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Research paper

TECHNICAL CRITERIA FOR LOW IMPACT DEVELOPMENT RETROFIT OF SPORTS GROUNDS IN THE CITY MUNICIPALITY OF MEDIJANA, NIŠ

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Abstract

Outdoor sports grounds can keep their sporting function and still help to manage stormwater. Methods for choosing sites for low impact development (LID) measures are written for city blocks or catchments. They rarely deal with the technical limits of sports surfaces or show where site data are missing. This paper defines technical criteria for the preliminary assessment of sports grounds for LID retrofit. The assessment is not a design. It shows how much potential a site has, how much of that rests on verified evidence, and which surveys are still needed. Seven criteria cover the playing surface, the court area, the local slope and run-on from surrounding areas (inflow of runoff onto the surface), the usable edge or subsurface space, the external impervious area that could be connected, the overflow route and the maintenance condition. Each criterion has fixed anchors for scores 1 to 5 and a stated minimum evidence for a verified score. Ownership, accessibility and operating regimes are left to the final decision stage. All criteria are treated as equally important, so no weighting is applied. Every score is marked verified or not verified, and the result is reported as the mean score S, the share of verified criteria E, and the interval $[S^{-}, S^{+}]$ that the unverified criteria still allow. The criteria are demonstrated on two 40 × 20 m school courts in Medijana, Niš, one with a sealed mineral surface and one with an acrylic surface. They score 3.29 and 3.14, but only 29 % of the criteria are verified at either site, so the intervals overlap and neither court can be called the better one. For an illustrative 40 mm event, assumed runoff-volume reductions are 16.0 m^3 and 12.8 m^3 at Schools 1 and 2; these are indicators, not measured storage capacities.

Key words: *low impact development, sports grounds, technical criteria, field evidence protocol, stormwater retrofit*

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1. INTRODUCTION

Urban development seals natural ground and increases both the volume and the peak of stormwater runoff. Low impact development (LID), sustainable drainage systems (SuDS) and similar approaches manage rainfall where it falls [1–3]. Outdoor sports grounds suit such measures well: they are spread across the city, usually publicly managed, and large enough to store or treat runoff while still in use for sport [4]. However, a sports ground is not ordinary open space. Playing quality, user safety, surface durability and continuous use decide which measures can be considered at all.

Published LID site-selection methods work at the scale of plots, sub-catchments or urban blocks, and their criteria are mainly environmental, social and hydrological [5–7]. They do not address the technical limits of sports surfaces. Li et al. [8] used a hydraulic model with expert judgement to compare LID options inside one sports centre, but only as design variants at a single site. What is missing is a simple, repeatable procedure for one facility that respects the sports surface, separates preliminary potential from proven feasibility, and makes missing site data visible.

The aim of this research is therefore to: (1) define technical criteria, evidence rules, and eligibility conditions for a reproducible preliminary assessment and ranking of sports grounds, particularly in situations with incomplete local data; and (2) develop a technically feasible retrofit concept for sports grounds compatible with the sports surface, focusing solely on engineering and technical solutions without addressing urban planning or dual-use considerations. Ownership, accessibility, operating regimes, maintenance responsibility, demographic justification and the wider urban context are therefore not assessed here. They belong to the final decision stage, in which planners and facility owners take part.

Two school courts demonstrate the criteria. They come from a 2023 field inventory of 38 outdoor sports and recreational facilities in Medijana, compiled by the authors after earlier stormwater studies of the same area [9,10]. They are examples only, not a representative sample, and no ranking of the full inventory is given here. The criteria will be applied to all 38 facilities in a separate study.

2. TECHNICAL CRITERIA AND EVIDENCE RULES

Figure 1 shows the whole procedure and marks the parts defined and demonstrated here: the eligibility check, the seven criteria, the evidence rules, the reporting of the result and the conditional retrofit concept. Ranking of the full inventory and the design-stage investigations lie outside it.

