

SPORTS INFRASTRUCTURE AS A CATALYST FOR SUSTAINABLE URBAN TRANSFORMATION? COUNTY- AND CITY LEVEL EVIDENCE FROM HUNGARY (2014–2024)

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Abstract: Sustainable urban development has gained growing importance in recent years, with increasing attention to integrating economic, environmental, and social considerations into city planning. The European Union and Hungary have prioritized green space preservation, brownfield rehabilitation, and the promotion of healthy environments and active lifestyles. In this context, Hungary has made substantial investments in sports infrastructure—including stadiums, complexes, academies, and courts—across various regions. This study comprehensively analyses over 200 large—and medium-scale sports facility projects implemented in Hungary over the past decade. It employs a mixed-methods approach, combining statistical methods, including factor analysis, decision trees, ANOVA, and crosstabs analyses, with qualitative case studies and policy reviews to assess their impact on environmental sustainability, economic growth, and social well-being. The research identifies key trends, opportunities, and challenges in aligning sports development with sustainable urban strategies. The findings suggest that well-planned sports facilities can play a vital role in urban transformation when integrated into broader sustainability goals, particularly those related to green infrastructure, community engagement, and long-term economic viability. This study contributes to the broader discourse on sustainable city planning by highlighting best practices and providing evidence-based insights for policymakers, urban planners, and stakeholders. It emphasizes the multifaceted role of sports infrastructure in enhancing the quality of urban life and shaping more resilient, inclusive, and sustainable cities.

Keywords: sustainability, urban development, sport, well-being

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INTRODUCTION

The growing urgency of urbanization and climate change has made sustainable urban development a central priority for policymakers, planners, and researchers. Sustainable cities aim to balance environmental protection, social well-being, and economic development—often referred to as the three pillars of sustainability. Within this framework, the concept of strong sustainability prioritizes ecological limits and environmental integrity as prerequisites for social and economic progress. A key strategy supporting sustainable land use is the rehabilitation of brownfields instead of greenfields, which helps limit urban sprawl and protects valuable natural areas. Brownfields are abandoned or underutilized sites, frequently burdened by actual or perceived contamination resulting from previous industrial, commercial, or military uses.

Their redevelopment can transform neglected urban areas into environmentally, socially, and economically valuable spaces through targeted revitalization efforts (Jacek et al., 2022). This study addresses a relatively underexplored aspect of urban sustainability: the integration of sustainability and land-use implications of sports facility investments, with a particular emphasis on brownfield-based development in Hungary. Sports infrastructure has long been recognized for its potential to support public health, social inclusion, and community engagement. Moreover, sports facilities and related urban projects may contribute to neighborhood revitalization and improvements in perceived safety and destination image (Szabolcs et al., 2022). Despite these potential benefits, the role of sports infrastructure in sustainable urban transformation especially in relation to land recycling and brownfield regeneration—remains insufficiently documented in empirical research. This gap is particularly relevant in the European and Hungarian policy context, where brownfield reuse has been increasingly emphasized as a strategic priority for sustainable urban development.

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To address this gap, the study analyses more than 200 sports infrastructure projects implemented in Hungary between 2014 and 2024, using a mixed-methods design that combines quantitative assessment with qualitative case studies and policy reviews. The analysis focuses on territorial distribution, land-use context (brownfield versus greenfield), facility type, investment characteristics, and sustainability-related elements. Based on the identified research gap, this study aims to assess sustainability integration, spatial patterns, and land-use implications of sports infrastructure development in Hungary between 2014 and 2024. The research objectives are: (1) to describe the territorial distribution and typology of sports infrastructure investments; (2) to examine the relationship between investment characteristics and sustainability-oriented elements; and (3) to evaluate the prevalence of brownfield-based developments relative to greenfield projects. To address these objectives, the study applies a mixed-method approach combining statistical analyses (crosstabulation, ANOVA, decision tree modelling, and PCA) with qualitative case studies and policy review.

Research Objectives

This study aimed to comprehensively examine the structural, functional, and sustainability characteristics of sports facility investments in Hungary. Despite substantial public funding for sports developments in recent years, their environmental integration, socio-economic impacts, and regional disparities remain underexplored. The research addressed six main questions:

1. What factors determine investment value?
2. How are investments distributed by settlement category and region?
3. Do sustainability-based investment profiles exist?
4. Are there sport-specific differences in the integration of green components?
5. What regional patterns emerge?

6. Has sustainable brownfield redevelopment been prioritised over greenfield when developing sports facilities? To address these questions, the study employed quantitative methods including factor analysis, decision-tree modelling, ANOVA, and crosstabulation. Table 1 summarizes the research questions, corresponding analytical methods, and study objectives.

