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Outdoor thermal comfort - review on the main relationships and methodological components of a comprehensive study

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Relationship-network concerning outdoor thermal comfort and area usage

OUTDOOR PLACE

Urban public spaces (parks, squares, plazas, etc.) offer places for various outdoor activities for citizens. The design of an outdoor place define and localize the function of the area, i.e. the forms of outdoor activity people can perform (route-place, shopping area, resting place, sport arena, playground, etc.). The aesthetic quality offered by the area may have a significant (emotional) effect on the visitors' comfort sensation and other subjective evaluations.
Regarding human comfort and outdoor activity, the following characteristics of the places may have great importance:

- *geographical location*
- *location in the city*
- *surface cover*
- *water (e.g. pond, fountain)*
- *artificial objects (e.g. statues, benches)*
- *vegetation*
- *shading conditions, solar access*
- *diversity of morphology*
- *neatness, cleanliness*

Methodology:

- mapping existing places through field surveys;
- constructing the models of new (planned) and existing places with micro-scale models.

THERMAL ENVIRONMENT

The design of an outdoor place coupled with the local-scale weather processes evolve the micro-biometeorological conditions on the given site. Thermal factors, i.e.

- *air temperature*
- *air humidity*
- *air movement*
- *thermal radiation (solar and terrestrial fluxes)*

affect the human heat budget, consequently thermal sensation and thermal stress level.
The outdoor activity, i.e. the usage of open public areas in cities is more frequent, as well as their subjective assessment is more positive if they offer thermo-physiologically comfortable microclimate, i.e. nearly neutral thermal conditions.

Methodology:

- on site measurements (mobile met. station);
- numerical simulations (modelling).

WEATHER CONDITIONS

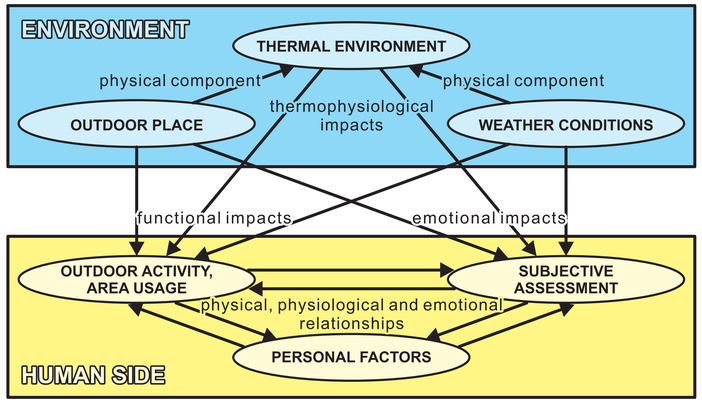
Outdoor activities can be promoted or hindered by the local-scale meteorological parameters (climate factors), i.e. the weather conditions at a given day:

- *air temperature*
- *air humidity*
- *air movement*
- *global radiation: direct and diffuse solar radiation*
- *sky conditions: sunshine, cloudiness, visibility*
- *air pressure*
- *precipitation*
- *weather front*

Thermal parameters determine the weather's appropriateness for outdoor staying. Long rain and strong wind have an over-riding effect ceasing almost every open-air activity. The sunny/cloudy and calm/windy periods favour different activities. Sky conditions and day length may have significant (emotional) impact on the comfort sensation and as a consequence on the patterns of area usage.

Methodology:

- automatic measurements near to the site (stationary met. station);
- simulation of the weather conditions of certain days (modelling).



OUTDOOR ACTIVITY, AREA USAGE

Utilization patterns of open-air public spaces are dependent on the conscious and unconscious behavioural reactions of people given on the physical environment.

- *Spatial and temporal patterns of area usage:*
  - number of visitors
  - distribution of visitors, preferred sub-areas
- *Behaviour of visitors in the area:*
  - performed actitity
  - body posture
  - solar exposure
  - time spent in the area
  - frequency of visit
  - company

Methodology:

- observation of the area usage and the visitors
- questionnaire survey with visitors

PERSONAL FACTORS

- *Demographics:*
  - gender
  - age
  - race
  - culture
  - home place
- *Body built:*
  - height
  - weight
  - body fat
- *Clothing*
- *Time of exposure*
- *Reasons for being in the place*
- *Fitness, lifestyle:*
  - smoking habit
  - sport
  - alcohol consumption
  - caffeine consumption
  - diet
- *Health conditions*
- *General feelings:*
  - fatigue
  - mood
  - nervousness
- *Attitudes*
- *Expectations*
- *Experiences*

Methodology:

- observation of the visitors staying in the area
- questionnaire survey

SUBJECTIVE ASSESSMENTS

- *Subjective evaluations of the place:*
  - *perceptions* concerning the area
  - *preferences* for any changes in order to make the place more comfortable
- *Assessments concerning the thermal environment*
  - *thermal sensation*
  - *perceptions* of the climate-parameters
  - *preferences* for any changes of these factors to feel more comfortable
- *Overall comfort sensation*

Subjective evaluation of the physical environment is influenced by the numerous human-related parameters not only physically and physiologycally, but also on a psychological way.

