Improving social sustainability through comfortable outdoor spaces

Outdoor Thermal Comfort effects on urban design

Constanta | Romania

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ABSTRACT: What defines the character of a city is the vibrancy of people on its streets and public spaces. Serving a multifunctional and multi-disciplinary nature, public spaces are becoming an urgent topic in the New Urban Agenda. The target 11.7 of the Sustainable Development Goals calls for universal access to safe, inclusive and accessible, green public spaces by 2030.

The urban social life needs high availability of comfortable open spaces to raise the quality of living. By providing comfortable outdoor spaces the number of people and the time they spend outside increases. People experiencing life outside the buildings adapt their level of physical activity to the ambient thermal conditions. An outdoor space with high thermal comfort conditions contributes to a healthier environment, increases the intensity of activities in the neighbourhood and establishes social connections. At the same time it promotes local businesses and also has an impact on energy use and CO2 emissions.

The goal of the following research is to provide guidelines for improving social sustainability through creating comfortable outdoor spaces. The objective is to increase the thermal outdoor comfort for a public space in Constanta, Romania. The study is based on a bachelor project which proposed the redevelopment and integration of a previous industrial port area. A continuous public promenade animated by a mix of activities and outdoor spaces had been designed. The following research complements the project by rethinking the design in response to human's thermal sensation under the influence of the atmospheric environment. A series of outdoor comfort strategies are investigated in order to reach an optimized urban design that provides good microclimate conditions for people engaged in outdoor activities.

In order to achieve a holistic design that leverages the given advantages of a specific location, the findings and conclusions of the research follow an iterative process. Specific parameters are taken into consideration: climatic conditions on site for representative periods of the year, properties of different ground materials, influence of solar and wind exposure, humidity level, metabolic rate according to the type of activity and the clothing factor according to the ambient parameters. The initial master plan design is tested and the massing, orientation and form are optimized in order to reach high outdoor comfort conditions.

One highlighted conclusion is that each outdoor space requires site-specific and customized comfort strategies that consider geographical location as well as the built and climatic context. Early stage design should consider outdoor comfort. It is shown that outdoor thermal comfort is more effectively achieved with adapting massing orientation and shape of the urban layout at concept stage than with local interventions.

Keywords: outdoor thermal comfort, microclimate conditions, quality of outdoor spaces, urban design optimization

INTRODUCTION

What defines the character of a city is the vibrancy of the people on its streets and public spaces. The quality of this spaces is essential for the prosperity of the city. Having access to "good public spaces enhances community cohesion, promotes health, happiness, and well-being for all citizens as well as fosters investment, economic development and environmental sustainability". *UN-Habitat-public spaces for all*

Despite its high influence in the sustainable development of cities, public spaces have often been overlooked and undervalued in policy and action. Reaching almost a crisis with the escalating privatisation of land, the issue of public spaces is becoming an urgent topic in the New Urban Agenda. In 2011, UN-Habitat adopted a resolution on, sustainable urban development through access to quality urban public spaces and also launches a worldwide “Global Public Spaces Programme” in partnership with the cities authorities. The target 11.7 of the Sustainable Development Goals (SDGs) calls for universal access to safe, inclusive and accessible, green public spaces by 2030.

Through its multifunctional and multi-disciplinary nature, public space offers a holistic view of the city, such as: social inclusion, governance, health, safety, education, climate change, transport, energy and the local economy.

The urban social life needs high availability of comfortable open spaces to raise the quality of living. By providing comfortable outdoor spaces the number of people and the time they spend outside increases. People experiencing life outside the buildings adapt their level of physical activity to the ambient thermal conditions. An outdoor space with high thermal comfort conditions contributes to a healthier environment, increases the intensity of activities in the neighbourhood and establishes social connections. At the same time it promotes local businesses and also has an impact on energy use and CO2 emissions.

The following summary provides guidelines of improving social sustainability through access to comfortable outdoor spaces. A series of outdoor comfort strategies are investigated in order to reach an optimized urban design that provides good microclimate conditions for people engaged in outdoor activities.