Table 1. Summary of Research Questions, Methods and Objectives

Research Question	Method	Objective
1. What factors determine investment value?	Log-log regression, decision tree, crosstabs	Identify predictor variables and explain investment value
2. How are investments distributed by settlement category?	Crosstabs, ANOVA	Analyse the relationship between urban hierarchy and investment volume
3. Do investment profiles exist?	Cluster analysis (Quick Cluster, TwoStep), PCA	Identify investment types based on sustainability dimensions
4. Are there sport-specific differences in the integration of sustainability elements?	ANOVA, Kruskal–Wallis, crosstabs	Examine differences by sport
5. What regional patterns emerge?	Map visualisation, GIS	Visually explore the spatial distribution of investments
6. Has sustainable brownfield redevelopment been prioritized over greenfield when developing sports facilities?	Case Study Analysis, Spatial and Land Use Analysis; Descriptive Qualitative Analysis, Extensive fieldwork, Document and Secondary Data Review	Explore the volume of brownfield developments, Key Features and Sustainable Benefits

LITERATURE REVIEW

Is the term 'sustainable city' a Paradox? The definition of a sustainable city varies across disciplines but is commonly framed around the three pillars of sustainability—economic, environmental, and social—many city models labelled as "sustainable," such as zero-carbon or ubiquitous eco-cities, tend to prioritise technology and environmental goals at the expense of social equity and economic inclusivity. In contrast, the compact city model, though less technologically advanced, aligns more closely with sustainability principles by promoting mixed land use, reduced car dependency, and urban density, suggesting a more realistic framing of cities' transition toward sustainability. This process-centred view emphasises adaptive, place-specific approaches and the critical role of energy efficiency and community inclusion in achieving long-term, sustainable urban development (Hassan & Lee, 2014).

Brownfields are lands previously developed for industrial, commercial or military purposes but are now underused, derelict, or potentially contaminated. The U.S. Environmental Protection Agency (EPA) defines them as properties "the expansion, redevelopment, or reuse of which may be complicated by the presence of a hazardous substance, pollutant, or contaminant." At the same time, Europe lacks a precise definition, although the term is generally associated with land contamination. Redeveloping brownfields is crucial from a sustainable city perspective, as it mitigates urban sprawl, reduces the pressure on greenfields, curbs soil sealing, and contributes to environmental, social, and economic resilience. In the European Union, where over 70% of the population lives in urban or suburban areas, redeveloping brownfields is crucial in addressing environmental degradation, public health risks, and land scarcity. The EU has supported brownfield regeneration through various funding instruments, such as the European Regional Development Fund and the Cohesion Fund; however, challenges persist due to the absence of standardised definitions and remediation frameworks. In contrast, the United States has a more established brownfield policy landscape, including dedicated funding and regulatory mechanisms under the Environmental Protection Agency (EPA). Both regions view brownfield redevelopment as a strategic approach to promoting healthy, inclusive, and sustainable urban development (Morar et al., 2021).

In Hungary, the large-scale emergence of brownfield sites began after the regime change, resulting in industrial decline, military facilities closure, and railway infrastructure transformation. These areas typically consist of abandoned, underutilised, or contaminated former industrial, military, or railway properties, often burdened by unclear ownership and regulatory gaps. According to a 2003 survey by VÁTI, at least 12,000 hectares of brownfield land exist across 119 municipalities, with Budapest alone accounting for 13% of its urban area as brownfield land. Successful redevelopment projects have primarily been realised near city centres, while demand remains low in rural or peripheral industrial areas. Due to the cost advantages of greenfield investments, cities often cannot fully capitalise on brownfield development opportunities, even though such reuse would support compact urban land use, preserve green space, and promote sustainable development (Kádár, 2011).

Hungary's legislative framework for brownfield redevelopment has undergone significant evolution to support sustainable urban regeneration. The Building Act LXXVIII of 1997 originally defined brownfield sites as abandoned, underutilised, or degraded parcels—often environmentally polluted due to former industrial, transport, or military use—that could be redeveloped through remediation and technical intervention. A significant shift occurred with the adoption of the Architecture Act XXIII of 2023, reaffirming this definition and introducing stricter priority rules for brownfield use. Notably, the new law mandates that greenfield development is only permissible if no brownfield exists within a 5 km radius unless justified by significant public interest. Government Decree 619/2021 (XI. 8.) defines the designation of brownfield action areas, also known as rustbelts, and sets out specific requirements for related developments. It prioritises investments linked to projects within these areas, applying accelerated administrative procedures with defined deadlines (e.g., a 15-day processing period).

Furthermore, the decree promotes brownfield reuse by introducing tax incentives and defining tailored urban planning, including special provisions for architectural planning, urban image assessments, environmental impact assessments, and the construction process. It allows for tailored regulation of minimum plot size, building methods, construction height, green space ratio, parking, and infrastructure requirements. Overall, the legislation provides an organisational and technical framework for developing these action areas, focusing on expediting investments, enforcing strict environmental and architectural standards, and simplifying legal implementation. Complementing this, Government Decree 280/2024 replaced the previous National Urban Planning and Building Regulation (No. 253/1997), providing more specific rules for integrating brownfields into urban development. Similarly, local legislation highlights how municipalities embed brownfield redevelopment into strategic urban planning. Altogether, these legislative updates represent a significant step forward by offering more targeted, enforceable, and incentivised mechanisms for the sustainable transformation of brownfields.

Modern sport infrastructure development must incorporate the latest scientific knowledge, especially with urbanism, sociology, economics, and kinanthropology (Hobza, 2008; El Archi et al., 2023).

Sports infrastructure is vital in community development, as it is highly demanded and essential for urban life. Its expansion is often seen as a reflection of a city's or nation's capacity to promote inclusive development and to support the evolving social role of sport. Closely integrated with urban structures, these facilities enhance the functionality and quality of public spaces. Frequently driven by local initiatives, such developments respond to community needs and significantly improve urban quality of life (Hardekar et al., 2018).

Recent studies have shown that individuals with strong nature involvement and green consumption values are increasingly drawn to recreational and infrastructure developments that reflect environmental consciousness and aesthetic integration with natural landscapes (Çakici et al., 2017).

