

EVOLUTION ASSESSMENT OF MAIN STADIUM STRUCTURES OF
SUMMER OLYMPIC GAMES: FROM 1896 TO 2012.

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ABSTRACT

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Main stadium structures of summer Olympic Games are large scale structures which are specifically-designed to accommodate a very crowded amount of people and international many sports competitions of Olympic Games. There are many written documents on Olympic stadiums, however there is scarcity of knowledge on assessment of their physical performances/capacities and evolution in time based on quantitative data. The study, therefore was shaped to examine the inherent physical performances of those structures and to better understand their appropriateness, specifically potentials and limitations, for international and regional prospective events.

In total, 26 main stadiums of summer Olympic Games were examined in terms of their spectator capacity performance, physical performance of geometrical layout with a focus on viewing comfort conditions for athletes and spectators, and long-term functioning in reference to the technical recommendations and/or guidelines.

The presence of fully-sheltered stands area is essential due to the climatic conditions of host cities. There is a trend of reducing original spectator capacities of Olympic stadiums to the recommended/operable seating capacities during renovations. That

signals the efforts for achieving to be able to host either many international or regional sports competitions. Non-sports activities, soccer and athletics games are the activity types mostly hosted in stadiums as post-Olympic events. Cultural significance of Olympic stadiums is one of the main determinative factor for their survival while correct positioning of stadiums and their geometric layouts and fully-sheltered stands area, if all three provided, make the stadiums preferable/remarkable for many international sports competitions, specifically soccer and athletics games. The adaptability of Olympic stadiums for regional uses/activities, if foreseen during the design stage, is an encouraging situation for their post-use in accordance with regional preferences. The individual evaluation of each stadium has shown their potentials for specific type(s) of post events as well as pointed out some improvements needed for their functioning in time. The efforts on environmentally sensitive design of stadiums is promising for the long-term functioning of stadiums with a care on environment protection. However, there is a necessity of emphasizing “physical performance requirements defined for stadiums” as sustainability criteria in “the sustainability design technical manuals” for properly-performing stadiums during their lifelong functioning.

Keywords: main stadiums of summer Olympic Games, spectator capacity, orientation of playing field, optimum viewing distances, post-Olympic uses.

ÖZ

YAZ OLİMPİYAT OYUNLARI ANA STADYUM YAPILARINDAKİ GELİŞİMİN DEĞERLENDİRİLMESİ

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Yaz Olimpiyat Oyunları'nın ana stadyum yapıları büyük ölçekli yapılar olarak, çok kalabalık seyirci gruplarını ağırlamak ve Olimpiyat Oyunları'nda gerçekleşen birçok spor yarışmasına ev sahipliği yapmak için özel olarak tasarlanmıştır. Olimpiyat stadyumlar üzerine birçok yazılı belge olmasına rağmen, bu yapıların fiziksel performansları / kapasiteleri ve zaman içinde evrimleri üzerine yapılmış nicel değerlendirmeler yok denecek kadar azdır. Bu çalışma ile Olimpiyat yapılarının kendine has fiziksel performanslarının incelenmesi ve onların, uluslararası ve bölgesel müsabakalar için olanak ve sınırlarının belirlenerek müsabakalar için uygunluğunun tartışılması hedeflenmiştir.

Toplamda 26 adet Yaz Olimpiyat Oyunları ana stadyumu; seyirci kapasiteleri, sporcular ve seyirciler için görsel konfor şartlarının uygunluğu üzerinde durularak geometrik tasarımlarının fiziksel performansı ve yapıların uzun vadeli kullanımı teknik öneriler içeren kaynaklar ve/veya kılavuzlarda yer alan bilgiler göz önüne alınarak incelendi.

Stadyumlarda tam korunaklı tribün alanının var olması özellikle oyunlara ev sahibi yapan şehirlerin iklim koşulları nedeniyle gereklidir. Olimpiyat stadyumlarının orijinal

seyirci kapasitelerinin, yenilemeler sırasında azaltılarak tavsiye edilen/işletilebilir seyirci kapasitesine düşürülmesi eğilimi vardır. Bu eğilim, stadyumların ulusal/bölgesel spor etkinliklerine ev sahipliği yapabilme imkânlarının arttırılması çabasının bir göstergesidir.