OBJECTIVE

The target of the research is to increase the thermal outdoor comfort for a public space in Constanta, Romania. The work is based on a bachelor thesis project of the University of Architecture and Urbanism “Ion Mincu”, Bucharest. As part of the project, the urban design parameters of a previous industrial port area had been analysed. The concept for the area aimed the redevelopment and integration of the lost industrial space with a continuous public promenade animated by a mix of activities and outdoor spaces (underwater archaeology museum, tourist information centre, belvedere restaurant, multicultural and conference centre).

The following research complements the thesis by rethinking the design in consideration of the people’s thermal sensation influenced by the atmospheric environment. The research defines strategies to improve the microclimate comfort conditions of the designed outdoor spaces.

In order to achieve a holistic design that leverages the given advantages of a specific location, the proposed strategies follow an iterative process. Specific parameters are taken into consideration: climatic conditions on site for representative periods of the year, properties of different ground materials, influence of shading membranes and wind barriers, humidity level, metabolic rate according to the type of activity and the clothing factor according to the ambient parameters.

The initial master plan design is tested and the massing, orientation and form are optimized in order to reach high outdoor comfort conditions.

METHODOLOGY

Through an iterative process, the original design is being investigated, tested and finally optimized. Climatic hourly data from a relevant weather station localised on the coast of the city is used as driving input for the research process.

The following steps were taken in order to: identify the strengths and weaknesses of the current design, improve the outdoor comfort with local interventions and finally to adapt the massing layout for an optimized design *(table 1)*.

	Steps	*Description*
1	Climate analysis	Identifying the main influencing climate parameters for the city in study
2	Outdoor comfort strategies General scale	Using as scale the UTCI index, according to season the best strategies for a city are set
3	Original design Solar exposure simulations Wind exposure simulations	Zoom into the design site. Evaluating the selected case study for 2 periods of the year.
4	Outdoor comfort strategies Local scale	Assessing the comfort results for the master plan and comparing the comfortable percentage reached with the city scale target
5	Re-adapt Original Design	Identify the strengths and weaknesses
6	Test design Solar exposure simulations Wind exposure simulations UTCI results	Reassessing outdoor thermal comfort results and comparing with the target.
7	Optimized design	Master plan layout advantageous for the outdoor spaces comfort and usage

Table 1: Steps for master plan optimization.

The original design includes 5 buildings and 4 main public outdoor areas:

Nr.	*Typology*	*People status*	*Area*
1	Building entrance	walking	1778m²
2	Event plaza	standing	1333m²
3	Open air amphitheatre	siting	1547m²
4	Restaurant esplanade	Siting and eating	1704m²

Table 2: Typologies of the analysed open spaces.

The selected location for this study is Constanta, the second biggest city in Romania with a population of around 283 thousand inhabitants. It is the oldest continuously inhabited city in the country, it was founded around 600 BC and belongs under the category of port cities which developed around a natural protected golf. As a waterside city characterized by its high shores silhouette the selected location is analysed according to the quality of its public recreational space by the water. In the current situation the promenade is the most frequented public space of the city having the advantage that people are always drawn by nature presence despite the comfort conditions provided by the public space. In the meantime, half of this promenade is under the negative influence of the port proximity and the lack of a point of appeal, therefore the quality of this space is inconsistent, with no future vision, low quality solutions and no local identity.

The following research investigates the outdoor comfort on a waterfront situation through a series of strategies in order to achieve thermal comfortable open spaces. For assessing the results the investigation was based on the following studies:

1. Outdoor comfort strategy variants using UTCI index assessment done with TRNSYS, program computing weather based data and user based parameters.
2. Solar exposure using solar grid based radiation maps done with Ladybug for Grasshopper.
3. Wind exposure using CFD maps (computational fluid dynamics simulation) with OpenFoam steady state simple solver for two wind directions and different wind profiles
4. Geometry re-design done with Rhino.

Always keeping in mind the climate of the project's location, 2 periods of the year (table 3.) were chosen to be investigated in order to maximize the intensity of outdoor activities and presence of people in comfortable conditions:

Period of the year	*Date interval*	*Operation time*
Winter & shoulder season period	01oct – 30april	10 am – 04 pm
Summer period	30 sept – 01may	10 am – 10 pm

Table 3: Periods of analysis.