Soft reuse of brownfields involves restoring land without sealing the soil, creating recreational areas, parks, green spaces, or natural habitats, rather than building infrastructure (Kabil et al., 2024). This supports circular land management by recycling land and minimising the use of greenfield areas. Soft reuse can be temporary or permanent, offering environmental, social, and economic benefits while mitigating the risks associated with complicated redevelopment. Successful examples in Europe demonstrate that it improves urban quality of life (Bardos et al., 2016).

Large-scale sports infrastructure projects significantly revitalise neglected urban and brownfield areas by transforming them into attractive, multifunctional public spaces that enhance social acceptance, improve living conditions, and boost local economies. These developments contribute to sustainable city growth by promoting environmental restoration, preventing chaotic urban sprawl, reducing social segregation, and enhancing urban competitiveness (Dávid, & Archi, 2024). Their iconic architectural design attracts tourism and investment while supporting improved infrastructure and transportation. However, their success depends on overcoming economic, social, and legal challenges through effective planning (Taraszkiewicz & Nyka, 2017). While major league sports arenas can contribute to urban revitalisation and economic growth, their positive impacts on sustainable development—such as meaningful land use transformation and increased property values are not guaranteed and often take a decade or more to materialise. Therefore, cities should consider the long-term and gradual nature of these benefits when planning such infrastructure as part of sustainable urban development strategies (Gerretsen, 2018).

Historically, the Olympic Games were hosted mainly by wealthy industrialised nations, but recently, the International Olympic Committee (IOC) has encouraged emerging economies to bid, as seen with China (2008) and Brazil (2016). This shift highlights how host countries use mega-events to drive infrastructure development and economic growth. Examining brownfield investments for past Games in cities such as London and Paris provides valuable insights into successful strategies. For instance, the 2012 London Olympics involved significant redevelopment of the East London area, transforming the previously abandoned industrial site of the Olympic Park into a vibrant community and sporting hub. Similarly, Paris plans to use the 2024 Olympic Games as a catalyst for substantial urban redevelopment, enhancing public transportation infrastructure and repurposing former industrial sites into recreational and residential areas (Baumann et al., 2013). The Beijing 2022 Winter

Olympics achieved significant sustainability by integrating sustainable land management and green ecology principles into venue planning and legacy use. The venues leveraged existing infrastructure from the 2008 Summer Olympics, minimising new construction and maximising resource efficiency. Following the games, venues like the Wukesong Sports Centre maintained high usage rates, supporting long-term social and economic benefits. Overall, Beijing's approach to Olympic infrastructure exemplified a sustainable urban development model aligned with the Olympic Movement's goals and the United Nations' Agenda 2030, providing a replicable example for future mega-events (Wang et al., 2023). The Asian Games in Hangzhou supported brownfield development primarily by transforming previously underused or industrial lands into modern sports venues and related infrastructure. These developments acted as catalysts for regenerating brownfield sites, turning them into vibrant, functional urban spaces. The construction of venues and supporting facilities utilised land that might otherwise have remained idle or contaminated and integrated with wider urban renewal plans, helping to optimise land use and reduce pressure on undeveloped greenfield areas (Fan et al., 2021). These developments acted as catalysts for regenerating brownfield sites, turning them into vibrant, functional urban spaces (Szabolcs et al., 2022).

Various decision support systems (DSSs) have been developed over the past two decades to support brownfield redevelopment. Existing DSSs focus narrowly on environmental and contamination issues during late redevelopment stages, such as remediation technology selection, often using multi-criteria decision analysis (MCDA) and GIS tools. However, there is limited support for early-stage decision-making, and key limitations include the insufficient integration of socio-economic criteria, underutilisation of predictive modelling, and poor user interfaces. More holistic, sustainable, and user-friendly brownfield DSSs are still needed to support planning and redevelopment better worldwide (Hammond et al., 2024).

Within the framework of an international study, the Sustainable Brownfields Redevelopment (SBR) Tool was developed, comprising 40 indicators across four areas—environmental health, financial, liveability, and socio-economic—to assess the success of brownfield redevelopments. The tool aims to support sustainable and balanced redevelopment that benefits communities and investors. It integrates green building principles, helping stakeholders evaluate projects more transparently and systematically. This is considered a helpful tool, but it faces challenges related to data variability and difficulties in measuring long-term impact and addressing differing stakeholder priorities (Wedding & Crawford-Brown, 2007).

This framework is relevant for the present research as it outlines key sustainability dimensions in brownfield redevelopment, providing a useful conceptual basis for discussing the sustainability implications of brownfield-based sports infrastructure investments in Hungary.

MATERIALS AND METHODS

This study applies a mixed-methods approach to analyse sports facility developments in Hungary between 2014 and 2024. Quantitative analysis is complemented by qualitative case studies and policy review to assess the environmental, economic, and social implications of these developments for sustainable urban transformation, with particular attention to brownfield-based investments and their potential contributions to land reuse, green infrastructure, mobility improvements, and community engagement. The analysis draws on multiple data sources, including official documentation, on-site primary research, news articles, academic studies, and government reports, and evaluates facility types, spatial distribution, and land-use context (brownfield vs. greenfield (Morabi et al., 2023)). Additionally, the study considers how sports infrastructure investment may improve accessibility and transportation integration within urban development strategies.

Sample Description

The final database contains 213 investment cases implemented across 99 settlements in Hungary (2014–2024). The sample covers 42 sports disciplines and includes a broad range of facilities (e.g., sports halls, swimming pools, stadiums, and with sport centers), showing strong heterogeneity in investment value. The spatial distribution of the analyzed settlements is presented in Figure 4.

