UDC 72+72.011+ББК Ч481
DOI https://doi.org/10.32782/2415-8151.2026.40.26

ENVIRONMENTAL QUALITY INDICATORS AS A BASIS FOR RENOVATION-ORIENTED DESIGN OF PUBLIC SPACE (A CASE STUDY OF A FRAGMENT OF DYUKIVSKYI GARDEN IN ODESA)

Khoroian Natalia Petrivna
Candidate of Architecture, Associate Professor,
Associate Professor at the Architectural Environment Department,
Odesa State Academy of Civil Engineering and Architecture, Odesa, Ukraine,
e-mail: natalia.khoroian@odaba.edu.ua, orcid: 0000-0002-0889-8826

Abstract. The renovation of urban parks and squares is often carried out through ad hoc, localized selection of amenities and landscaping elements without a unified system of comparable indicators, which results in conflicts between shading provision, pedestrian-level wind conditions, accessibility, wayfinding, and the resource implications of design decisions. This paper proposes an indicators-first parametric protocol for designing public-space amenities, in which environmental quality indicators constitute the primary problem model, while digital tools and algorithms are derived from requirements for measurability and reproducibility.

***Purpose.** To develop an indicators-first, indicator-oriented parametric approach for the renovation and re-equipment of public space, in which environmental quality indicators constitute the primary problem model and design algorithms are subordinated to the requirements of measurability and reproducibility.*

***Methodology.** The method includes criteria-based indicator selection in terms of controllability by design decisions, measurability, data availability, sensitivity to parametric changes, and cross-variant comparability; development of indicator "passports" as an interface between analysis and design (definition, units, spatio-temporal framing, assumptions, expected trade-offs, and linkage to controllable parameters); parametric generation of configuration and placement variants for shading structures, pavilions, and modular furniture within realistic ranges; and solution comparison through indicator normalisation and trade-off analysis by identifying a set of mutually non-worse variants.*

***Results.** A core set of environmental quality indicators was established, covering outdoor thermal comfort in stay areas, solar exposure and shading, pedestrian-level wind conditions, barrier-free route performance, geometric visibility metrics relevant to safety, and the resource intensity of elements as a proxy for material intensity. The approach was demonstrated on a case study of a selected fragment of Dukivskyi Garden in Odesa, enabling reproducible derivation of renovation and amenity-design rules with explicit representation of trade-offs among key environmental quality requirements.*

***Scientific novelty.** The paper formalises an indicators-first approach through standardised indicator passports and an explicit mapping between environmental quality indicators and controllable parameters of design solutions.*

***Practical relevance.** The study provides a transparent decision-making procedure for design teams and municipal stakeholders, ensuring cross-variant* *comparability, explicit control of assumptions, and structured handling of trade-offs at early stages of public-space renovation design.*

Keywords: *environmental quality indicators, indicator-oriented design, indicators-first approach, parametric design, renovation, public space, urban amenities, small architectural forms, microclimate, outdoor thermal comfort, solar exposure and shading, pedestrian-level wind, barrier-free accessibility, geometric visibility, trade-off analysis.*

INTRODUCTION

Renovation and equipping of urban parks and squares in Ukraine [23] are often implemented as a set of local improvement actions and the installation of typical elements of urban equipment. At the same time, contemporary requirements for public spaces have become substantially more complex: alongside aesthetic and functional expectations, the importance of microclimatic comfort during heat waves, predictable shading performance at peak hours, pedestrian-level wind conditions [3, p. 1–10], and barrier-free and universally usable environments for diverse user groups has increased. In the European regulatory framework, these requirements are reflected, in particular, in standards for accessibility and usability of the built environment (e.g., EN 17210 [7, p. 1–12]) as well as standards harmonized with international provisions on accessibility of the built environment (in particular ISO 21542 [11, p. 1–12]). Practically, this underscores the relevance of formalized accessibility and comfort criteria already at early design stages, when spatial solutions can still be adjusted without high costs.

At the same time, in the practice of designing urban equipment, quality criteria often remain either informal or fragmented across disciplines and separate checks that are difficult to compare. A typical situation is that decisions about shading structures are made without verification of wind effects; accessibility routes are formally «closed» by slope and level-change requirements but are not evaluated from the perspective of thermal comfort at stopping and resting points; and placement of pavilions and urban furniture supports use scenarios but is not accompanied by an analysis of geometric visibility and wayfinding potential that affect perceived safety. As a result, environmental contradictions arise that become visible after implementation and require costly corrections or quality compromises.

This study adopts the principle that the method follows the indicators. First, a set of controllable and measurable environmental quality indicators is fixed, and only then are the parametrization tools, modelling types, data structure, and rules for comparing variants determined. Such an approach reduces the risk of instrumental bias, when the study effectively demonstrates software capabilities but does not create a reproducible logic for design decision-making. For brevity, below this approach is referred to as indicators-first, i.e., the primacy of the indicator system over the choice of tools and procedures.

ANALYSIS OF PREVIOUS RESEARCH

In the international literature, design based on measurable environmental characteristics and data has become increasingly established, where geometry, placement, and configurations of design objects are shaped through quality indicators and optimization procedures [20, p. 308–312]. In particular, for shading and seating structures in public spaces, digital workflows have been developed that combine variant generation with multi-criteria comparison and contextual constraints [20, p. 308–312]. In this logic, a shading structure is treated not as «form in itself» but as a means of controlling comfort and stay scenarios in space [20, p. 308–312].

A separate body of research concerns integrating microclimate models into design procedures at the scale of open space. Typically, this involves parametric environmental modelling and climate-analysis modules (enabling assessment of solar exposure, shading, radiative conditions, and thermal comfort indicators) and comparison of such calculations with specialized microclimate models [15, p. 1–4; 9, p. 1–6; 10, p. 69–81]. These studies emphasize that design-stage tools can be resource-efficient at early phases, but require careful interpretation and explicit documentation of modelling assumptions [15, p. 1–4; 9, p. 1–6; 10, p. 69–81].

To assess outdoor thermal comfort, indices are widely used that account for the combined influence of air temperature, wind, humidity, and radiative conditions. One of the best-known examples is the Universal Thermal Climate Index (UTCI), which is presented in review publications as an integrated indicator of climatic thermal stress on humans [5, p. 1–3; 4, p. 1–3; 14, p. 1–6]. For public spaces this is essential, since radiative and wind factors often determine the usability of stay areas during peak hours of the warm season [5, p. 1–3; 4, p. 1–3; 14, p. 1–6].