Methodology:

- questionnaire survey with the visitors of the area

Methods for a comprehensive outdoor thermal comfort study

HUMAN THERMAL COMFORT

Psychological aspect:
Thermal comfort is a condition of mind which expresses satisfaction with the thermal environment. The lack of thermal comfort (neutral thermal sensation) eventually results in feeling either warm or cold.
Physical (energetic) aspect:
Human thermal comfort can be achieved in the case of thermal equilibrium with the thermal environment: when the heat generated by the metabolism added to the heat gain from the environment are balanced with the heat loss to the environment. Any heat gain or loss beyond this generates the sensation of thermal discomfort.
Physiological aspect:
When thermal comfort exists the firing of the thermal receptors in the skin and in the hypothalamus is minimal.

OBJECTIVE SIDE - ENVIRONMENT

To estimate thermal comfort conditions of a place in an objective way, **thermo-physiologically significant indices** have to be calculated from the following 6 main physical variables:

- 4 factors of the thermal environment:
  - *air temperature*
  - *air humidity*
  - *wind velocity*
  - *mean radiant temperature (thermal radiation)*
- 2 human-related parameters:
  - *insulation level of clothing*
  - *metabolic heat produced by activity.*

State of the art human-biometeorological indices are for example:

- *Predicted Mean Vote (PMV)*
- *Physiologically Equivalent Temperature (PET)*
- *Universal Thermal Climate Index (UTCI).*

They are derived from the energy-balance model of the human body which contains the most important mechanisms of the thermoregulation:

- *contraction and dilatation of blood vessels*
- *sweat secretion*
- *shivering.*

Besides the physical parameters, human thermal comfort depends on a number of subjective factors, therefore it is almost impossible to predict thermal comfort for individuals; it is mostly related to a group of people.
For comparison of different places in terms of their thermal comfort conditions, the **human-related parameters** are often ***standard values*** and the mentioned indices refer to a fictive, average person.

Thermal factors can be obtained by:

METEOROLOGICAL MEASUREMENTS:

- field measurements on the site of interest by the usage of a ***mobile bio-meteorological station*** (measurement height: 1.1 m a.g.l.)
- using the dataset from the nearest automatic ***stationary weather station*** (parameters should be reduced to 1.1 m a.g.l.)

NUMERICAL SIMULATIONS:
modelling of ***current*** and ***future thermal conditions*** on existing and planned urban places (preliminary survey of existing urban structures are required to construct the model environment).

SUBJECTIVE HUMAN SIDE

Thermal comfort, especially outdoors, depends not only on the mentioned 6 physical factors, but also on different subjective features. As many individuals as many thermal comfort sensations or area usage patterns may develop in a given environmental situation. So, besides the objectively determinable environmental parameters the human side is also in the centre of a complex human comfort study.

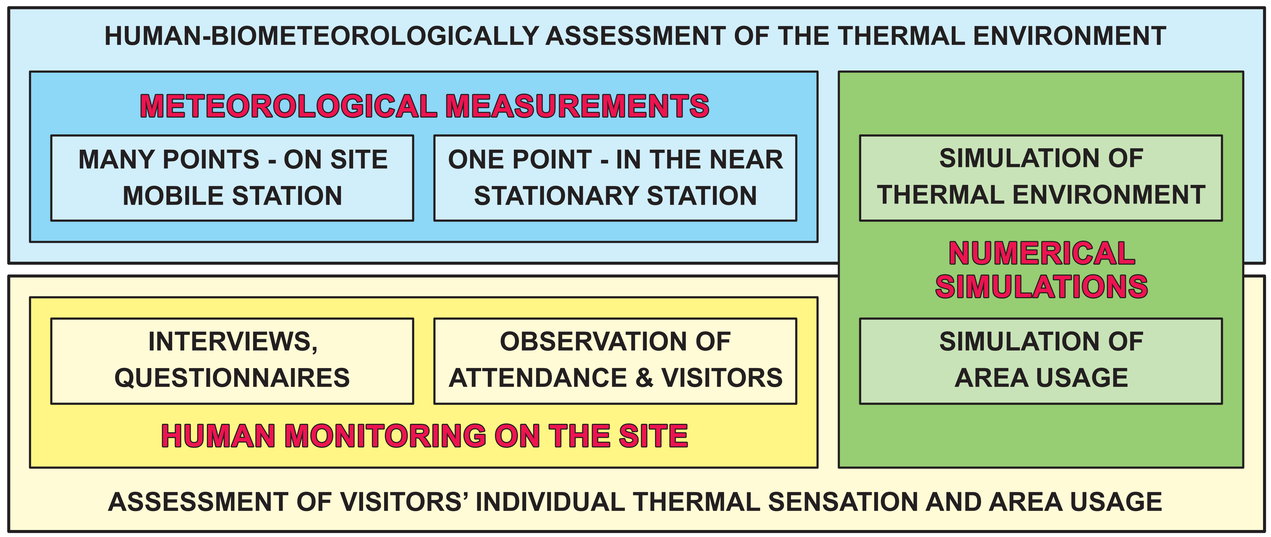
HUMAN MONITORING:

- ***social surveys*** by means of ***questionnaires***:
  detailed information could be obtained about
  - personal characteristics
  - behaviours and thermal history
  - subjective assessments of:
    - thermal environment
    - weather conditions
    - place

  these data help to enlarge the knowledge on the topic of outdoor thermal comfort
  but this method can be reactive and unrealistic
  it works well only with on-site measurements
- unobtrusive ***observations*** of:
  - visitors' natural behavioral reactions
  - attendance on a place

  data about many more people can be gained in a given time period
  the area usage can be analyzed according to the current weather or thermal conditions.

NUMERICAL SIMULATIONS:
simulations of the area usage of fictive subjects as a function of the modelled thermal environment on a place (existing or planned urban area).



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