Data sources and dataset construction

Since Hungary does not provide a single official database that comprehensively lists sports facility investments, an original database was compiled for this research. Projects were identified primarily through official publication and communication platforms, including Magyar Közlöny, professional architecture and construction portals (e.g., Építészfórum), and municipal webpages, and were complemented by public procurement documentation (Hungarian procurement announcements and EU-level procurement records) and publicly available project descriptions. Project identification followed a systematic search and screening procedure for 2014–2024 using Hungarian keywords such as “sportfejlesztés” (sports development), “sportberuházás” (sports investment), “sportlétesítmény-fejlesztés” (sports facility development), “stadion” (stadium), “sportcsarnok” (sports hall/arena), and “uszoda” (swimming pool/complex). Projects were included if they involved new construction or major renovation/expansion and if key information (at minimum, location and investment value) could be verified through official documentation or triangulated sources. To enhance reliability, each entry was cross-checked using at least two independent sources, prioritising official procurement and municipal/governmental documentation in cases of inconsistency.

Variables and coding

Extracted variables included investment year, investment value (HUF), facility type, settlement category, regional location, and land-use context (brownfield versus greenfield). Sustainability-related elements were coded as binary indicators (0 = not reported/not implemented; 1 = implemented), including solar energy, geothermal energy, rainwater

retention, and green space expansion/landscaping. The dataset is expected to provide high coverage of medium- and large-scale publicly supported developments due to publication and procurement transparency requirements; however, minor renovations without formal procurement documentation may be underrepresented. Evidence supporting the relevance of procurement-based sources is provided by a comparative analysis of sport-related public procurement using the EU’s TED database (2017–2019), which identified the dominance of construction works and significant relationships between contract type, duration, and value. The study also found that Hungary accounted for 7% of total procurement value, despite relatively few tenders, and reported exceptionally high average tender values compared to many other European countries, raising concerns regarding spending priorities and procurement transparency (András et al., 2022).

RESULTS

The investment values were categorised into four groups. The most significant proportion (40.4%) fell into the category of investments between HUF 1–5 billion, followed by projects exceeding HUF 5 billion (30.0%). Investments between HUF 501 million and 1 billion accounted for 18.8% of cases, while the smallest category (HUF 101–500 million) represented only 10.8% of the sample. This distribution indicates that most sports investments in Hungary are medium- or large-scale (Figure 1). The distribution of facility types also showed considerable diversity. The most common type was the sports hall, accounting for 23% of cases (49 investments), followed by swimming pools (22 cases).

General halls and sports centres each appeared in 10 cases. Stadiums and sports complexes were recorded in 9 cases each, while numerous other facility types appeared with only a few instances. This pattern indicates that sports infrastructure development efforts have focused on expanding indoor sports opportunities.

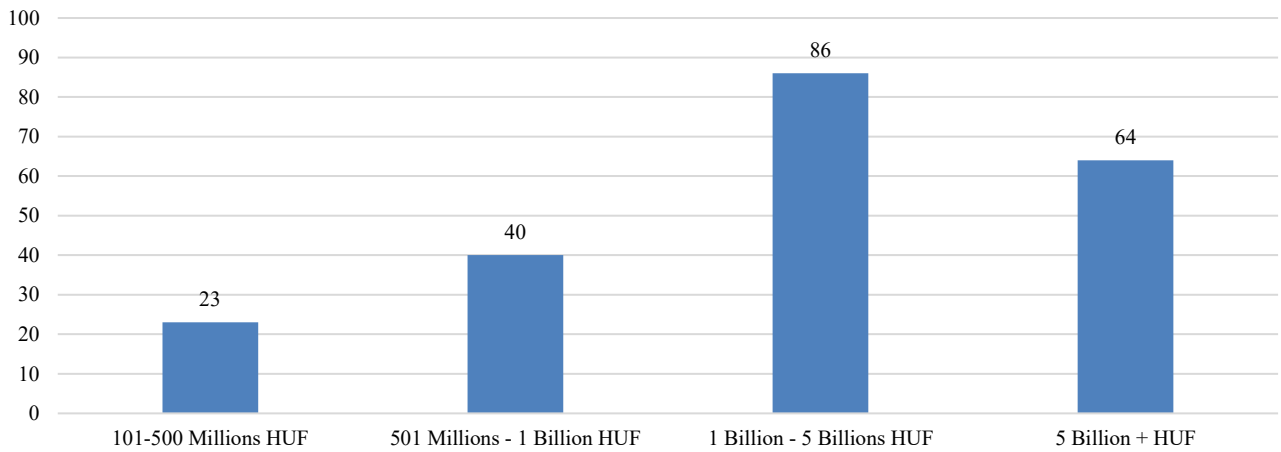


Figure 1. Distribution of cases by value of investment (Source: based on own calculations and editing)