Alongside microclimatic measurements, environmental studies develop geometric approaches to spatial evaluation aimed at supporting safety and orientation. Such tasks are often addressed within space syntax: visibility-field analysis (isovists–areas of space visible from a given point) and indicators of visibility and spatial connectedness are used, which are interpreted as spatial preconditions for perceived safety or the potential for social interaction [2, p. 47–65; 19, p. 103–121]. For this paper it is crucial to maintain the correct level of claims: geometric visibility metrics can be objectified and reproduced, but they are not equivalent to real «activity» or social effects without behavioral data [2, p. 47–65; 19, p. 103–121].

Finally, when several heterogeneous indicators are considered simultaneously (comfort, solar exposure and shading, wind, accessibility, visibility, resource intensity), the problem of comparing variants and working with trade-offs becomes unavoidable. For this, multi-criteria analysis and decision-making approaches are used, where a key risk is arbitrary weighting and instability of rankings under changes in assumptions. Therefore, contemporary studies emphasize transparency of criteria selection, correct normalization of indicators, and testing the robustness of conclusions (sensitivity analysis) with respect to priorities [6, p. 9–33; 22, p. 1–18].

Thus, the current research context provides the necessary components of a future protocol–parametric variant generation, microclimate assessments, geometric visibility metrics, and procedures for multi-criteria comparison [20, p. 308–323; 15, p. 1–4; 2, p. 47–65; 6, p. 9–33]. At the same time, in the practice of designing urban equipment there is often a lack of a reproducible indicators-first framing that disciplines tool choice and prevents the methodology from expanding into a purely instrumental demonstration.

PURPOSE

The research problem lies in the absence in Ukraine of a reproducible, procedurally clear protocol for designing urban equipment for public spaces that: first, starts with operationalizing environmental quality indicators; second, establishes an explicit link between indicators and controllable parameters of equipment elements; and third, ensures comparability of variants without reducing the task to an arbitrary single score that is not supported by robustness checks. In practice, this manifests in the fact that decisions based on different indicators (shading, wind, accessibility, visibility, resource constraints) are evaluated in non-commensurable ways, and selection is often intuitive or driven by one dominant criterion, which reduces environmental coherence and increases the risk of conflicts after implementation.

The aim of the study is to develop and demonstrate a parametric protocol for designing equipment for public space based on the indicators-first principle, in which the logic of modelling and parametrization is determined by a predefined system of measurable and reproducible indicators, and variant comparison is implemented through transparent trade-off analysis. The protocol was tested using a selected fragment of Dyukivskyi Garden in Odesa as a demonstrative in-situ case.

To achieve this aim, the following tasks were set: to justify criteria for selecting indicators for designing elements of urban equipment in terms of controllability by design decisions, measurability, sensitivity, and comparability; to develop «indicator passports» as a standard description format (definition, units, spatio-temporal setup, assumptions, linkage to parameters); to define a parametric vocabulary of variables for small architectural forms and equipment elements (shading structures, pavilions, modular furniture) and rules for generating variants within realistic ranges; to build a procedure for calculating and normalizing the core indicator set covering thermal comfort in stay areas, solar exposure and shading, pedestrian-level wind, barrier-free route continuity, geometric visibility metrics for safety, and resource intensity as an approximate proxy of material intensity; to implement comparison of solutions through trade-off analysis over non-dominated compromise variants with the possibility of testing robustness to changes in priorities; and to formulate design rules for equipping (and re-equipping) the selected public-space fragment as the practical output of the protocol.

The object of the study is the process of designing equipment for public space under conflicting environmental requirements. The subject is an indicators-first parametric protocol that ensures a reproducible linkage in the sequence «environmental quality indicators – controllable parameters – variants – trade-offs – design rules» (Fig. 1). The scope is deliberately limited to the level of urban equipment and local organization of a fragment of public space; the protocol does not extend to city master planning or block morphology, since the aim is methodological precision and practical reproducibility within a narrow domain.

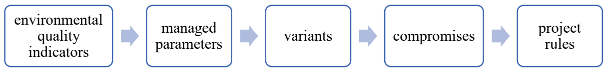

Fig. 1. Sequence of the proposed indicators-first approach (N. Khoroian)

RESULTS AND DISCUSSION

1. Positioning the indicators-first approach

Parametric methods in urban environmental design are typically implemented in two logics. Variant-generative logic emphasizes the speed of producing solutions and formal diversity. Reproducible logic focuses on ensuring that the same input data and rules lead to comparable sets of solutions and that results can be read as concrete design actions. We argue that for renovation-oriented design of public spaces, reproducible logic is more relevant, since the end product is not «interesting forms» but solutions suitable for approval, budgeting, operation, and transfer to other sites with similar conditions.

Within this paper, the indicators-first approach means that environmental quality indicators constitute the primary model of the design task. The indicators determine which spatial entities are analyzed (stay areas, routes, viewpoints), which temporal situations are critical (peak thermal-load hours, characteristic wind conditions), which data are mandatory, and which assumptions are permissible without losing reproducibility. We explicitly distinguish what can be objectified physically and geometrically (solar exposure and shading, pedestrian-level wind, thermal comfort indicators as an index or as a share of «suitable» stay areas, geometric characteristics of barrier-free accessibility, visibility metrics, and resource intensity as an approximate proxy of material intensity) from what requires behavioral, sociological, or detailed economic data.

To demonstrate how indicators directly affect design decisions, two brief examples are provided. The first concerns shading structures in open space. If the indicator is defined as «reducing thermal load in a stay area» or as «the share of shaded area during peak hours» for key resting places, the design levers become unambiguous: additional tree planting, the area and configuration of canopies, their height, degree of permeability (solid/perforated), orientation relative to the sun, and their location relative to stay areas and routes. Studies of the impact of shading devices on outdoor comfort show that shading substantially reduces radiative load and improves thermal comfort indicators; meanwhile, effects on air temperature and wind speed are usually much smaller or close to zero [13, p. 1–4], which matters for correctly selecting design levers. For design calculations, it is also essential to document the limits of applicability of digital modelling: studies exist where free-standing shading modelling is verified against field measurements and where shortwave and longwave radiation components are analyzed separately to avoid systematic bias in predicting shading effects [15, p. 1–6].

The second example concerns visibility as a spatial precondition for safety and orientation. If the indicator is formulated as «geometric visibility» (e.g., presence/absence of blind spots, connectedness of viewpoints along a route, openness of space from key points), the corresponding design actions are also direct: avoiding screening barriers at movement nodes, adjusting the placement of pavilions and vegetation elements, creating transparent edges, and maintaining visual corridors along primary trajectories. The analytical basis is visibility-field analysis (isovists–areas of space visible from a given point), which describes the visible portion of the environment through geometric characteristics of the field of view [2, p. 47–65]. Applied studies show that computed visibility-field variables correlate with assessments of perceived openness [21, p. 14–28] and may be associated with psychophysiological stress indicators (in configurations with higher «prospect» and better visibility) [18, p. 1–11]. For our problem framing, it is important to keep the level of generalization correct: such metrics can serve as reproducible proxies for spatial preconditions of safety and orientation, but they are not a direct measure of social «activity» without behavioral data.