Olimpik stadyumların kültürel önemi, bulunduğu yerin uygun konumu, geometrik tasarımlarının nitelikli oluşu ve tam korunaklı tribünlerinin olması; ulusal spor müsabakaları ve özellikle futbol ve atletik yarışlar için bu yapıların olimpiyat sonrası kullanılarak yaşamlarını sürdürmesini desteklemektedir. Henüz tasarım aşamasındayken, olimpiyat sonrası kullanımda, stadyumun bölgesel aktiviteler için adapte edilebilmesinin planlanması, bu yapıların yerel olarak kullanımı tercih edilen yapılar arasında olmasını sağlamaktadır. Tez kapsamında, seçilen stadyumların özelliklerinin değerlendirilmesiyle, olimpiyat sonrası kullanımda hangi tür etkinliklere uygun oldukları belirlenmiş ve uzun vadeli kullanım için yapılabilecek düzenlemeler saptanmıştır. Stadyumların çevreye duyarlı tasarlama çabaları, bu binaların çevre dostu bir yaklaşımla uzun vadeli olarak kullanımına olanak sağlaması açısından umut vericidir. Bununla birlikte, sürdürülebilir tasarımı ele alan teknik kılavuzlarda, uzun vadeli kullanım çerçevesinde stadyumların fiziksel performans gereksinimlerinin ele alınması ve vurgulanması gerekmektedir.

Anahtar kelimeler: Yaz Olimpiyat Oyunları ana stadyumları, seyirci kapasitesi, oyun alanının konumlanması, Optimum izleme mesafeleri, Olimpiyat sonrası kullanım

To my parents and my brother Kiarash

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CHAPTER 1

INTRODUCTION

Since their earliest existence in ancient Greek and Roman civilizations, stadiums have been regarded as architectural masterpieces and focal points in their surrounding cities. Those structures are important buildings in society not only as a venue which hosts sport events but also as a place where individuals in the society gather and share a common interest in form of sports and/or entertainment. The modern Olympic Games started from 1896 in Athens-Greece and the small scale of sports games with the participation of athletes in certain amounts in the early 20th century increased to the largest scale sports event, namely Olympic Games, in the world today. Due to the social and economical challenging impacts of Olympic Games, the main stadiums come into prominence especially for the host cities and host countries. The main stadiums are the most significant component of Olympic Games and Olympic Venue where Athletics (track & field) events, final football matches, and opening/closing ceremonies during the Games are held and high spectator capacities are accommodated. Considering their importance, those large scale structures require advanced design in order to depict the cultural, artistic, and sportive values and to represent architectural and technological features of their periods.

Olympic stadiums are planned generally for the purpose of accommodating large number of people as much as possible thus increasing the revenue for the Olympic Games and its organization expenses. On the other hand, those oversized structures may have negative effects for the host city and citizens after Olympic Games. Due to their inherent large capacities those structures may not be feasible to be effectively-used for many sports and non-sports activities in future while still being able to

accommodate international mega events that rarely may occur in future. Therefore, their post-Olympic uses or strategies need to be considered in preliminary design stages in order to sustain their service life. In this regard, the physical performance and capacities and their appropriateness for specific and many sports events/competitions have vital importance with an emphasis on their functioning for international and/or regional uses.

The study, therefore was shaped to assess some basic physical performances/capacities of all main stadiums for summer Olympic Games, mainly in terms of spectator capacity performance, physical performance of geometrical layout with a focus on viewing comfort conditions for athletes and spectators, and long-term functioning performance of stadiums.

Here, the brief explanations on the argument and main objectives of the study were done under relevant subheadings. The procedure of data acquisition and analytical studies as well as contents of main chapters/sections were introduced under the subheadings of “Procedure” and “Disposition”, respectively.

1.1 ARGUMENT

Main stadium structures of Summer Olympic Games are large scale structures which are designed in such a way to accommodate thousands of spectators, a crowded athlete population and many sports competitions during Olympic Games. The Olympic stadiums, therefore, should be designed based on some major performances criteria and involve some technical features well-integrating with their Olympic and post-Olympic uses. It was observed that there are knowledge in written/published documents especially on some architectural and technological features and renovations underwent before and after Olympic Games in the form of introductory/informative texts, and urban-scale impact of stadiums to their host cities. However, there is scarcity of knowledge on assessment of their physical

performances/capacities as well as evolution in time based on quantitative data/parameters.