OUTDOOR COMFORT

Outdoor comfort is evaluated with the UTCI index (universal thermal comfort index).This index has been developed by 45 scientists over 23 countries and has been released in 2009. It is based on a 340 nodes model which simulates human heat transfer phenomena.

The UTCI is defined as temperature of a standard person in a reference environment where the same perception of warm or cold would occur as in the actual environment. The standard person is defined by the following parameters:

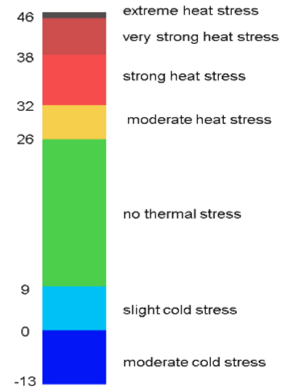
• Male, 1.75 meters, 75 kg • Body surface = 1.78 m² • Emissivity of skin and clothes = 0.97 • Solar absorption coefficient = 0.7 • Work performance = 2.3 met (~134 W., equivalent to walk at ~ 4km/h)

The reference environment is defined by the following parameters:

• Shaded, mean radiant temperature = air temperature
• Calm wind (0.1 m/s) • 50% relative humidity

Finally, to have a better understanding of the comfort rated by UTCI, for given UTCI ranges is associated a thermosphysiological stress, as seen on the right.

The section between 9°C ≤ UTCI < 26°C is rated as no thermal strees and represents excellent outdoor comfort conditions.



Outdoor comfort is influenced by 8 major parameters from which some are weather related: solar direct and diffuse radiation, the temperature of the surrounding surfaces, air temperature, humidity and air velocity, and other parameters are user related, such us: the clothing insulation and the activity level. The image below shows the driving parameters for UTCI.

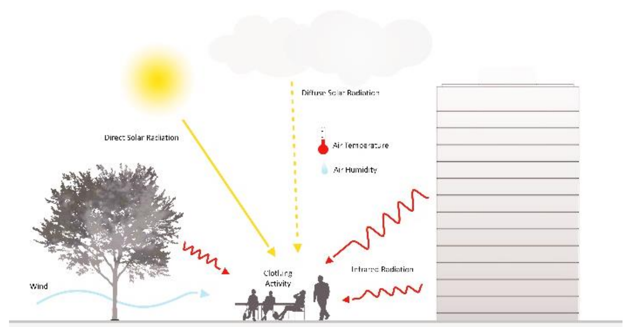


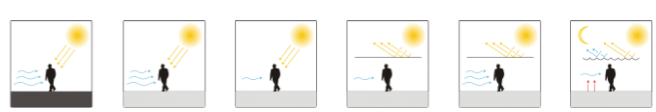
Fig1: Outdoor comfort influencing parameters

1. Outdoor comfort variants for general scale

Changing parameters:

Variant	*Ground Concrete albedo*	*Sun Shading system*	*Wind access*
1	dark 20% albedo	no shading	70%
2	light 60% albedo	no shading	70%
3	light 60% albedo	no shading	20%
4	light 60% albedo	fixed shading	20%
5	light 60% albedo	fixed shading	70%
6	light 60% albedo	low-e operable during night-time	20%
6`	light 60% albedo	low-e operable during daytime	70%

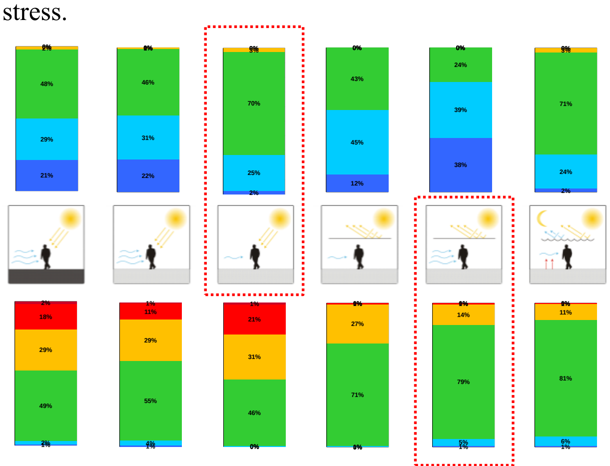
Table 4: Investigation changing parameters.