Within the indicators-first approach, these examples are important not as a list of tools, but as a demonstration of disciplined problem framing: an indicator defines what exactly is measured, where and when it is measured, what input data are required, and which parameters of the design solution act as levers. Therefore, the paper deliberately selects indicators that can be reproducibly calculated on a typical dataset and that yield actionable design conclusions without conceptual substitution.

Table 1 systematizes the logic of indicator-oriented parametric design for renovating public space, where environmental quality indicators are primary and design-solution parameters act as controllable levers of influence. The table distinguishes variant-generative and reproducible logics, specifies which spatio-temporal entities and input data are defined by the indicators, and outlines interpretation limits for indicators that require behavioral or socio-economic data.

Using two examples (shading/thermal load and geometric visibility), it demonstrates the transition from indicator definition to a set of concrete design parameters and decisions suitable for coordination and practical implementation.

2. Core indicator set and selection criteria

Within the indicators-first approach, the core assessment of environmental quality is specified in advance as a limited but reproducible set of indicators that are simultaneously measurable, interpretable, and controllable through design. Selection of this core is not arbitrary: it relies on performance- and data-informed design principles in which spatial solutions are compared through quality indicators rather than through descriptions of «form as such», and where transparent work with trade-offs between heterogeneous requirements is essential [6, p. 9–33; 22, p. 1–18]. For renovation of public space, this means that indicators must, first, correspond to design spatial entities (stay areas, routes, viewpoints); second, have a clear spatio-temporal setup (peak hours,

Table 1

Structure of indicator-oriented parametric design (based on two indicators)

Stage / block	Content	Input data / conditions	Output / design action	Notes and sources
1	Parametric methods in urban environmental design	—	Prerequisite for choosing the working logic	—
2A	Variant-generative logic: • speed • formal diversity	Form parameters; constraints may be minimal	A set of formal variants	Not a priority for renovation (does not guarantee comparability and practical feasibility)
2B	Reproducible logic: • same data + rules • comparable sets of solutions	Standardized input data; fixed rules and assumptions	Solutions read as design actions (approval / budget / operation / transfer)	Selected as the base logic for renovation of public space
3	Indicators-first approach: environmental quality indicators = primary task model	Defined indicators and their «passports» (definition, units, scenarios, assumptions)	Indicators define the analysis structure and the set of controllable parameters	—
4	Indicators determine the analysis setup	Space: stay areas; routes; viewpoints. Time: peak thermal-load hours; characteristic wind conditions. Data: mandatory; permissible assumptions.	A reproducible scheme of calculations and comparison of variants	—
5A	Group 1: objectifiable (physical / geometric) indicators	solar exposure/shading; pedestrian-level wind; thermal comfort (index or share of «suitability»); barrier-free accessibility (geometry); visibility (geometric metrics); resource intensity (approximate material intensity).	Quantitative indicator values suitable for comparing variants	Reproducibly computed on a typical dataset
5B	Group 2: indicators requiring additional data	Behavioral; sociological; detailed economic data	Refined conclusions on use / activity / life-cycle economics	Within this paper, do not substitute the physical-geometric indicators
6	Example 1: shading structures (stay comfort)	Indicator: reduced thermal load or share of shaded area during peak hours	Levers: tree planting; canopy area/configuration/ height; permeability; orientation; localization	Shading reduces radiative load and improves comfort; impact on air temperature and wind often small [12]. Modelling limits: comparison with field data [1, p. 1–4; 2, p. 1–8; 3, p. 1–6].
7	Example 2: visibility (safety and orientation)	Indicator: geometric visibility (blind spots; connectedness of viewpoints; openness from key points)	Levers: avoid screening; adjust pavilions and vegetation; transparent edges; visual corridors	Visibility-field analysis (isovists) [6]. Linked to perceived openness [15] and stress indicators [16]. Not a direct measure of social «activity» without behavioral data.
8	Conclusion	An indicator defines: what, where, and when we measure; what data are needed; which parameters are levers of influence	Selection of indicators that are reproducibly computed on a typical dataset and yield actionable design conclusions	—

characteristic scenarios); third, be linked to controllable parameters of renovation solutions; and fourth, remain reproducible on a typical set of input data.

The formed core indicator set was grouped into three interrelated blocks. The first block describes the microclimatic suitability of stay areas in the warm season: (1) thermal comfort in stay areas, recorded either as an index or as the share of area/time within an acceptable range; (2) solar exposure and shading as a characteristic of the radiative regime at peak hours; (3) pedestrian-level wind as a condition of comfort and safety (Fig. 2). This choice is justified because, for open public spaces, the combination of air temperature, wind speed, humidity, and radiative conditions determines human thermal load; in this context, UTCI is widely used as an integrated indicator of climatic impact on humans [5, p. 1–3; 4, p. 1–3]. In this paper, microclimatic indicators are interpreted not as «absolute truth» but as reproducible estimates sensitive to spatial configuration and suitable for comparing variants under fixed scenarios.

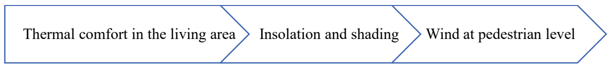

Fig. 2. Microclimate indicators (N. Khoroian)

The second block describes accessibility and continuity of use: (4) barrier-free routes as an indicator of continuity of an accessible circuit considering slopes, level changes, local obstacles, and travel time/distance (Fig. 3). This indicator was selected because it has a direct design counterpart in route tracing and detailing solutions at level-change nodes, and because it sets minimum conditions of usability for diverse user groups. Within the indicators-first approach, barrier-free accessibility is treated not as a formal «slope check» but as a structural indicator that must be coordinated with the comfort of stopping points and the logic of staying.

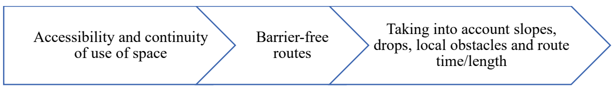

Fig. 3. Spatial accessibility indicators (N. Khoroian)

The third block describes spatial preconditions for safety, orientation, and feasibility of solutions: (5) geometric visibility metrics as a reproducible description of spatial conditions for orientation and reduction of blind spots; (6) resource intensity of elements as an approximate proxy of material intensity suitable for early-stage comparison within a single class of solutions (Fig. 4). Visibility metrics are introduced based on space-syntax approaches and visibility-field analysis (isovists) as a geometric description of which parts of space are visually accessible from specified positions [2, p. 47–65; 19, p. 103–121]. At the same time, an interpretation boundary is explicitly fixed: geometric visibility can be an objectified spatial precondition, but it is not a direct measure of social «activity» or subjective safety without behavioral data. Resource intensity, in turn, does not replace full life-cycle environmental assessment, but it helps discipline the choice of renovation solutions by filtering out evidently excessive constructions and ensuring comparability at an early stage.