There are some technical recommendations/manuals based on physical performance criteria to be fulfilled by modern stadium structures. For instances, some basic features of stadiums' plan layout, mainly in terms of seating capacity, sheltered seat capacity, ideal positioning of stands and playing field areas are some of major criteria to define physical capacity/performance of stadiums in relation to both Olympic and post-Olympic uses (FIFA & UEFA, 1995; DIN, 200; BSI, 2003; DFB, 2004; MVStatt, 2005; FIFA, 2007; Nixdorf, 2008; Geraint *et al.*, 2013). However, the studies on performance assessment of Olympic main stadiums whether they fulfil those criteria in accordance with the technical recommendations/specifications, or not, are limited in number. Here, a study was shaped to examine the efficiencies of all main stadiums, 26 structures in total, originally-built or renovated for summer Olympic Games from 1896 to 2012 in regard to “*the capacity requirements for many sports types in the context of their multi-purpose uses*”, “*viewing comfort performance in terms of playing field orientation and stands geometrical layout*”, and “*sheltered stands area*”.

In addition, the current states of those structures were also examined in terms of “minimum/recommended seating capacity”, “sheltered seat capacity”, “proper positioning of stands area” to define the appropriateness/efficiency of their physical performances/capacities for many types of sports activities and competitions. Such an evaluation of their current state is needed to better understand their potentials for post-Olympic uses and/or to present the features that have to be improved for long-term functioning.

In published literature, a few stadium structures, Olympic ones and non-Olympic ones, were observed to be examined in terms of some criteria related with their physical performances. However, this study covers the examinations of all main stadiums of summer Olympic Games, one by one from 1896 to 2012, and allows to better understand the evolution/changes occurred in time.

International Olympic Committee (IOC) included sustainability issues in their technical guidelines till 1999 in order to support the protection of environment and ecological lives in Olympic venue and host cities. Many issues related with sustainability development and environmental protection, in fact, has been started earlier and involved in building guidelines by Brundtland report (WCED, 1987) and Rio Earth Summit Agenda 21 (UNCED, 1992). The documentation of technical features related with some sustainability issues, such as “site preservation”, “water and energy efficiencies” and “long-term use” is carried out for the stadium structures built after 1995 in order to discuss the integration of some sustainability issues in stadiums design.

All discussions and concluded remarks are based on individual evaluation of each stadium. The assessment of each stadium, in fact, is an example/case and expected to be a demonstrative examination for researchers or people who are interested in stadium design in order to practically- and preliminary-assess their designs and to improve their insights for designing well-performing stadium structures. The efforts/some possible solutions which have been involved in design of those mega structures can show the initiatives to function them in a harmony with their immediate environment as much as possible.

1.2 AIMS AND OBJECTIVES

The main Stadium Structures of Modern Summer Olympic Games, in total 26 stadiums from 1896 to 2012, were examined particularly:

- to better understand the evolution of spectator capacities in time,
- to assess their efficiencies in terms of some basic features required for Olympic and post-Olympic uses, such as minimum seating capacity, sheltered seat capacity, ideal positioning of stands and playing field areas, as well as
- to discuss the integration of some sustainability issues in stadiums design by documenting the relevant technical features involved in their design.

By the study, it is intended to achieve the following objectives:

- to assess spectator capacity evolution in time in reference to Olympic capacity requirements declared by technical committees;
- to investigate the potential of stadiums for their post-Olympic uses in reference to the capacity requirements for specific sports games and international many sports competitions in the context of their multi-purpose uses;
- to examine the viewing comfort performance of stadiums for athletes and spectators in terms of playing field orientation, viewing comfort of stands plan layout, and presence of roof sheltering the stands area;
- to clarify whether there is a relationship between spectator capacity of stadiums and their host city population;
- to review the presence of sustainability features in stadiums in terms of water and energy efficiencies, site preservation, and long-term use,
- to point out some guiding remarks on Olympic stadium design for their long-term use.

The results of the study as well as discussions and concluded remarks are expected to be guiding for professions related/interested in Olympic and non-Olympic stadium designs with emphases on spectator capacity, positioning of playing field, stands geometrical layout, and long-term functioning.

