

ACOUSTIC DESIGN OF A STADIUM: CHALLENGES, TECHNOLOGIES AND URBAN INTEGRATION

*Alessandra Lisiero, Diletta Romagnolo, Gianfranco Quartaruolo,
Thomas Dimasi, Roberto Zecchin*

ABSTRACT

In view of UEFA Euro 2032, this paper illustrates the principles of acoustic design for contemporary stadiums, which are multifunctional infrastructures operating continuously and involving significant engineering and environmental challenges, as they must integrate within complex urban contexts. The current situation in Italy and Europe is analyzed, highlighting critical issues and approaches, with a focus on design strategies for mitigating noise sources and optimizing indoor sound quality [1].

1. UEFA Euro 2032 Objectives: An Opportunity for Renewal

The organization of UEFA Euro 2032 imposes significant regulatory and infrastructural constraints on Turkey and Italy, requiring major upgrades to national stadiums involved in the event. For this event, stadiums must belong to UEFA "Category 4," the highest classification, for which specific technical parameters are defined.

2. Evolution and Configuration of Stadiums in Italy and Europe

To date, only one stadium in Italy fully meets UEFA requirements (Juventus Stadium); several others are undergoing renovation, while some are in the design phase with that goal.

Italian stadiums, with an average age of over 50 years and shaped by different historical phases, now face the challenge of multifunctionality in dense urban contexts. Urban expansion has transformed 80% of stadiums from peripheral to urban facilities, creating critical conflicts between the high acoustic impact of events and the protection of nearby residential areas. In this context, meticulous acoustic design becomes essential to ensure social and economic sustainability.

Across Europe, many stadiums are also of older generation. However, in recent decades, there has been a push toward building new facilities or deeply renovating existing ones to meet modern requirements, with increasing attention to acoustic aspects.

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Partita IVA 04387520283
Capitale Sociale € 1.000.000,00 i.v.
Iscrizione al Registro Imprese di Padova 04387520283
R.E.A. Padova 385357

www.manens.com

info@manens.com

Sede legale/operativa

Padova - Corso Stati Uniti, 56, 35127 T+39 049 87 05110

Sedi operative

Verona - Via Campofiore, 21, 37129 T+39 045 80 36100

Padova - Via Venezia, 59/15-C, 35131 T+39 049 86 91111

Bari - Via V. Aulizio, 61, 70124 T+39 049 86 91111



[2,3] Examples such as the Tottenham Hotspur Stadium in London demonstrate how acoustics is now a fundamental design requirement. It must balance two opposing needs: enhancing the internal atmosphere and protecting the external environment. This is achieved through compact and enclosed bowl configurations, sound-insulating roofs with calibrated sound-absorbing portions, and optimized PA systems.

3. New Functional Requirements

The concept of a stadium has evolved significantly. From a single-purpose sports facility, it has become a complex multifunctional infrastructure and a strategic asset for urban regeneration.

Modern stadiums operate year-round, integrating complementary functions (retail, museums, cultural hubs, food services), acting as socio-economic drivers for surrounding neighborhoods. This new role introduces noise-related challenges and requires advanced acoustic design.

Four main objectives emerge:

- Creating an engaging atmosphere for spectators
- Maximizing intelligibility of emergency messages (EVAC)
- Enhancing sound quality during concerts
- Controlling sound propagation toward the outside environment

Additionally, integration of such infrastructures raises broader sustainability issues beyond acoustics. Projects must undergo Strategic Environmental Assessments (SEA) and Environmental Impact Assessments (EIA), addressing impacts such as:

- Increased traffic
- Land consumption
- Pressure on infrastructure and local resources

4. Acoustic Regulatory Framework and International Standards

Stadium acoustic design is governed by a complex regulatory framework.

In Italy, key references include:

- Law 447/1995 – general principles of acoustic protection [4]
- D.P.C.M. 14/11/1997 – emission and immission limits based on zoning [5]
- D.P.C.M. 5/12/1997 – building acoustic insulation requirements [6]

Football matches, as regular sporting activities, are exempt from differential emission limits [7]. Concerts, however, are subject to these limits, although international event providers often consider them too restrictive [8].



[1] UEFA defines standards for stadium audio systems to ensure uniform sound coverage and emergency message intelligibility (EVAC). It also recommends careful design of roofs and materials to control reverberation and improve acoustic comfort.

Municipalities may grant temporary exemptions for a limited number of events. However, reliance on exemptions must not replace proper acoustic mitigation design, as otherwise large parts of the population may be exposed to excessive noise levels.

5. The Santiago Bernabéu Case: Acoustic Non-Compliance

A significant case highlighting stadium acoustic challenges is the Santiago Bernabéu in Madrid. In 2024, after renovation, concerts were banned due to exceeding noise limits at nearby building façades, with sound pressure levels reaching up to 90 dBA.

This case demonstrates how aesthetic-focused interventions without adequate acoustic insulation can compromise full functionality [9].

The ban resulted in:

- Loss of hundreds of millions of euros from canceled events
- Additional legal costs
- Costs for acoustic retrofitting

6. Fundamental Design Principles

Two key aspects must be considered in stadium acoustic design:

1. Identification of Sound Sources

Main sources include:

- Crowd movement outside
- Concourse areas (food & beverage zones)
- Spectators in stands
- Fixed sound systems
- Concert configurations (depending on stage position)
- Technical systems
- Temporary outdoor stages (fan zones)

These variables are complex due to variability in type, number, position, and directivity.

2. Management Strategies

Strategies aim both to mitigate and enhance different sound sources and must be integrated early in the architectural design process.

Key elements include:

- **Bowl and roof configuration:**
 - Inclination affects internal atmosphere and sound propagation
 - Continuity between bowl and roof acts as primary acoustic barrier



- **Degree of enclosure and materials:**
 - Critical for both insulation and amplification
- **Concourse design:**
 - Open/closed layouts influence sound leakage
 - Mitigation via acoustic ceilings and perimeter barriers
 - Acoustic lobbies with doors between concourse and bowl
- **Sound systems (PA):**
 - Loudspeaker type, placement, directivity, and power must be optimized
 - Goal: uniform coverage and minimal external dispersion
- **Crowd noise management:**
 - Controlled entry/exit flows
 - Distance from sensitive receptors
 - Temporary acoustic barriers where necessary
- **Technical systems:**
 - Must be properly silenced and strategically located

Overall, acoustic design requires a **multidisciplinary approach**, combining architecture, materials, spatial planning, and engineering systems.

7. Conclusions and Future Developments

With UEFA Euro 2032 approaching, many Italian stadiums must comply with updated guidelines. This represents a major opportunity to recognize acoustic design as a fundamental component.

The Santiago Bernabéu case clearly shows the risks of underestimating acoustics. Italian legislation imposes strict limits, and exemptions for concerts are often unavoidable. However, beyond administrative constraints, legal principles such as “normal tolerability” make it nearly impossible to justify inadequate mitigation.

Even when exemptions are granted, it is essential to minimize community exposure to disturbing noise levels. This requires integrated design with high acoustic standards from the earliest stages.

Stadiums represent important drivers of the national economy. Future developments should include:

- Legislative improvements (simplifying procedures while protecting public health)
- Technical advancements
- Targeted acoustic measurement campaigns to validate mitigation strategies and improve predictive models

The ultimate goal is to ensure full compatibility between stadium operations and urban quality of life.



8. References

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