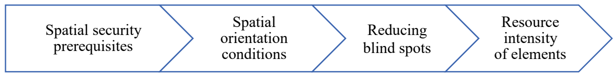

Fig. 4. Spatial safety indicators (N. Khoroian)

Thus, the core indicator set covers those aspects of environmental quality that are critical for renovating public space and can be reproducibly calculated and compared based on typical input data. Variant comparison is performed as an analysis of trade-offs without imposing universal weighting priorities, consistent with contemporary multi-criteria decision-making approaches and the requirement to test robustness of conclusions to assumptions and priorities [6, p. 9–33; 22, p. 1–18].

3. Demonstration case: a fragment of Dyukivskyi Garden (Odesa)

Dyukivskyi Garden was considered as a representative urban park for renovation, within which typical spatial situations of green zones coexist: open areas with high solar load in the warm season, fragments with different planting density, nodes of pedestrian trajectory intersections, areas with relief changes, and local places for short-term and long-term stays. Such diversity is important for demonstrating the indicators-first approach, because it allows each indicator to be assigned a specific spatial «carrier» and avoids reducing environmental quality assessment to averaged values that are poorly interpretable in design decisions.

The practical framing of the case began with structuring the fragment into three types of entities: stay areas, routes, and viewpoints. Stay areas included functional attractors (cafes, a multifunctional viewing platform, bicycle rental and parking areas), resting platforms and nodes, and places of potential crowding (waiting, short stops, viewpoints, etc.), for which solar exposure and shading, thermal comfort, and pedestrian-level wind are critical. Routes were divided into a primary accessible circuit and alternative trajectories, enabling both barrier-free accessibility and continuity of movement with consideration of slopes, level changes, and local obstacles. This also aligned renovation decisions with actual movement scenarios, including preserving existing directions and pedestrian trajectories within Dyukivskyi Garden. Viewpoints and route segments of increased significance (movement nodes, trajectory changes, entrances/exits, potential flow-conflict locations) were used as reference positions for calculating geometric visibility metrics that describe spatial preconditions of orientation and perceived safety.

After that, a renovation proposal was formulated as a search configuration of the spatial solution for the garden fragment and its equipment elements, intended to increase the suitability of stay areas during peak hours of the warm season, not worsen the barrier-free continuity of the primary accessible circuit, avoid creating pedestrian-level wind discomfort, maintain sufficient visibility along key trajectories, and keep resource intensity within acceptable limits.

A separate component of the renovation proposal was the introduction into the park composition of a cascade of artificial ponds that complements the existing water body and forms a sequence of water accents along the main stay trajectories. The cascade is located with reference to areas of high thermal load and highest use intensity in the warm season in order to reinforce the microclimatic effect at stopping and resting places. Within the indicators-first approach, water elements are treated not only as decorative additions but as a controllable environmental means of supporting a comfortable microclimate [16, p. 1–12; 17, p. 1–15], requiring coordination with shading solutions, route accessibility, visibility, and operational feasibility.

Under the proposed approach, each indicator in this framing has a direct counterpart in controllable design levers: for shading and thermal comfort–in the area, configuration, height, and permeability of shading elements, as well as decisions regarding tree planting and its placement; for wind regime–in the spatial organization of screens, openings, and directions of open corridors; for barrier-free accessibility–in route tracing, local structural solutions at level-change nodes, and removal of obstacles; for visibility–in the placement of elements, vegetation masses, and screening objects relative to viewpoints and visual corridors; for resource intensity–in the choice of structural scheme, material solutions, and scale of elements (as an approximate proxy of material intensity).

Thus, the case provides a complete but scale-controlled cycle of moving from environmental quality indicators to parameters of renovation solutions and their comparison under inevitable trade-offs.

4. Output format and derivation of design rules

Based on the work performed, it can be stated that the results of indicator-oriented parametric design should be presented not as a

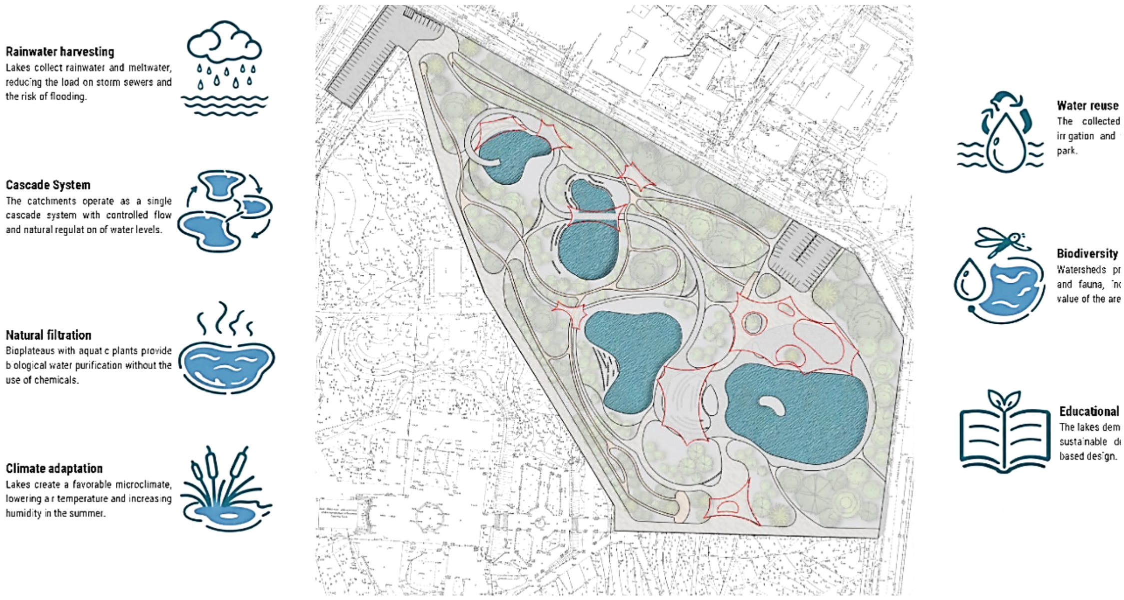

Fig. 5a Diagram of the renovation design proposal for a fragment of Dyukivskyi Garden (Odesa): water-management elements (T. Nidzelsky, OSACEA)

Fig. 5b Diagram of the renovation design proposal for a fragment of Dyukivskyi Garden (Odesa): greening elements (T. Nidzelsky, OSACEA)

Fig. 5a, b. Diagrams of the renovation design proposal for a fragment of Dyukivskyi Garden (Odesa), (T. Nidzelsky, OSACEA)

single «best» solution, but as a managed set of comparable variants and as a set of design rules that generalize the identified trade-offs between environmental quality indicators. This format corresponds to reproducible logic, since it allows a transparent explanation of why specific solutions were selected, which indicators were improved and which were accepted as inevitable constraints, and how these conclusions can be transferred to other sites with similar conditions.