1.3 PROCEDURE

The study starts with literature survey which consists of two main parts. First part is about Stadium design principles, and Fundamental regulations and standards for the Olympic Games which clarify important aspects of design for stadiums and highlights the rules to be considered for Main structures of Summer Olympic Games. The second part is a comprehensive description for all twenty six modern Olympic Stadiums from 1896 to 2012 which makes an assessment with focus on architectural and technological features of those stadiums.

Firstly data on date, architect, overall spectator capacity, and Post-Olympic events for each Olympic stadium, were conducted to the study using published literature and official releases. In addition, climate zones of host cities were identified in reference to world climate classification map. Later, demographic data and information gathered by direct contact with official demographic agencies for all twenty-two Olympic host cities. The drawings, sketches, and figures obtained from the literature were processed as scaled schematic drawings to be used for “playing field orientation” and “viewing comfort of stands” analyses.

1.4 DISPOSITION

The study is composed of five chapters. The first chapter is introduction, where the purpose and content of the study is introduced and the procedure is briefly described. In the second chapter, brief history of stadium building, stadium design principles related to their physical performances, and brief information about main stadiums of summer Olympic Games from 1896 to 2012 are involved. The third chapter comprises the material and method of the study. In the fourth chapter, results of the study are submitted and in the fifth chapter are discussed. Finally, conclusions are outlined in the sixth chapter.

CHAPTER 2

LITERATURE REVIEW

In this chapter a survey of literature related with the origination of stadiums and their design principles is presented together with the review of main stadiums of summer Olympic Games from 1896 to 2012.

2.1 THE ORIGATION OF STADIUMS

The concept and design for stadiums, like many other historical engineering masterpieces, was first developed in Ancient Greece and Rome. Stadiums as a huge theatre for the exhibition of physical feats, combine dramatic function and monumental scale which leads to powerful civic architecture. The word “Stadium” comes from the Greek word “stadion”, which is an ancient unit of length ranging between 177 and 192 meters. The stadium and hippodrome, two Greek buildings, and amphitheatre and circus of Romans contributed to the modern day stadiums which have many characteristics in common among themselves and with the modern day stadiums (Geraint *et al.*, 2013). In modern day, Stadium is an covered or uncovered athletic field which is surrounded by seating tiers. The central field is also called arena (Nixdorf, 2008).

2.1.1 Greece

Heracles started the Olympic Games in Olympia, Greece in 776 BC in honour of his father Zeus. The origin of the Olympic Games is based on myths and legends like a majority of ancient history (OCA, 1896). One such legend is that Heracles walked

six hundred steps, one after another, to determine the length of the track for the running event at the Olympics. This length, which amounted to about 192 m, was named a “stadion”. The term 'stadium' was then used from here as the name for the running event and the field for the foot racecourse (OCA, 1896; Geraint *et al.*, 2013).

Greek stadia also known as foot racecourses were laid out in a U-shape, with the straight end forming the starting line. These stadia varied in length for different cases, for instance the one at the Delphi was 183m long, and the one at Olympia was about 192m. Such stadia were built in all cities where games were played. Some were formed naturally benefiting from hillside like the pattern of Greek theatres while others were built on flat ground. The similarity of the hillside stadia built in Olympia, Thebes and Epidauros to ancient Greek theatres is apparent. Those stadia are elongated theatres for exhibition of spectacular heroic feats. From those masterpieces, a direct line of development firstly runs to the multi-tiered Roman Amphitheatres, and ultimately to modern-day sports stadia (Nixdorf, 2008; Geraint *et al.*, 2013).

2.1.2 Rome

Romans like Greeks perceived to integrate purpose-built buildings as part of their lives. The two of those buildings which are many characteristics in common with modern-day stadium are amphitheatres, which were designed especially for gladiator combat, and the circuses which were designed for chariot races (Geraint *et al.*, 2013).

A new building in amphitheatrical form was developed by militaristic Romans in order to accommodate the mortal combat spectacle. The building was an elliptical arena surrounded by high-rising seating tiers on all sides allowing the maximum number of spectators to have clear view of the fearful events staged at the arena (Nixdorf, 2008). The word arena comes from the Latin word for sand, or sandy land which refers to layers of sand spread on activity area to absorb blood (Geraint *et al.*, 2013). The overall form of the building was a complete ellipse which was shaped by

joining two ancient Greek theatres together. The size of Roman amphitheatres necessitated to construct the seating profile instead of benefiting from natural slope (Nixdorf, 2008). The greatest exemplar of this building type is the Flavian Amphitheatre, in Rome, better known as the Colosseum from the eighth century onwards which has seldom been surpassed to this day as a rational fusion of engineering, theatre and art. Construction of the Colosseum started in AD 70 and completed 12 years later (OCO A, 1896; Geraint *et al.*, 2013).