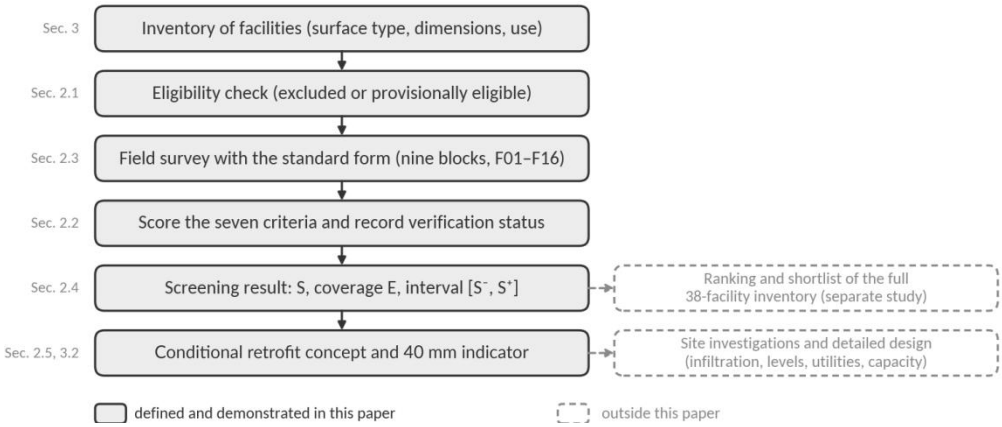


Figure 1. The preliminary assessment procedure and the parts covered here. Source: authors.

2.1. Eligibility check

The eligibility check decides whether a facility can be scored at all. A facility is excluded only when a confirmed site condition makes every realistic retrofit concept impossible. If some conditions are unknown, the facility is provisionally eligible and is scored; the unknowns are recorded and checked later. A constraint that rules out one concept excludes that concept, not the facility. Groundwater depth, bearing capacity, buried utilities, receiving-system capacity and sports-surface compliance are design-stage checks.

2.2. The seven technical criteria

Seven criteria, labelled P1 to P7, describe a facility from an engineering point of view. Table 1 gives the anchors and the minimum evidence for a verified score.

P1, surface conversion opportunity. P1 records how easily the playing surface can be made permeable. A sealed mineral surface, concrete or asphalt, scores highest, because it can be replaced by a permeable sports surface without changing the sport. Acrylic and polymeric surfaces score one step lower, artificial turf and modular tiles lower again, natural turf lowest. P1 depends on the type of surface only; its condition is recorded separately, because condition decides whether the concept replaces the surface or keeps it.

P2, core playing-surface area. P2 is the area of the court itself, from measured dimensions and not from a plot boundary. It sets the upper limit of the rainfall volume the facility can handle.

P3, local slope and run-on. P3 combines the slope of the court and its surroundings with any runoff arriving from outside. Each condition is scored separately and the lower score is used. A flat court with no external run-on is easy to drain and to build storage under; a steep court, or one receiving uncontrolled runoff, is not.

P4, usable edge or subsurface space. P4 records where a bioretention strip, a trench or a buried tank could be placed. Only continuous usable width counts; obstacles, mature trees and machine access are recorded and reduce the score.

P5, external impervious area that can be connected. P5 is the ratio $r = A_{ext}/A_{court}$ between the external impervious area that could realistically be led onto the facility and the court area. A high ratio increases the hydrological benefit, but also the storage needed and the risk of polluted inflow.

P6, overflow and hydraulic connectivity. P6 records whether water above the storage volume can leave the site safely. The highest score needs a confirmed route and a confirmed receiving point. If no safe overflow is possible at all, this is a site-level exclusion under Section 2.1, not a score of 1.

P7, maintenance and operating condition. P7 records ponding after rain, the cleaning regime of the existing gullies and any record of clogging. Permeable systems fail mainly through clogging [11], so a known maintenance problem lowers the score.

Two rules keep the scoring unambiguous. Where the anchors are nested, the highest fully supported category applies. Where a criterion combines two conditions, each is scored separately and the lower score is used. Two observers with the same measurements should therefore choose the same category.

All seven criteria are treated as equally important and no weighting is applied. At this stage the evidence is too incomplete to justify weights, and the message is carried by the coverage and the interval, not by a small difference between mean scores.