1 2 3 4 5 6 – 6`

2. Outdoor comfort assessments for the winter & shoulder season period

The figure below is showing the investigated variants and the results in percentage of time with no thermal stress 9°C ≤ UTCI < 26°C according to the investigated variants. Best strategy for this period being: person on light coloured ground 60% albedo, exposed to solar radiation and protected by the cold wind. This strategy reaches **70%** of time during this period with no thermal stress.



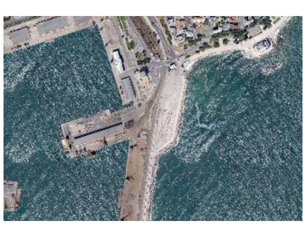
3. Outdoor comfort assessments for the summer period

(figure above) showing the percentage of time with no thermal stress 9°C ≤ UTCI < 26°C for the same variants but during the summer season. Best strategy being: person on light coloured ground 60% albedo, protected by solar radiation and exposed to the refreshing wind. This strategy reaches **79%** of time during this period with no thermal stress.

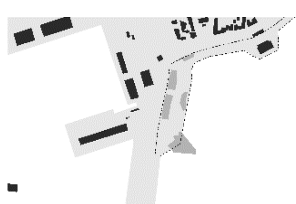
The best strategies for both periods of the year represent the comfort targets that are further compared with the UTCI results reached at local scale, having the cluster buildings set and the outdoor areas influenced by the layout.

ORIGINAL DESIGN ASSESSMENT

In order to assess the comfort present in the current state of the urban layout, each outdoor area was analysed for solar and wind exposure. The outputs of these simulations were used to set the changing parameters for the UTCI evaluation. The results were compared with the season target and the weaknesses of the original design were identified.



Analysis site



Analysis layout

1. Original design analysis Outdoor areas of analysis:

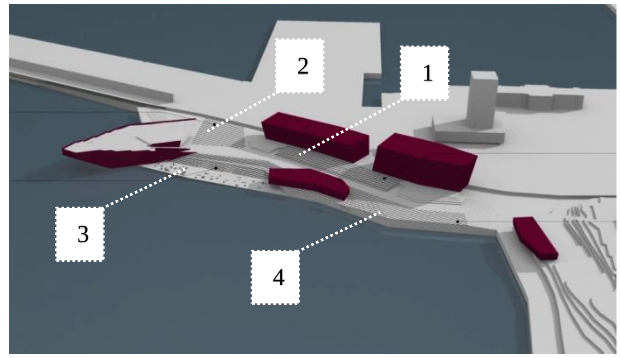
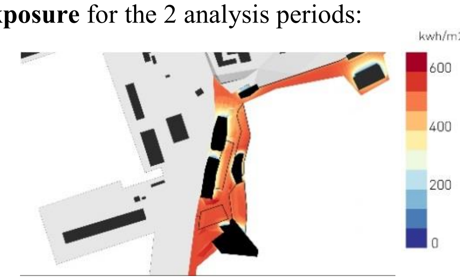


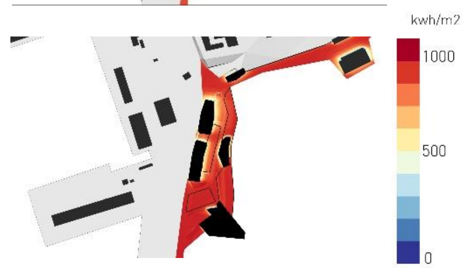
Fig.2 Original design analysis context with the 4 outdoor areas.

2. Solar radiation exposure for the 2 analysis periods:

For the winter & shoulder season: outdoor areas receive a significant amount of radiation and the spaces can be rated as well solar exposed.



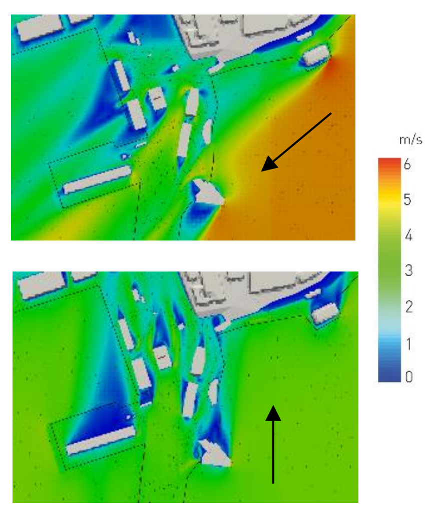
For the summer season: outdoor are under full solar exposure which is a negative effect present on the site. Shading mitigations are needed, either locally or by adapting the master plan.