2.1.3 Medieval and after

Society has emphasized different activities through the history. The ancient Greeks and Romans set theatre, sports, and combat at the centre of their lives but this was slowly faded out in middle Ages when religion began to expand and the public activities outside of Church were neglected (OCO A, 1896, Nixdorf, 2008; Geraint *et al.*, 2013). Therefore, architectural efforts for building of churches came into prominence and places of recreation and entertainment remained in the background. For the next 15 centuries no major new sports stadia or amphitheatres were built (OCO A, 1896). However, nations eventually found ways to balance different aspects of life and sports made a comeback during the Renaissance. Since then, stadium construction and rehabilitation has been ongoing across the world (OCO A, 1896; Nixdorf, 2008).

2.1.4 19th century

After the industrial revolution in 19th century, sports and stadium started to be grown after 15 centuries. In this respect, sport games became properly defined and different clubs and federations were developed. Great Britain was the first place to welcome organized sport, especially with great enthusiasm for soccer and rugby. Along with the growing fan population, the industrial revolution led to advancements in structural technologies so that appropriate stadiums could be built for specific sports (Nixdorf, 2008).

2.1.5 Rebirth of Olympic Games

The stadium as a building type saw a revival after the industrial revolution. There was a growing demand for mass spectator events from the public; there were entrepreneurs who wished to cater for this demand; and there were new structural technologies to facilitate the construction of stadia or sports halls. A particularly important motivation came from the revival of the Olympic Games at the end of 19th century (OCOIA, 1896; Nixdorf, 2008).

The modern Olympic Games began in 1896 in Athens, Greece, through the efforts of the Frenchman Baron Pierre de Coubertin. He made the Olympic dream his life's work to revive the Olympic Games which had first begun in ancient Greece several centuries before the common era (Mallon & Ture, 1997; Mallon, 1998). At the instigation of Baron Pierre de Coubertin, a congress met in 1894, which led to the organization of first modern Olympic Games at Athens in 1896. For this purpose, the ancient stadium of 329 BC, which had been excavated and studied by a German architect and archaeologist called Ernst Ziller, was rebuilt to accommodate about 50,000 spectators (OCOIA, 1896; Geraint *et al.*, 2013). From 1896 Olympic Games were held every 4 years except the years interrupted by World Wars. The modern Olympic Games are now more than a century old; the world celebrated the centennial games in Atlanta in the summer of 1996 (Mallon & Ture, 1997).

2.2 STADIUM DESIGN PRINCIPLES

Main Olympic stadium structures are designed to function properly and effectively for sport activities, particularly for summer Olympic Games. Those structures can also be used for multi-purpose activities during their service life. Therefore, those structures are expected to fulfill some specific requirements of their use. Those requirements have been defined in some standards, technical manuals or recommendations and guidelines, all of which have been prepared by the experts of relevant Committees. The list of those manuals/guidelines is given in Table 2.1.

Table 2.1 List of technical guidelines/recommendations on stadiums design.