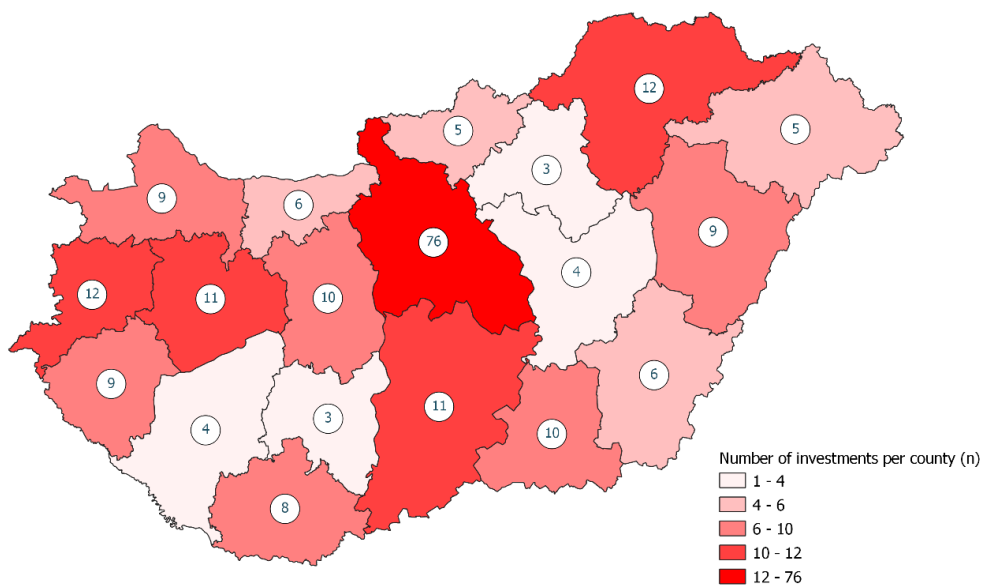


Figure 2. Regional distribution of sports investments by county (number of investments, n) (Source: based on own calculations and editing)

Regarding regional distribution, the number of investments (n) showed an intense concentration in Budapest (n = 76). This was followed by Borsod-Abaúj-Zemplén, Szabolcs-Szatmár-Bereg, and Hajdú-Bihar counties, each recording 10–12 investments. Several counties recorded only 3–6 investments. Overall, the results indicate a highly uneven territorial distribution of sports infrastructure development during the analyzed period (Figure 2).

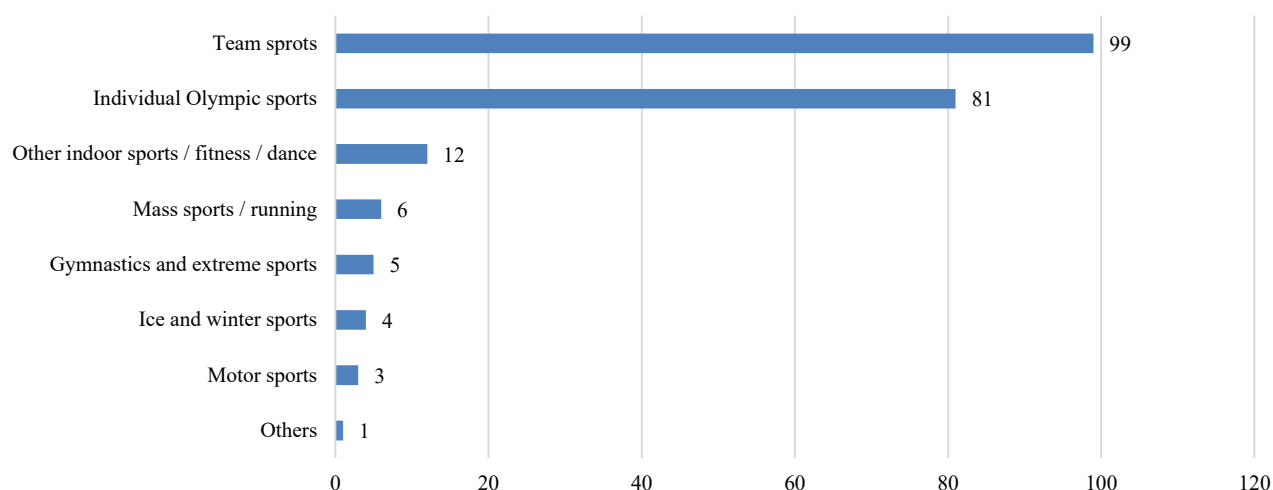


Figure 3. Distribution of cases by sport category (Source: based on own calculations and editing)

Based on the aggregated sport categories, the largest group was Category 1 (Team sports), comprising 99 cases. This category includes ball games such as football, handball, basketball, volleyball, futsal, beach volleyball, and floorball, as well as other major team sports (e.g., ice hockey, indoor hockey, and rugby). Category 2 (Individual Olympic sports) represented the second largest group with 81 investments, including swimming, athletics, gymnastics, judo, table tennis, tennis, badminton, fencing, wrestling, shooting, weightlifting, karate, and canoe-kayak. The remaining categories were represented by substantially fewer cases. Category 3 (Other indoor sports/fitness/dance) accounted for 12 projects, including general indoor sports, bodybuilding, indoor cycling, and dance. Category 4 (Mass sports/running) included 6 cases, while Category 5 (Gymnastics and extreme sports) comprised 5 cases. Category 6 (Ice and winter sports) recorded 4 cases, Category 7 (Motor sports) included 3 cases, and Category 8 (Others) was represented by 1 case (Figure 3). Overall, the distribution indicates that sports infrastructure development is strongly shaped by a limited number of dominant sport categories, while several sport types receive only marginal investment attention.

Predictors of Investment Value

A log-log regression model was first tested using a log-transformed numeric estimate of investment value. However, results were non-significant due to the ordinal nature of investment categories and the limitations of midpoint estimations, which violated linearity assumptions.