3. Wind exposure for the 2 main wind directions N-E and S according to the analysis periods:

In the cold period the dominant wind is coming from the NE segment, at an average wind speed of 5 m/s. The layout is not comfortable with wind from this direction.

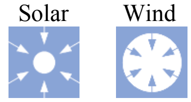
In summer the wind direction changes to the south segment and flows with an average wind speed of 3.5 m/s. The outdoor areas are ventilated, wind is an advantage.



From the solar and wind simulations the following parameters require adaptation according to each outdoor area:

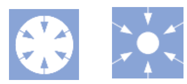
During the winter & shoulder season: the user should be provided with protection from the cold wind and exposed to the full solar insolation.

Solar Wind



Exposed Protected

In the summer season: the user should be exposed to the wind velocity and protected during long solar exposure.



Protected Exposed

Therefore the following table describes the parameters of the 4 outdoor areas, under the influence of climate and building layout.

area	*Floor concrete*	*Sun shading system*	*Winter wind access*	*Summer wind access*
1	light 60% albedo	no shading	60%	80%
2	light 60% albedo	no shading	80%	100%
3	light 60% albedo	no shading	90%	20%
4	light 60% albedo	fixed shading	40%	60%

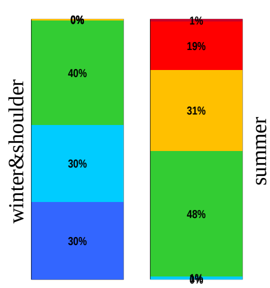
The comfort results for each area were further assessed according to the UTCI evaluation. Out of limited document size, this paper will show only the results for one of the outdoor areas:

Nr	*Typology*	*People status*	*Area*
3	Open air amphitheatre	siting	1547m²

4. Outdoor comfort results for local scale - area nr. 3

Outdoor comfort simulation results show a high discomfort in winter caused by the openness and orientation of the area in the direction of the dominant winter wind.

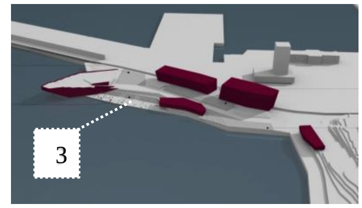
Due to the high cold wind exposure the area is unsuited for the desired outdoor activity. Only 40 percentage of this period is rated as comfortable.



In the summer period the area is highly exposed to the solar radiations while the south wind is blocked by one of the buildings, keeping the area low ventilated, only 48 percentage of this period is comfortable.

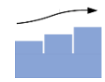
5. Original design weaknesses

Negative effects present on the area nr 3.

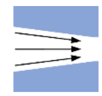


Wind effects:

Stepping effect: continuously rising obstacles heights divert the wind over the top and increase the air speed.

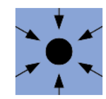


Funnel effect: narrowing buildings cause accelerated air speed.



Solar effect:

Long exposure: can be highly dangerous to the user's health, during summer period, causing headaches, skin burn, solar retinopathy and others.



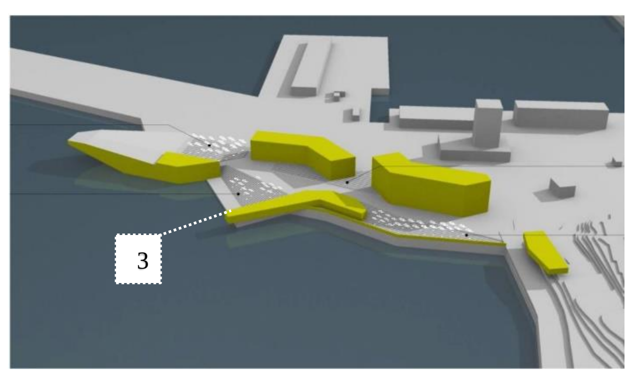
6. Improvement Recommendations

In order to rise the percentage of comfortable time on area nr. 3 the following mitigations that unify the strategies for both periods of the year were proposed:

- The area should feature removable shading systems that protect the user from the high solar exposure during the summer season and allow the positive exposure desired in the winter and shoulder season.
- During the cold season, the wind coming from the north-east segment should be blocked as much as possible by the buildings layout while in summer due to the change of wind direction, coming from south, the wind should be at least 70 percent allowed to ventilate the outdoor areas.

