w_{max}} \tag{5}$$

The closer the normalized weight is to 1, the more important is the criteria in achieving the objective.

Moreover, the coherence of the assigned judgment can be verified through a consistency test. A consistency index (CI), which increases proportionally with the incoherence of the matrix, is defined (Saaty, 1980):

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

Where *n* is the number of elements of the judgment matrix *A*. λ_{max} is obtained by multiplying *A* with the weight vector (*w*), obtaining a new vector w^a (Eq 7). Then, each element of w^a is divided by the corresponding element of *w* and the results are averaged (Eq 8).

$$w^a = Aw = \sum_{k=1}^{n} A_{ik} w_k \tag{7}$$

$$\lambda_{max} = \frac{\sum {}^{w_i^a}/_{w_i}}{i} \tag{8}$$

The CI is then compared to its expected value, the Random Index (RI). We used Noble and Sanchez's RI (Noble & Sanchez, 1993) (Table S23).

Table S23 Noble and Sanchez RI values

n	1	2	3	4	5	6	7	8	9	10	11
R.I.	*0*	*0*	*0.49*	*0.82*	*1.03*	*1.16*	*1.25*	*1.31*	*1.36*	*1.39*	*1.42*

The ratio between CI and RI is referred as the Consistency Ratio (CR).

$$CR = \frac{CI}{RI(n)}. \tag{9}$$

The judgements are considered consistent if CR's value is lower than 0.1 (Saaty, 1980).

Expert Polls

To obtain information about the importance of the alternatives according to the criteria investment, time and effectiveness, we sent polls to different experts. The expert is first asked to indicate which criterion between I and T is more important on a scale from 1 to 9. Then, for each criterion, the expert is asked to compare two mitigation solutions at a time on a scale from 1 to 9:

- For Investment, the expert is asked to select which alternative is more expensive and by relatively how much.
- For Time, the expert is asked to select which alternative requires less time to be fully functional and by relatively how much.

Scores for investment and time are then evaluated using AHP, as described previously.

Regarding effectiveness, the experts are asked to score each UHI-mitigation solution in the context of each LCZ on a scale of 1 to 9, with a higher score representing higher mitigation potential. Effectiveness scores are then evaluated with AHP.

Thus, for each poll, AHP is applied 11 times: to calculate the relative importance of IT criteria, to calculate the importance of the single solution against IT, and for 9 LCZs to calculate the relative effectiveness of the solutions. AHP weights expert across polls were then averaged.

Subsequently, the score of the UHI-mitigation solution sets for I, T and E were obtained as follows:

- For Investment: by adding the scores of the solutions in the set (e.g., a set with GR, GW, and IC will have a weight equal to W11 + W21 + W51). Some solutions, however, occupy the same physical space and can only be partially implemented at the same time over half the area (i.e., GR and RR, GW and EI, UF and EP, UF and CS). When the incompatible solutions appear together in a set, their investment score is considered to be the half of the sum of their individual scores (e.g., a set with GR, GW, RR and EI will have a weight equal to 1/2(W11 + W31) + 1/2(W21+W41)). The obtained scores are later normalized to one.
- For Time, we considered for simplicity that the construction of all the solutions in a set would start at the same time and the time score of the set is equal to the lowest score among the solutions.
- Effectiveness scores are computed the same as Investment, computed once for each LCZ. The obtained scores are normalized to one.

- **Statistical summary of economic (IT) criteria weights**

A summary of the weights obtained for Investment (I) and Time to benefit (T) criteria based on the expert polling is shown in Table S24.

Table S24: Mean and standard deviation of weights for I and T

Criterion	Mean weight	Standard deviation
Investment	0.81	0.33
Time to benefit	0.60	0.37

- **Statistical summary of economic (IT) scores**

A summary of the economic (IT) scores of each of the eight mitigation measures is shown in Table S25.

Table S25: Mean and standard deviation of economic (IT) scores

Measure	**Investment Score**		**Time Score**	
	Mean	**Std dev**	**Mean**	**Std dev**
GW	0.64	0.28	0.22	0.20
GR	0. 63	0.22	0.31	0.21
RR	0.23	0.33	0.76	0.29
EB	0.63	0.28	0.52	0.34
IC	0.72	0.19	0.64	0.33
UF	0.72	0.27	0.19	0.25
EP	0.54	0.28	0.44	0.28
CS	0.46	0.31	0.58	0.37

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