Subsequently, a CHAID decision tree model was applied. This identified seating capacity as the sole significant predictor:

- Facilities with <500 seats had an average investment of ~HUF 2.4 billion
- Facilities with >501 seats had an average investment of ~HUF 3.8 billion

The model’s high-risk estimate (4.02E+18) indicates limited predictive power. Notably, variables such as sport type or sustainability features did not enter the model, suggesting their low standalone explanatory effect.

Distribution by Settlement Category

Crosstab analysis indicates that high-value sports facility investments were disproportionately concentrated in Budapest and county-ranked cities, which typically represent the upper level of the Hungarian settlement hierarchy (often exceeding 100,000 inhabitants). In contrast, non-county-ranked cities and smaller settlements primarily hosted lower-value, smaller-scale developments. Although an ANOVA was initially considered, the investment value variable was analyzed in ordinal categories and exhibited a non-normal distribution; therefore, crosstabulation with percentage distributions was applied as a more appropriate and methodologically robust approach for comparing investment patterns across settlement categories.

Sustainability-Based Investment Profiles

Cluster analyses (Quick Cluster, Twostep) were applied to typologies investments but failed to produce stable, interpretable results due to the binary nature of input variables and low silhouette values.

Therefore, Principal Component Analysis (PCA) was conducted on solar energy, geothermal energy, rainwater retention, and green space expansion variables, yielding two components:

- Component 1 (33.2% variance explained): rainwater retention (+), geothermal energy (–) axis
- Component 2 (26.8% variance explained): solar energy (+), green space expansion (+) axis

Table 2. Quadrant-based profiling based on factor scores identified four distinct investment profiles

Profile	Description	Proportion
Complex Sustainability	High values on both components	27.6%
Geothermal–Rainwater Focused	High Factor1, low Factor2	23.5%
Solar Energy–Green Space Focused	Low Factor1, high Factor2	36.4%
Minimal Green Component	Low values on both components	10.6%

Table 2 presents the distribution of 213 investments across the four PCA-based sustainability profiles. Percentages are based on observations with complete data available for PCA profiling; totals may not equal 100% due to rounding.

This typology offers a novel framework for evaluating the environmental integration of sports investments, with implications for strategic planning and sustainability prioritisation.

Sport-Specific Differences in Sustainability Integration

ANOVA results showed no significant differences in the composite green index by sport group ($F(7,199) = 1.338$, $p = 0.234$). However, a χ^2 test for solar energy usage revealed a significant but weak-moderate association ($\chi^2(7) = 15.615$, $p = 0.029$, Cramer's $V = 0.275$):

- Highest solar energy adoption: motorsports (100%), team sports (55.1%), individual Olympic sports (51.9%).

This suggests that while overall sustainability integration is sport-independent, certain solutions (e.g. solar energy) may exhibit sport-specific implementation patterns. Moreover, the long-term success and community acceptance of such developments are closely tied to residents' perceptions of their socio-economic benefits—highlighting the importance of aligning sports infrastructure projects with local expectations and quality of life improvements (Erden & Yolal, 2016).

Regional Patterns and GIS Visualisation

A municipality-level map visualisation of investment profiles was generated (Figure 4). Colours indicate the four identified sustainability profiles.

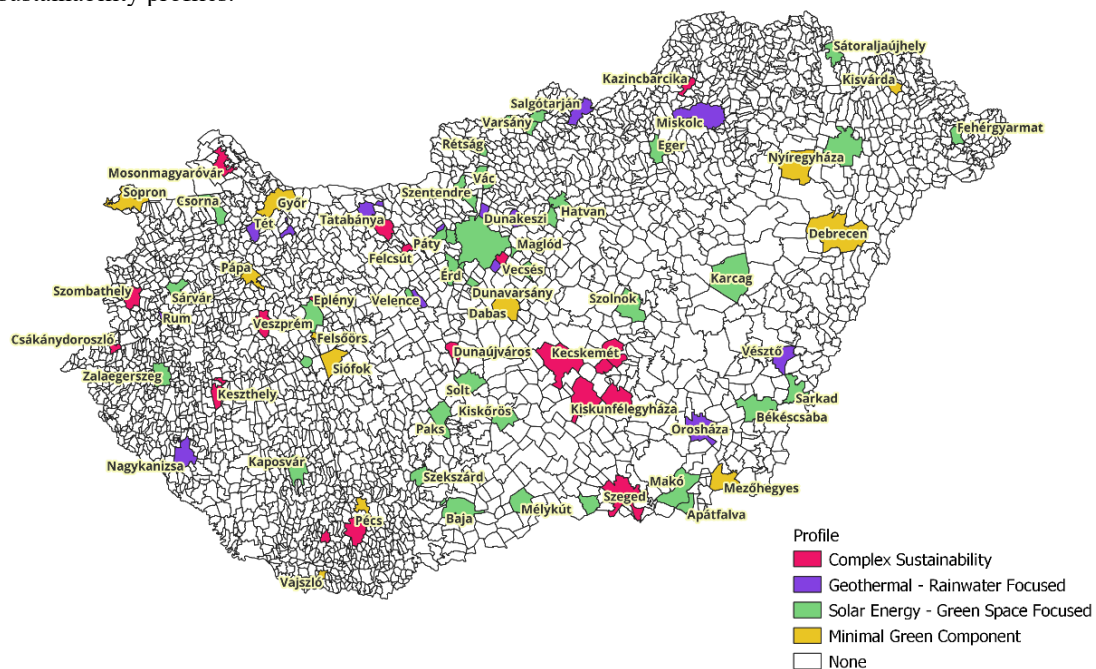


Figure 4. Municipal distribution of investment sustainability profiles in Hungary (Source: based on own calculations and editing)

- Complex sustainability profile (red): characterised by high values on both PCA components, typically occurring in county-level cities with larger-scale investments.
- Geothermal–rainwater focused profile (purple): characterised by the dominance of rainwater retention and/or geothermal energy, primarily in medium-sized towns.
- Solar energy–green space focused profile (green): characterised by high occurrence of solar energy installations and green space expansion, scattered primarily in medium and small towns.
- Minimal green component (yellow): low sustainability integration, with a more dispersed geographical distribution.