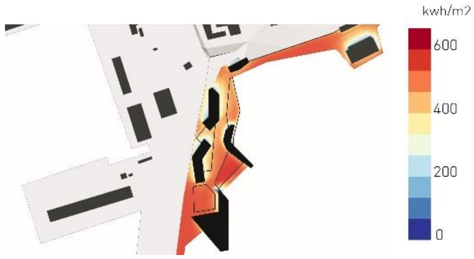
OPTIMIZED DESIGN

Design criteria from the presented methodology are applied to the urban plan and optimization decisions have been made. While the solar aspect can be solved with local removable systems, the wind aspect can be more efficiently tackled with a change in the orientation and shape of the geometry. After a series of test geometries were put through the same iterative process of simulations and an optimized layout was identified.



1. Solar exposure for the 2 analysis periods:

In the cold period the solar exposure is kept even after the geometry changes of the the massing. The solar radiation is in the advantage of the open spaces for this season.



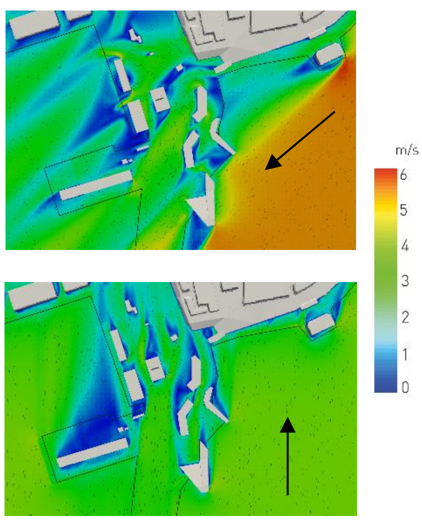
In the summer period almost all areas still fully exposed. As local mitigations, operable sun shading systems are proposed to lower the solar exposure.

2.

2. Wind exposure for the 2 main wind directions N-E and S representative for the analysis periods:

The wind situation for the optimized design in the cold season looks much improved.
The massing is protecting the outdoor spaces from the cold NE wind.

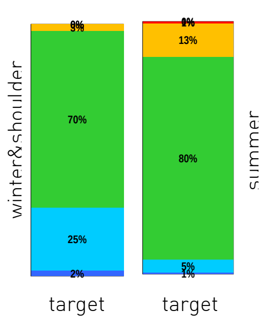
Analyzing the summer wind, the air distribution on the new layout is good. The new shape and orientation of the massing is allowing the South wind to flow through the areas without creating discomfort.



3. Outdoor comfort results for local scale - area nr. 3

Outdoor comfort simulation results show for both of the periods the comfort target being reached or exceeded in the summer case.

In summer a reduction of only 15 percent out of the initial wind velocity with the shading systems activated and light coloured ground material is considered the best outdoor comfort strategy for area nr. 3.



During winter, the new configuration of the area with the border buildings blocking the wind from north east and allowing the wind from south in balance with the ground material and the set parameters is the optimal design strategy for an open air amphitheatre.

The same methodology has been applied for the other 3 outdoor areas and the results for both periods of the year reach the target and the comfort threshold for the analysed climate and desired outdoor activities.

CONCLUSIONS

The research provides guidelines of improving social sustainability through testing and designing comfortable outdoor spaces based on thermal comfort strategies.

Early stage design should consider outdoor comfort. It is shown that the thermal comfort of outdoor environments can be significantly improved not only through local measures that upgrade the design but even more by adapting, at concept stage, the massing orientation and shape in the advantage of the outdoor public spaces.

One highlighted conclusion is that each outdoor space requires site-specific and customized comfort strategies that consider geographical location as well as the built and climatic context.

Nevertheless, the project aims for a better understanding of the economic, social and environmental influence of comfortable outdoor spaces in the development of cities.

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