For the demonstration case of the Dyukivskyi Garden fragment, it is practical to present results in three interrelated layers. The first layer fixes the baseline conditions and a «constraint map» that the renovation solution must respond to: the distribution of solar exposure and shading during peak hours of the warm season, potential zones of pedestrian-level wind discomfort, the structure of the primary accessible circuit and alternative trajectories, as well as stopping nodes and places of short-term stay. In this layer, indicators are interpreted as spatially referenced quantities rather than averaged values, which ensures correctness of subsequent design actions.

The second layer shows «indicator profiles» for a representative set of variants: how changes in controllable parameters (geometry and placement of shading elements, additional planting decisions, organization of open corridors, tracing of the accessible route, placement of equipment and planting relative to viewpoints, resource intensity of solutions) affect each indicator. Importantly, comparison at this stage is not reduced to a single aggregate score: analysis is conducted by identifying mutually non-dominated variants, i.e., those where improving one indicator inevitably requires worsening at least one other. This set forms a «managed choice space» for the design and municipal team.

The third layer is a synthesis in the form of design rules formulated as reproducible recommendations for renovating the fragment. Such rules describe: first, principles of locating shading structures and/or additional planting relative to stay areas and routes during peak hours; second, acceptable ranges of shading-element geometry (height, configuration, degree of permeability) that deliver the required microclimatic effect without excessive growth of resource intensity; third, principles of placing urban furniture and pavilions relative to flows, stopping nodes, and viewpoints; and fourth, strategies for removing barriers on the primary accessible circuit while simultaneously checking the comfort of resting places (so that new pause points do not end up in zones of excessive solar exposure or wind discomfort). If water elements are used in the renovation proposal (a cascade of artificial ponds as an extension of the existing water body), this layer also records rules for their localization relative to overheating zones and stay scenarios, as well as conditions for coordinating water accents with shading, route accessibility, and operational constraints.

The derivation of design rules relies on recurring trade-off patterns identified within the set of mutually non-dominated variants. For example, increasing the area of shading usually improves thermal comfort in stay areas, but may increase resource intensity and create risks of reduced visibility if a shading structure or vegetation screens critical visual corridors. A reproducible approach makes it possible to formulate rules by which comfort gains are achieved primarily through orientation and localization of elements at the most critical points, rather than through excessive growth of constructions.

Similarly, improving barrier-free accessibility may require adjusting the trajectory of the primary accessible circuit, implementing local structural solutions at level-change nodes, and introducing short-rest places. Indicator analysis makes it possible to check whether formal accessibility is «compensated» by the appearance of uncomfortable stops in overheated or overly windy zones, and accordingly to formulate rules that combine accessibility with microclimatic suitability. Ultimately, the output is presented as a transparent transition from environmental quality indicators to renovation design actions and rules that can be applied both within Dyukivskyi Garden and at other sites with related spatial conditions.

5. Discussion and limitations

The indicators-first, indicator-oriented approach reduces methodological randomness in parametric design, because the problem framing is fixed through standardized indicator descriptions and their spatio-temporal linkage. This disciplines the process: criteria cannot be arbitrarily changed «to fit a desired result», since each indicator has a definition, measurement units, a calculation scenario, a list of required data, and permissible assumptions. Thus, digital procedures and controllable parameters are derived from the content of indicators, not vice versa.

A second key effect is reproducibility. Given the same input data and the same indicator definitions, different teams can obtain comparable sets of solutions and formulate similar design rules. This is especially important for renovation projects of public spaces, where the process is often multi-actor (design team, city, maintenance services, community) and decisions must be transferable to other sites with similar conditions.

A third effect is communicative transparency. Trade-offs among thermal comfort, solar exposure and shading, wind regime, barrier-free accessibility, visibility, and resource intensity become explicit before detailed design. This enables discussing decisions at the level of priorities and acceptable indicator bounds rather than post factum–after working drawings or even after implementation.

At the same time, the approach has limitations that must be explicitly documented in the text and in the description of input data. Geometric visibility metrics do not replace studies of subjective safety and real behavioral scenarios. They formalize only spatial preconditions of orientation and passive surveillance (openness, blind spots, connectedness of viewpoints); therefore, interpretation should be limited to this level and should not substitute behavioral conclusions with geometric proxies.

Assessment of thermal comfort, solar exposure/shading, and pedestrian-level wind depends on the adopted meteorological scenarios, seasonality and time of day, and modelling simplifications. In each practical application these assumptions must be stated explicitly: which hours are considered «peak», which meteorological conditions are taken as characteristic, how shading effects are interpreted (including radiative components), what spatial resolution is used, and what threshold values are applied. Without such documentation, results lose comparability and may be misused as an argument for a preselected solution.

Resource intensity, presented as an approximate proxy of material intensity, is not a full life-cycle environmental assessment and does not replace engineering calculations of durability, maintenance cost, or carbon footprint. It should be treated as an early-stage metric that helps discard evidently excessive solutions and compare variants within a single class of elements.

A specific limitation for renovation cases is dependence on the quality of input data. Inaccuracies in a digital terrain model, lack of up-to-date information on vegetation, surfaces, utilities, or barrier nodes directly affect the reliability of indicators and may shift trade-off profiles. Therefore, the paper retains the principle of a narrow and reproducible framing: indicators and input-data formats are selected that can be provided for a typical urban site without turning the work into a dissertation-scale effort.

6. Practical steps for implementation

To integrate the indicators-first approach into a real renovation process, it is advisable to formalize it as a short technical guideline or as an annex to the design brief. Such a guideline should define: the minimum set of input data (planning base, terrain, vegetation, surfaces, existing equipment elements, barrier nodes, and flow-conflict points); standardized indicator descriptions (definitions, units, spatio-temporal scenarios, threshold values, assumptions); requirements for deliverables (indicator maps, indicator profiles for a set of variants, a set of mutually non-dominated variants, synthesized design rules); and rules for moving from results to design actions (which parameters are adjusted when a specific indicator worsens/improves and which trade-offs are considered acceptable).

Such formalization enables using the approach both as a design tool and as a quality-control tool: at the concept stage–for justifying renovation configurations, at the detailing stage–for verifying that refinements have not degraded key indicators, and during author supervision–for verifying that implemented solutions correspond to those design parameters that ensure the stated environmental quality.