Table 1. Score anchors and minimum evidence for the seven criteria; Section 2.2 explains what each criterion measures

Code	Score anchors (5 → 1)	Minimum evidence for a verified score
P1	5 sealed mineral (concrete or asphalt); 4 acrylic or polymeric; 3 artificial turf or modular tile; 2 natural turf; 1 non-standard or protected construction	Inventory record and a photograph of the surface. The binder need not be identified: concrete and asphalt share score 5.
P2	5 ≥ 4,000 m²; 4 1,500–3,999 m²; 3 800–1,499 m²; 2 400–799 m²; 1 < 400 m²	Measured dimensions, or a plan that can be trusted.
P3	Slope: 5 ≤ 2 %; 4 > 2–5 %; 2 > 5–8 %; 1 > 8 %. Run-on: 5 none; 4 minor and manageable; 2 significant; 1 severe and uncontrolled. 3 = not verified	Three longitudinal and three transverse slope measurements, and the direction of surface runoff.
P4	5 usable width ≥ 3 m in at least two zones, or a confirmed open subsurface area; 4 one continuous strip ≥ 2 m; 3 one strip 1–2 m, or not verified; 2 one strip 0.5–1 m; 1 no continuous strip ≥ 0.5 m	Measured length and usable width of each zone, with obstacles and machine access. Buried utilities remain a design-stage check.
P5	$r = A_{ext}/A_{court}$: 5 $r \geq 2.0$; 4 $1.0 \leq r < 2.0$; 3 $0.5 \leq r < 1.0$, or not verified; 2 $0 < r < 0.5$; 1 $r = 0$, confirmed	A sketch of the catchment, its approximate area and a realistic connection route.

Code	Score anchors (5 → 1)	Minimum evidence for a verified score
P6	5 confirmed safe route and receiving point; 4 receiving element identified and connection plausible with minor works; 3 not verified; 2 only major or off-site works possible; 1 severe unresolved constraint	The receiving point, the route and the levels. A proven impossibility is a site-level exclusion, not a score of 1.
P7	5 documented low risk; 4 routine maintenance and no record of ponding; 3 not verified or mixed evidence; 2 documented ponding or clogging; 1 documented high risk	An operator record, repeated observation, or evidence collected after rain.

For P3 and P5 to P7 the value given to an unverified criterion equals one of the verified categories; the two are told apart by the verification status in the field record and by the coverage *E* of Section 2.4.

2.3. Field evidence and verification

A standard field form is used so that different observers record the same things. It has nine blocks: header data; surface, dimensions and use; slope profiles and runoff direction; edge and subsurface zones G1 to G4; external impervious sub-areas C1 to C4; drainage elements D1 to D4; use regime; maintenance and ponding records; and a closing summary with the score and status of each criterion and the two main unknowns. Sixteen coded photographs, F01 to F16, are taken at every facility, so that the same views always exist. Zones, sub-areas and elements are numbered on a site sketch, so every measurement and photograph can be located. The complete form is supporting material.

A criterion counts as verified only when the evidence places it in one anchor category with certainty. A photograph of a green strip proves that space exists, but not its usable width. Partial observations stay in the record and count as not verified. This avoids false precision and keeps the result repeatable.

2.4. How the result is reported

The screening score S_i of facility *i* is the mean of the seven criterion scores:

$$S_i=(1/n)\sum_j p_{ij} \quad (1)$$

where $n = 7$ is the number of criteria and p_{ij} is the score of facility *i* for criterion *j*, on the scale 1 to 5. A criterion that is not verified is given the value 3. This is a central assumption and not a safe one: it can be too high for a poor site and too low for a good one. The evidence coverage E_i is the share of verified criteria:

$$E_i=n_V/n \quad (2)$$

where n_V is the number of verified criteria and $n_M = n - n_V$ the number that are not verified. The bounds replace every unverified criterion by its worst and by its best possible value:

$$S_i^{-}=(1/n)\left(\sum_{j\in V_i} p_{ij}+n_M\right)\ ;\ S_i^{+}=(1/n)\left(\sum_{j\in V_i} p_{ij}+5n_M\right) \quad (3)$$

The result is therefore not a single number but the eligibility status together with *S*, *E* and [S^-, S^+]. Because the scale runs from 1 to 5, the interval width is always 4(1 − *E*): the lower the coverage, the wider the interval.

2.5. Retrofit concept and 40 mm indicator

After scoring, the type and condition of the surface select a conditional retrofit branch. A sealed mineral surface near the end of its life can be replaced by a permeable sports surface over an open-graded reservoir layer, with an underdrain and a safe overflow; one that is still serviceable keeps its surface and receives edge collection or subsurface storage. A serviceable acrylic surface is kept and connected to edge interception, pretreatment and then storage, reuse or bioretention. Artificial turf needs checks of the drainage build-up and infill containment; natural turf suits root-zone storage with controlled drainage. Permeable systems need a planned cleaning regime [11], and the final design must meet the standards for water infiltration and sports surfaces [12–16].