The spatial distribution indicates regional concentration patterns, particularly in Western Transdanubia and the central Great Plain region. This provides a basis for future research on funding priorities and territorial equity.

These findings resonate with broader global trends in the scaling-up of tourism and leisure infrastructure, where multifunctional, high-capacity developments—such as sports venues and public event spaces—are increasingly used as tools for enhancing territorial competitiveness and symbolic urban status (Szöllős-Tóth et al., 2025).

A case study in Szekesfehervar, Hungary, highlighted that public administration plays a key role in transition by creating strategic, locally grounded governance frameworks supporting renewable energy use and sustainable development. The findings emphasise that coordinated efforts between public and private actors are essential for achieving green economic transformation, with potential relevance beyond Central and Eastern Europe (Márton et al., 2022).

Brownfields

Table 3 summarizes the eight brownfield-based sports facility developments identified in the dataset, outlining their previous site uses and contributions to sustainable urban renewal and community value.

Table 3. Brownfield development projects and their key features and benefits

Location and former Land Use	New Function and Facility	Key Features and Sustainable Benefits
Budapest, VITUKI Industrial site	National Athletics Stadium & Recreational Park	Sustainable urban renewal, flood protection, health promotion, civic pride, international events
Budapest, Taurus Rubber Factory	Sportpark with 3 buildings, 3 playing fields, parking, and future pool	Hosted Maccabi Games 2019, large-scale multi-sport complex with potential pedestrian bridges
Budapest, Military School, former Soviet Barack	Community sports & leisure centre for youth	Facilities for wrestling, fencing, swimming, planned ski slope, revitalisation of municipal property
Hatvan, Sugar Factory	Sports & cultural centre with multifunctional hall, future ice hall	Serves local sports needs, community engagement, cultural development, flexible-use hall
Kaposvár, Brick Factory	Kaposvár Arena – modern multi-purpose sports venue	Part of Modern Cities Program, swimming pool nearby, enhances infrastructure and community access
Pápa, Gas Distribution Plant	Athletic centre with standard track, park, playground	Promotes green space, demolishes outdated infrastructure, encourages physical activity
Tatabánya, Mining Hospital	Szent Margit Gymnasium with new sports hall	Adaptive reuse of historic building, reduces new construction, supports education and urban revitalisation
Vác, Esze Tamás Barack	National female handball academy	Youth development, regional talent support, rare opportunity for city regeneration

As shown in Table 3, these sports infrastructure investments, implemented on brownfield sites, illustrate how former industrial and military areas can be reused for public sport and community functions. The cases demonstrate settlement-specific outcomes linked to both former land use and the new facility role. In Budapest, redevelopment pathways include the conversion of the former VITUKI industrial site into a national athletics venue combined with a recreational park (Építészforum, 2020; Építészforum, 2023), the transformation of the former Taurus factory area into a multi-functional sport park (Magyar Építők, 2017; Magyar Építők, 2025), and the reuse of a former military/barracks site into a youth-oriented sport and leisure centre (Magyar Építők, 2017). Beyond the capital, brownfield regeneration supported local infrastructure upgrading in Hatvan (former sugar factory) (Magyar Építők, 2018), Kaposvár (former brick factory) (Magyar Építők, 2019), and Pápa (former gas-related site), where new sport facilities were combined with broader community and public-space functions (Magyar Építők, 2021). In Tatabánya, adaptive reuse of the former mining hospital site strengthened educational and neighborhood functions (Magyar Építők, 2017), while in Vác, the redevelopment of the former Esze Tamás barracks enabled the establishment of a women's handball academy with regional youth development capacity (Magyar Építők, 2018). Overall, the cases indicate that brownfield-based sport developments can deliver combined urban renewal and community benefits, yet remain rare within the national investment landscape. In several cases, redevelopment was complemented by sustainability-oriented measures, including renewable energy solutions and sustainable mobility improvements (e.g., enhanced public transport access and support for walking and cycling), increasing the added value of the investments beyond the facility itself.

Although more than 200 sports facility projects were analysed across Hungary over the last decade, only eight were located on brownfield sites, despite the environmental, social, and economic benefits such redevelopments may offer. This highlights significant untapped potential to convert underutilized former industrial or military areas into valuable recreational and sports spaces. Environmental benefits include reduced land consumption, mitigation of urban sprawl, and climate-conscious design elements such as green spaces, flood protection, and active transport integration.

Such transformations may also contribute to the aesthetic and experiential quality of urban landscapes, as observed in nature-based tourism destinations, where the visual appeal of revalorized spaces enhances public use value (Gozner et al., 2017). Social impacts may involve stronger community identity, youth development, and revitalized public spaces supporting inclusion, education, and healthier lifestyles. Sports can reduce inequalities and ecological burdens through environmentally efficient infrastructure, technological innovation, and collective decision-making (Köves et al., 2021).