CONCLUSIONS

The paper substantiates an indicator-oriented approach to parametric design for renovating public space, in which environmental quality indicators constitute the primary model of the design task, and the choice of digital procedures and controllable parameters is subordinated to the requirements of measurability and reproducibility. A workflow is proposed that includes criteria-based indicator selection, standardized indicator description (definitions, units, spatio-temporal scenarios, assumptions, and linkage to controllable parameters), parametric generation of variants, and comparison of solutions through indicator normalization and trade-off analysis without imposing universal weighting priorities. In this framing, the main output is not a single "optimal" configuration, but a transparent basis for justifying design choices under explicitly stated assumptions and constraints.

The core indicator set covers thermal comfort in stay areas, solar exposure and shading, pedestrian-level wind, barrier-free route continuity, geometric visibility metrics as spatial preconditions of orientation and perceived safety, and resource intensity of solutions as an early-stage proxy of material intensity. The demonstration using a fragment of Dyukivskyi Garden in Odesa confirmed the practical applicability of the approach for structuring space into stay areas, routes, and viewpoints; generating a comparable set of renovation solutions; and deriving design rules, including the localization of shading elements, organization of comfortable stopping places, maintaining continuity of the accessible circuit, ensuring visibility along key trajectories, and coordinating decisions with resource constraints. The renovation proposal also illustrates the possibility of integrating a cascade of artificial ponds as a controllable environmental means of supporting microclimatic suitability of stay areas, provided it is coordinated with accessibility, visibility, and operational feasibility requirements.

Further development of the work should be linked to local verification of assumptions for microclimatic indicators (field observations during peak hours of the warm season) and to strengthening the empirical basis for interpreting the visibility indicator (surveys and observation of use scenarios), while preserving the principle of indicator primacy. A separate direction is to refine the resource component for typical structural solutions and maintenance scenarios in order to improve the accuracy of variant comparison without overloading the methodology at early design stages.

BIBLIOGRAPHY

[1] Belton V., Stewart T. J. Multiple criteria decision analysis: An integrated approach : monograph. Springer, 2002. DOI: https://doi.org/10.1007/978-1-4615-1495-4.

[2] Benedikt M. L. To take hold of space: Isovists and isovist fields. *Environment and Planning B: Planning and Design.* 1979. Vol. 6, no. 1. pgs. 47–65. DOI: https://doi.org/10.1068/b060047.

[3] Blocken B., Stathopoulos T., van Beeck J. P. A. J. Pedestrian-level wind conditions around buildings: Review of wind-tunnel and CFD techniques and their application. *Building and Environment.* 2016. Vol. 100. pgs. 50–81. DOI: https://doi.org/10.1016/j.buildenv.2016.02.004.

[4] Bröde P., Fiala D., Błażejczyk K., Holmér I., Jendritzky G., Kampmann B., Havenith G. Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). *International Journal of Biometeorology.* 2012. Vol. 56, no. 3. pgs. 481–494. DOI: https://doi.org/10.1007/s00484-011-0454-1.

[5] Błażejczyk K., Broede P., Fiala D., Havenith G., Holmér I., Jendritzky G., Kampmann B., Kunert A. Principles of the new Universal Thermal Climate Index (UTCI) and its application to bioclimatic research in European scale. *International Journal of Biometeorology.* 2013. Vol. 57, no. 3. pgs. 373–386. DOI: https://doi.org/10.1007/s00484-013-0647-3.

[6] Dodgson J., Spackman M., Pearman A., Phillips L. Multi-criteria analysis: A manual : methodical guide Department for Communities and Local Government, 2009. URL: https://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf (date of application: 11.04.2026).

[7] EN 17210:2021. European Committee for Standardization. Accessibility and usability of the built environment – Functional requirements. [effective from 2021]. URL: https://accessible-eu-centre.ec.europa.eu/content-corner/digital-library/en-172102021-accessibility-and-usability-built-environment-functional-requirements_en (date of application: 11.04.2026).

[8] Hillier B., Hanson J. The social logic of space : monograph. Cambridge University Press, 1984. DOI: https://doi.org/10.1017/CBO9780511597237.

[9] Ibrahim Y., Kershaw T., Shepherd P. Improvement of the Ladybug-tools microclimate workflow. *Proceedings of the Building Simulation and Optimization Conference 2020 (virtual):* col. of abstracts of the conf. rep. of the intern. scient. and pract. conf. 2020. Loughborough, UK. 2020 pgs. 1–8. URL: https://publications.ibpsa.org/proceedings/bso/2020/papers/bso2020_Ibrahim.pdf (date of application: 11.04.2026).

[10] Ibrahim Y., Kershaw T., Shepherd P. A methodology for modelling microclimates: A Ladybug-tools and ENVI-met verification study. *Proceedings of the 35th International Conference on Passive and Low Energy Architecture (PLEA 2020)*. A-Coruña, Spain. 2020. pgs. 1–6. URL: https://purehost.bath.ac.uk/ws/portalfiles/portal/212194165/A_methodology_For_Modelling_Microclimate._A_Ladybug_tools_and_ENVI_met_Verification_Study.pdf (date of application: 11.04.2026).

[11] ISO 21542:2011. International Organization for Standardization. Building construction – Accessibility and usability of the built environment. [effective from 2011]. URL: https://www.iso.org/standard/50498.html (date of application: 11.04.2026).

[12] Knöll M., Neuheuser K., Cleff T., Rudolph-Cleff A. A tool to predict perceived urban stress in open public spaces. *Environment and Planning B: Urban Analytics and City Science.* UK, 2018. Vol. 45. pgs. 797–813. DOI: https://doi.org/10.1177/0265813516686971.

[13] Lam C. K. C., Weng J., Liu K., Hang J. The effects of shading devices on outdoor thermal and visual comfort in Southern China during summer. *Building and Environment.* UK, 2023. Vol. 228. Art. 109743. DOI: https://doi.org/10.1016/j.buildenv.2022.109743.

[14] Mandić L., Đjukić A., Marić J., Mitrović B. A systematic review of outdoor thermal comfort studies for the urban (re)design of city squares. *Sustainability.* Basel, Switzerland (MDPI), 2024. Vol. 16, no. 12. Art. 4920. DOI: https://doi.org/10.3390/su16124920.

[15] Nicholson S., Nikolopoulou M., Watkins R., Löve M., Ratti C. Data driven design for urban street shading: Validation and application of Ladybug Tools as a design tool for outdoor thermal comfort. *Urban Climate*. Amsterdam, Netherlands, 2024. Vol. 56. Art. 102041. DOI: https://doi.org/10.1016/j.uclim.2024.102041.