An illustrative event runoff volume shows the scale of the task:

$$V=P\cdot A\cdot C/1000 \quad (4)$$

where *V* is the runoff volume [m³], *P* the rainfall depth [mm], *A* the court area [m²] and *C* a dimensionless event runoff coefficient. The comparison depth of 40 mm is close to the mean of the highest daily rainfall recorded in each month at the Niš station [17]; it is not a design storm with a return period. Before the retrofit, *C* = 0.90 for the sealed mineral court and *C* = 0.85 for the acrylic court. After it, the central values are *C* = 0.40 for the permeable reservoir branch and *C* = 0.45 for the retained surface with storage or reuse, with conservative and optimistic values of 0.55 and 0.20, and 0.60 and 0.30. These are assumed values, not measured performance. The assumed runoff reduction is also expressed as an equivalent depth over the court, $d = (C_{before} - C_{after})\cdot P$. Multiplying by the court area gives $\Delta V = d\cdot A/1000$. Here *d* is an equivalent runoff-reduction depth, not a storage depth; Δ*V* is an indicative runoff reduction, not a measured capacity. It is the volume to infiltrate, reuse or store. The calculation excludes the unverified external area of P5. Temporary storage only delays discharge unless water is infiltrated or reused.

3. DEMONSTRATION ON TWO SCHOOL COURTS

The 2023 inventory recorded the identity, dimensions, use and surface type of each facility; the scoring protocol was written afterwards. A targeted survey of the two courts was therefore carried out by I. Ilić on 4 August 2026 with the standard form. The weather was dry and sunny and, according to the observer's record, about ten days had passed since the last rain. There was no operator interview and no independent weather record. The surface and the visible drainage elements could therefore be

documented, but ponding behaviour, maintenance history, levels and the external catchment could not.

The courts are OŠ „Učitelj Tasa“ (School 1) and OŠ „Duško Radović 3“ (School 2). Both are 40 × 20 m (800 m²) courts for futsal and handball at public primary schools. They share area, sport and type of owner and differ only in surface type, which isolates the effect of P1. School 1 was recorded as concrete; the photographs do not prove the binder, so the surface is described as sealed mineral pavement. This does not change P1, because concrete and asphalt share the same anchor. School 2 has an acrylic or polymeric surface.



Figure 2. Targeted survey of 4 August 2026: unpaved edge strip at School 1 (F05) and gully D1 at the paved edge of School 2 (F06). Photographs by I. Ilić.

3.1. Scores and what they mean

The survey verified the surface group and court dimensions at both sites and confirmed active school use. It also produced two partial observations: gully D1 next to the paved edge of the acrylic court, and an unpaved strip around the sealed mineral court (Figure 2). Neither verifies P4 or P6, because usable widths, levels, route, capacity, buried utilities and tree roots were not established. P3 and P5 were not measured, and P7 needs observation after rain or a maintenance record. No site-level exclusion was found, so both facilities are provisionally eligible. Table 2 gives the scores and the evidence status.

Table 2. Scores and evidence status at the two facilities

Criterion	School 1	School 2
P1 Surface conversion	5 – sealed mineral (verified)	4 – acrylic (verified)
P2 Court area	3 – 800 m² (verified)	3 – 800 m² (verified)
P3 Slope and run-on	3 – not verified	3 – not verified
P4 Edge or subsurface space	3 – not verified (partial, F05)	3 – not verified (partial)
P5 External impervious area	3 – not verified	3 – not verified
P6 Overflow and connectivity	3 – not verified	3 – not verified (partial, F06)
P7 Maintenance condition	3 – not verified	3 – not verified

Criterion	School 1	School 2
Eligibility	provisionally eligible	provisionally eligible
Result: S; E; [S^-, S^+]	3.29; 28.6 % (2 of 7); [1.86, 4.71]	3.14; 28.6 % (2 of 7); [1.71, 4.57]

Two of the seven criteria are verified at each site, so the coverage is 28.6 % and each interval is 2.86 wide. The difference between the mean scores is 0.14 and comes only from P1, so the intervals overlap almost completely. The result does not show that School 1 is the better site, only that the criteria give higher conversion priority to a sealed mineral surface than to a serviceable acrylic one.