Economic advantages may include regional development effects, increased property values, event-based tourism, and cost-effective land use, especially where projects consider flexibility and sustainability.

Overall, the findings suggest that brownfield-based sport developments represent a strategic opportunity for sustainable urban regeneration in Hungary, which remains largely underexploited. At the same time, sustainable outcomes do not necessarily require higher investment; however, early-stage planning flexibility and transparent stakeholder communication are essential for successful revitalization (Schädler et al., 2011).

DISCUSSION

This research is among the first to systematically typologies Hungarian sports facility investments based on sustainability integration. Findings revealed that investment value is predominantly capacity-driven, with limited influence from environmental components on cost magnitude. This underscores the prioritisation of size and seating as symbolic and functional dimensions of sports development.

The PCA-based profiling revealed substantial heterogeneity in sustainability strategies:

- Complex Sustainability profiles suggest integrative approaches, potentially driven by higher funding availability or local strategic alignment with climate targets.
- Geothermal–Rainwater Focused profiles reflect regional resource endowments, particularly in geothermally active or water-scarce areas.

- Solar Energy–Green Space Focused profiles indicate opportunities for urban greening and renewable energy integration even in smaller towns.
- The prevalence of Minimal Green Component profiles highlights a policy gap in mainstreaming environmental considerations.

Moreover, while sport-specific sustainability integration remains limited overall, targeted interventions could amplify sectoral environmental impact, particularly in sports with high infrastructural or energy footprints.

Policy Implications

Building on the analysis of over 200 sports facility developments in Hungary—of which only a small fraction was on brownfield sites—there is a clear need for more strategic and sustainability-oriented policy interventions in sports infrastructure planning. The following recommendations are proposed:

- Prioritise Brownfield Redevelopment in National Sports Planning
- National and local governments should explicitly prioritise brownfield sites for future sports investments. This would maximise land-use efficiency, support urban regeneration, and reduce environmental degradation. Tools such as updated brownfield site registries and planning incentives should facilitate this shift.
- Introduce Targeted Funding Schemes for Sustainable Projects
- Public funding mechanisms should favour projects with complex sustainability profiles, integrating environmental, social, and economic objectives rather than addressing only single aspects (e.g., energy efficiency alone). Incentives should support projects that promote land rehabilitation, active mobility, and climate resilience.
- Align Sports Investments with Broader Urban and Climate Strategies
- Strategic planning frameworks must connect sports infrastructure development with regional resource capacities, urban resilience objectives, and decarbonisation pathways. This alignment ensures that new facilities contribute to sustainable urban transformation, not just sectoral development. Similar approaches have proven effective in inner rural areas, where the development of multifunctional parks and geosites has strengthened local identity, resilience, and territorial cohesion (Forleo et al., 2017).
- Mandate Sustainability Standards in Sport Federation Guidelines
- National sport federations should integrate minimum sustainability standards into their facility construction and renovation requirements. This could include environmental certifications, low-carbon materials, energy use targets, and inclusive design principles.
- Support Evidence-Based Policy Through Interdisciplinary Research
- Continued research is needed to understand better the interplay between social acceptance, economic performance, and environmental impacts of sport infrastructure. Such interdisciplinary insights will help improve long-term planning, policy design, and public accountability. This includes examining safety, policing, and tourism aspects related to large-scale sporting events, which form an integral part of sustainable urban development (Szabolcs et al., 2022).

CONCLUSION

This research has examined the intersection of urban development, sustainable land use, and sports infrastructure, focusing on brownfield redevelopment in Hungary and the broader European context. The findings reveal that while sport-led urban regeneration can act as a powerful catalyst for revitalising underutilised areas, its long-term success depends on integrated planning, inclusive governance, and adherence to sustainability principles. Between 2014 and 2024, Hungary experienced a dynamic shift toward sustainable urban transformation in the context of sports infrastructure. While greenfield and vacant site developments remain dominant, a notable number of strategic investments have successfully repurposed former industrial, military, and obsolete urban areas. These brownfield projects demonstrate environmental benefits such as land rehabilitation, reduced urban sprawl, and improved integration of green spaces.

Socially, the new facilities contribute to community cohesion, public health, and youth development. Economically, they support job creation, increase land values, and attract event-driven tourism, all while showcasing that sustainable design is feasible and cost-effective when paired with early-stage planning and broad stakeholder engagement. The findings highlight the significant potential of sports infrastructure to contribute to tourism development, particularly through event-based tourism and the revitalisation of urban landscapes. Brownfield-based sports facilities enhance local identity and the visual appeal of public spaces, creating new opportunities for sustainable and experience-oriented tourism in urban and peri-urban areas. From a methodological perspective, the study demonstrates that PCA-based typologies offer a robust alternative to traditional cluster analyses in classifying investments by sustainability criteria. This approach revealed substantial differentiation among Hungarian sports investments, particularly regarding their environmental integration.

These insights carry significant policy and planning implications for achieving equitable, climate-aligned infrastructure development. Despite these advances, the full potential of brownfield-based sports infrastructure remains underutilised in Hungary. To maximise the benefits of such developments, a stronger policy emphasis is required on integrated spatial planning, prioritisation of brownfield reuse, and improved sustainable mobility connections. National and local governments should promote brownfield redevelopment for sports infrastructure to conserve green spaces and regenerate urban areas, supported by central brownfield registries and targeted financial incentives. Sustainable planning must be embedded early in the process, with mandates for energy-efficient design, biodiversity conservation, and access to green transportation. Environmental impact assessments should be a prerequisite for public funding.

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