[16] Qiao Y., Sun H., Qi J., Liu S., Li J., Ji Y., Wang H., Peng Y. Examining water bodies' cooling effect in urban parks with buffer analysis and random forest regression. *Urban Climate.* Amsterdam, the Netherlands, 2025. Vol. 59. Art. 102301. DOI: https://doi.org/10.1016/j.uclim.2025.102301.

[17] Teshnehdel S., Akbari H., Di Sabatino S. Improving outdoor thermal comfort and air quality in a hot climate through water features in an urban park. *Land*. Basel, Switzerland (MDPI), 2022. Vol. 11, no. 3. Art. 431. DOI: https://doi.org/10.3390/land11030431.

[18] Torku A., Chan A. P. C., Yung E. H. K., Seo J. O. The influence of urban visuospatial configuration on older adults' stress: A wearable physiological-perceived stress sensing and data mining based-approach. *Building and Environment.* Kidlington, UK, 2021. Vol. 206. Art. 108298. DOI: https://doi.org/10.1016/j.buildenv.2021.108298.

[19] Turner A., Doxa M., O'Sullivan D., Penn A. From isovists to visibility graphs: A methodology for the analysis of architectural space. *Environment and Planning B*: *Planning and Design.* London, UK, 2001. Vol. 28, no. 1. pgs. 103–121. DOI: https://doi.org/10.1068/b2684.

[20] van Ameijde J., Ma C. Y., Goepel G., Kirsten C., Wong J. Data-driven placemaking: Public space canopy design through multi-objective optimisation considering shading, structural and social performance. *Frontiers of Architectural Research.* Beijing, China, 2022. Vol. 11, no. 2. pgs. 308–323. DOI: https://doi.org/10.1016/j.foar.2021.10.007.

[21] Weitkamp G., van Lammeren R., Bregt A. Validating isovist variables as measures of perceived spaciousness and enclosure. *Landscape and Urban Planning.* Amsterdam, the Netherlands 2014. Vol. 125. pgs. 140–145. DOI: https://doi.org/10.1016/j.landurbplan.2014.02.021.

[22] Więckowski J., Sałabun W. Sensitivity analysis approaches in multi-criteria decision analysis: A systematic review. *Applied Soft Computing*. Amsterdam, the Netherlands, 2023. Vol. 137. Art. 110915. DOI: https://doi.org/10.1016/j.asoc.2023.110915.

[23] Міністерство розвитку громад та територій України. Україна затвердила міжнародний стандарт безбар'єрного простору ДСТУ ISO 21542:2025 «Будівлі і споруди. Доступність та придатність до використання побудованого середовища». URL: https://mindev.gov.ua/news/ukraina-zatverdyla-mizhnarodnyi-standart-bezbariernoho-prostoru (дата звернення: 11.04.2026).

REFERENCES

[1] Belton, V., & Stewart, T. J. (2002). *Multiple Criteria Decision Analysis: An Integrated Approach*. Springer. https://doi.org/10.1007/978-1-4615-1495-4

[2] Benedikt, M. L. (1979). To take hold of space: Isovists and isovist fields. *Environment and Planning B: Planning and Design*, *6*(1), 47–65. https://doi.org/10.1068/b060047

[3] Blocken, B., Stathopoulos, T., & van Beeck, J. P. A. J. (2016). Pedestrian-level wind conditions around buildings: Review of wind-tunnel and CFD techniques and their accuracy for wind comfort assessment. *Building and Environment*, *100*, 50–81. https://doi.org/10.1016/j.buildenv.2016.02.004

[4] Bröde, P., Fiala, D., Błażejczyk, K., Holmér, I., Jendritzky, G., Kampmann, B., & Havenith, G. (2012). Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). *International Journal of Biometeorology*, *56*(3), 481–494. https://doi.org/10.1007/s00484-011-0454-1

[5] Błażejczyk, K., Broede, P., Fiala, D., Havenith, G., Holmér, I., Jendritzky, G., Kampmann, B., & Kunert, A. (2013). An introduction to the Universal Thermal Climate Index (UTCI). *International Journal of Biometeorology*, *57*(3), 373–386. https://doi.org/10.1007/s00484-013-0647-3

[6] Dodgson, J., Spackman, M., Pearman, A., & Phillips, L. (2009). *Multi-criteria Analysis: A Manual*. https://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf

[7] European Committee for Standardization. (2021). *EN 17210:2021 Accessibility and Usability of the*

Built Environment–Functional Requirements. https://accessible-eu-centre.ec.europa.eu/content-corner/digital-library/en-172102021-accessibility-and-usability-built-environment-functional-requirements_en

[8] Hillier, B., & Hanson, J. (1984). *The Social Logic of Space*. Cambridge University Press. https://doi.org/10.1017/CBO9780511597237

[9] Ibrahim, Y., Kershaw, T., & Shepherd, P. (2020). Improvement of the Ladybug Tools microclimate workflow: A verification study. *Proceedings of the Building Simulation and Optimization Conference 2020 (BSO 2020)*. https://publications.ibpsa.org/proceedings/bso/2020/papers/bso2020_Ibrahim.pdf

[10] Ibrahim, Y., Kershaw, T., & Shepherd, P. (2020). A methodology for modelling microclimates: A Ladybug Tools and ENVI-met verification study. *Proceedings of the 35th International Conference on Passive and Low Energy Architecture (PLEA 2020)*. https://purehost.bath.ac.uk/ws/portalfiles/portal/212194165/A_methodology_For_Modelling_Microclimate._A_Ladybug_tools_and_ENVI_met_Verification_Study.pdf

[11] International Organization for Standardization. (2011). *ISO 21542:2011 Building Construction–Accessibility and Usability of the Built Environment*. https://www.iso.org/standard/50498.html

[12] Knöll, M., Neuheuser, K., Cleff, T., & Rudolph-Cleff, A. (2018). A tool to predict perceived urban stress in open public spaces. *Environment and Planning B: Urban Analytics and City Science*, *45*(4), 797–813. https://doi.org/10.1177/0265813516686971

[13] Lam, C. K. C., Weng, J., Liu, K., & Hang, J. (2023). The effects of shading devices on outdoor thermal and visual comfort in Southern China during summer. *Building and Environment*, *228*, 109743. https://doi.org/10.1016/j.buildenv.2022.109743

[14] Mandić, L., Đjukić, A., Marić, J., & Mitrović, B. (2024). A systematic review of outdoor thermal comfort studies for the urban (re)design of city squares. *Sustainability*, *16*(12), 4920. https://doi.org/10.3390/su16124920

[15] Nicholson, S., Nikolopoulou, M., Watkins, R., Löve, M., & Ratti, C. (2024). Data-driven design for urban street shading: Validation and application of Ladybug Tools as a design tool for outdoor thermal comfort. *Urban Climate*, *56*, 102041. https://doi.org/10.1016/j.uclim.2024.102041