Because no weights are used, the result depends on no weighting judgement. Weights introduced later could not change the order either: the courts differ on one criterion only, so the difference keeps that criterion's sign for any positive weights. The two-site demonstration therefore cannot test how well the criteria separate facilities; that needs the full inventory.

3.2. Conditional concepts and the 40 mm indicator

Table 3 gives the concept for each court and the 40 mm indicator. The unresolved checks are similar at both sites: slope and levels, edge width and tree roots, groundwater and buried utilities, and a safe overflow route. School 1 also needs its surface material and remaining service life; School 2 needs the invert and capacity of gully D1, the external catchment, and sports-surface compliance. Both courts have the same area, so the difference between the reductions comes only from the assumed coefficients; the indicator shows an order of magnitude, not which facility is better. Gully D1 proves that a receiving element exists, not that a working connection is possible, and the unpaved strip shows space but also mature trees and their roots. The criteria turn both observations into tasks for the next survey, not into favourable scores.

Table 3. Conditional retrofit concepts and the illustrative 40 mm indicator

Facility	Conditional retrofit concept	40 mm indicator: V before/after; reduction; equivalent depth
School 1	Near renewal: permeable sports surface over an open-graded reservoir, with underdrain and safe overflow. Still serviceable: keep the surface and add edge or subsurface storage.	28.8 / 12.8 m³; 16.0 m³, 56 % (39–78 %); 20 mm over 800 m² = 16.0 m³ per event
School 2	Keep the acrylic surface; edge interception and pretreatment; subsurface storage or reuse under the adjacent paved or open area; bioretention if green space is confirmed.	27.2 / 14.4 m³; 12.8 m³, 47 % (29–65 %); 16 mm over 800 m² = 12.8 m³ per event

4. DISCUSSION

In the demonstration, one dry-weather visit left the evidence coverage (the share of verified criteria) at 28.6 % at both sites. Verifying P3 and P4 alone would raise it to 57.1 % and narrow the interval from 2.86 to 1.71, so the criteria also show which survey work reduces uncertainty fastest.

Compared with general LID site-selection methods [5–7], this procedure works at the level of one facility and deals with the technical limits of sports surfaces. It is deliberately limited to engineering questions; ownership, accessibility, operating regimes and the wider urban context are decided later, with planners and owners. The main limitations are the ordinal scale, the offsetting of a low score by high scores on other criteria, and the two-site demonstration; the illustrative 40 mm runoff-volume calculation is a simple indicator and does not model storage routing or peak flow.

5. CONCLUSIONS

Technical criteria were defined for the preliminary assessment of outdoor sports grounds for LID retrofit: seven criteria with fixed anchors and a stated minimum evidence, a two-level eligibility check, a nine-block field form with sixteen coded photographs, the central value 3 for an unverified criterion, and joint reporting of the mean score, share of verified criteria and uncertainty interval. No weighting is used, so the result depends only on the criteria and the evidence behind them.

The criteria were demonstrated on a matched pair of 40 × 20 m school courts. The mean scores are 3.29 and 3.14, but only 28.6 % of the criteria are verified at either site and the intervals overlap almost completely, so the difference reflects the type of surface, not proven site quality. For the illustrative 40 mm event, assumed runoff-volume reductions are 16.0 m^3 and 12.8 m^3 at Schools 1 and 2; they are indicators, not verified storage capacities.

The proposed procedure is a screening and evidence-management tool, not a site-selection or design model. Its output is a documented list of checks and a conditional retrofit concept that keeps the sporting function. Ownership, accessibility, operating regimes and maintenance responsibility remain planning decisions. The output partly matches the data required by the EPA Storm Water Management Model (SWMM) [20]: it identifies area, surface, slope, contributing impervious area, outlet and LID location; width, infiltration, roughness, network geometry and LID-layer parameters require design-stage data. Further work will apply the criteria to all 38 facilities, with more than one observer, locally calibrated thresholds and an AHP weighting [18] agreed by a multidisciplinary panel [19], followed by hydraulic and sports-surface design at the shortlisted sites.

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