[16] Qiao, Y., Sun, H., Qi, J., Liu, S., Li, J., Ji, Y., Wang, H., & Peng, Y. (2025). Examining water bodies' cooling effect in urban parks with buffer analysis and random forest regression. *Urban Climate*, *59*, 102301. https://doi.org/10.1016/j.uclim.2025.102301

[17] Teshnehdel, S., Akbari, H., & Di Sabatino, S. (2022). Improving outdoor thermal comfort in a steppe climate: Effect of water and trees in an urban park. *Land*, *11*(3), 431. https://doi.org/10.3390/land11030431

[18] Torku, A., Chan, A. P. C., Yung, E. H. K., & Seo, J. (2021). The influence of urban visuospatial configuration on older adults' stress: A wearable physiological-perceived stress sensing and data mining based approach. *Building and Environment*, *206*, 108298. https://doi.org/10.1016/j.buildenv.2021.108298

[19] Turner, A., Doxa, M., O'Sullivan, D., & Penn, A. (2001). From isovists to visibility graphs: A methodology for the analysis of architectural space. *Environment and Planning B: Planning and Design*, *28*(1), 103–121. https://doi.org/10.1068/b2684

[20] van Ameijde, J., Ma, C. Y., Goepel, G., Kirsten, C., & Wong, J. (2022). Data-driven placemaking: Public space canopy design through multi-objective optimisation considering shading, structural and social performance. *Frontiers of Architectural Research*, *11*(2), 308–323. https://doi.org/10.1016/j.foar.2021.10.007

[21] Weitkamp, G., van Lammeren, R., & Bregt, A. (2014). Validating isovist variables as predictors of perceived landscape openness. *Landscape and Urban Planning*, *125*, 140–145. https://doi.org/10.1016/j.landurbplan.2014.02.021

[22] Więckowski, J., & Sałabun, W. (2023). Sensitivity analysis approaches in multi-criteria decision analysis: A systematic review. *Applied Soft Computing*, *137*, 110915. https://doi.org/10.1016/j.asoc.2023.110915

[23] Ministerstvo rozvytku hromad ta terytorii Ukrainy. Ukraina zatverdyla mizhnarodnyi standart bezbar'iernoho prostoru DSTU ISO 21542:2025 «Budivli i sporudy. Dostupnist ta prydatnist do vykorystannia pobudovanoho seredovyshcha» (2025). [Ministry for Communities and Territories Development of Ukraine. *Ukraine approved the international barrier-free space standard DSTU ISO 21542:2025 "Buildings and structures. Accessibility and usability of the built environment"*]. https://mindev.gov.ua/news/ukraina-zatverdyla-mizhnarodnyi-standart-bezbariernoho-prostoru

АНОТАЦІЯ

Хороян Н. Показники якості середовища як основа реноваційного проєктування громадського простору (на прикладі фрагменту Дюківського саду в м. Одеса)

Реновація міських парків і скверів нерідко здійснюється через ситуативний, локалізований підбір елементів обладнання та благоустрою без єдиної системи зіставних показників, що призводить до суперечностей між забезпеченням затінення, вітровими умовами на рівні пішохода, доступністю, орієнтацією та ресурсними наслідками проєктних рішень. У статті запропоновано показниково-орієнтований параметричний протокол за принципом «спочатку показники» для проєктування реновації та переобладнання громадського простору, в якому показники якості середовища виступають первинною моделлю постановки задачі, а усі алгоритми є похідними від вимог до вимірюваності та відтворюваності.

Khoroian N. (2026). Environmental quality indicators as a basis for renovation-oriented design of public space (a case study of a fragment of Dyukivskyi Garden in Odesa).
Theory and practice of design. Architecture and construction. 2 (40). P. 271–283.
doi: https://doi.org/10.32782/2415-8151.2026.40.26

***Мета**. Сформувати показниково-орієнтований параметричний підхід за принципом «спочатку показники» для реновації та переобладнання громадського простору, у якому показники якості середовища є первинною моделлю постановки задачі, а алгоритми проєктування підпорядковані вимогам вимірюваності та відтворюваності.*

***Методологія**. Методика включає критерійний відбір показників за ознаками керованості проєктними рішеннями, вимірюваності, доступності даних, чутливості до параметричних змін і порівнюваності між варіантами; розроблення «паспортів показників» як інтерфейсу між аналізом і проєктуванням (визначення, одиниці, просторово-часова постановка, припущення, очікувані компроміси та зв'язок із керованими параметрами); параметричну генерацію варіантів конфігурацій і розміщення тіньових структур, павільйонів і модульних меблів у межах реалістичних діапазонів; порівняння рішень шляхом нормалізації показників і аналізу компромісів через виділення множини взаємно-некращих варіантів.*

***Результати**. Сформовано ядро показників якості середовища, що охоплює тепловий комфорт у зонах перебування, інсоляцію та затінення, вітер на рівні пішохода, безбар'єрність маршрутів, геометричні метрики видимості, дотичні до безпеки, та ресурсну інтенсивність елементів як наближену оцінку матеріалоємності. Підхід апробовано на кейсі обраного фрагмента Дюківського саду в Одесі, що дозволило відтворювано сформувати проєктні правила реновації та оснащення з явним відображенням компромісів між ключовими вимогами якості середовища.*

***Наукова новизна**. Запропоновано формалізацію підходу «спочатку показники» через стандартизовані паспорти показників та явне встановлення відповідності між показниками якості середовища і керованими параметрами елементів проєктного рішення.*

***Практична значущість.** Розроблено прозору процедуру прийняття проєктних рішень для проєктних і муніципальних команд, яка забезпечує зіставність варіантів, контроль припущень і керовану роботу з компромісами на ранніх стадіях реноваційного проєктування громадських просторів.*

Ключові слова: *показники якості середовища, показниково-орієнтоване проєктування, параметричне проєктування, реновація, громадський простір, міське обладнання, малі архітектурні форми, мікроклімат, тепловий комфорт, інсоляція та затінення, вітер на рівні пішохода, безбар'єрність маршрутів, геометрична видимість, ресурсна інтенсивність, аналіз компромісів.*

АВТОРСЬКА ДОВІДКА:

***Хороян Наталія,** кандидат архітектури, доцент, доцент кафедри дизайну архітектурного середовища, Одеська державна академія будівництва та архітектури, Одеса, Україна, e-mail: natalia.khoroian@odaba.edu.ua, orcid: 0000-0002-0889-8826.*

Дата першого надходження статті до видання: 26.03.2026
Дата прийняття статті до друку після рецензування: 24.04.2026
Дата публікації (оприлюднення) статті: 30.05.2026