Guidelines / Recommendations	Title	Date	Reference
FIFA & UEFA	Technical recommendations and requirements for the construction or modernisation of football stadia	1995	FIFA & UEFA, 1995
U.S Green Building Council	Sustainable Building Technical Manual: Green Building Design, Construction and Operation	1996	USGBC, 1996
International Olympic Committee	Olympic Movement's Agenda 21	1999	IOC , 1999
DIN 18035-1: 2003	Sportplätze-Teil 1: Freianagen für Spiele und Leichtathletik (Sports Facilities-Part 1: Free equipment for games and athletics)	2003	DIN, 2003
British standards Institutions BS EN 13200-1:2003	Spectator facilities. Layout criteria for spectator viewing area-specification	2003	BSI, 2003
German Football Association	Richtlinien Zur Verbesserung der Sicherheit bei Bundesligaspielen (english: Guidelines for improve safety in Bundesliga)	2004	DFB, 2004
MVStatt:2005	Muster-Versammlungsstättenverordnung, begründung und Erläuterung (english: Pattern venue regulations, justification and explanation)	2005	MVStatt, 2005
International Olympic Committee	Technical Manual on Venues – Design Standards for Competition Venues	2005	IOC, 2005
FIFA	Football Stadiums; Technical Recommendation and Requirements 4 th edition.	2007	FIFA, 2007
Department for culture, media and sport	Guide to Safety at Sport Grounds, 5 th edition	2008	Department for culture, media and sport, 2008
Stefan Nixdorf	Stadium Atlas: Technical recommendations for grandstands in modern stadia	2008	Nixdorf, 2008
Adrian Pitts and Hanwen Liao	Sustainable Olympic Design and Urban Development	2009	Pitts & Hanwen, 2009
Gerraint John, Rod Sheard, and Ben Vickery	Stadia; the Populous Design and Development Guide, 5 th edition	2013	Geraint <i>et al.</i> , 2013
International Association of Athletics Federations	Technical Regulations For IAAF World Championships	2014	IAAF, 2014

The regulations or recommendations related with the Olympic stadium design and their physical performances are summarized with a focus on some selected items, such as “spectator capacity”, “orientation of playing field in stadiums”, “viewing comfort of stands area”, “basic layout options for stands”, “safety zones”, “basic options recommended for stadiums roof”, “standard dimensioning of playing fields for many sports” and “sustainability issues for Olympic stadiums”. The relevant explanations were done in detail under respective subheadings.

2.2.1 Regulations on spectator capacity

The spectator capacity of a stadium depends on its function and purpose of design which affects the stadium size, amenities and overall design (Nixdorf, 2008). International Games require higher capacities compare to national and regional Games. There should be a right balance between required spectator capacity and desired spectator capacity.

The regulations on minimum overall spectator capacity, including both seating and standing capacities, required for ‘main stadiums of Olympic Games’ as well as required for ‘stadiums in relation to specific sports games’ are summarized below:

- The minimum overall spectator capacity, composed of seating and standing capacities, required for main stadiums of Olympic Games is declared as 60,000 persons (IOC, 2005).
- Since end games (final matches) of Olympic soccer games are performed in main stadiums, a minimum of 50,000 overall spectator capacity is required by Technical Manual on Venues – Design Standards for Competition Venues (IOC, 2005).
- In addition, International Association of Athletics Federations has determined the minimum overall spectator capacity as 30,000 persons for international athletics championships (IAAF, 2014).
- According to German Football Association (DFB) Safety Guidelines, the permitted ratio of standing capacity to seating capacity is 20% in maximum (DFB, 2004).

- On the other hand, DFB and German Football League (DFL) define overall spectator capacity of 10,000 persons as minimum licensing standard criterion of a stadium for the games of regional divisions (Nixdorf, 2008).

On the other hand, FIFA and UEFA Technical Regulations stipulate that all spectators should have a seat for qualifying matches, the Confederations Cup, World Cups and Olympic Games (UEFA, 2004, FIFA, 2007; Nixdorf, 2008).

The minimum seat capacities determined by FIFA Technical Recommendation and requirements are given below in relation to the nature of FIFA Cup Competitions (FIFA, 2007; Nixdorf, 2008):

- 30,000 seats for international tournaments
- 60,000 seats for group games, last sixteen and quarter finals
- 60,000 seats for opening matches, semi-finals and finals
- 50,000 seats for Confederations Cup

The minimum seat capacities defined by UEFA Venue Regulations are given below in relation to the nature of UEFA Cup and Championships (UEFA, 2004; Nixdorf, 2008):

- 30,000 seats for group games, last sixteen and quarter finals
- 40,000 seats for quarter and semi-finals
- 50,000 seats for opening matches/finals

2.2.2 Recommended axes for the orientation of playing field in stadiums

The favourable orientations for the stadiums related to sun exposure are defined or recommended in regulations/standards (DIN, 2003; Nixdorf, 2007; FIFA Football Stadiums, 2007; UEFA, 2011; Geraint *et al.*, 2013) in terms of slopes in certain ranges which show the deviation for axis of operation in stadiums; in other words, slopes positioned between the axis of play zone and N/S axis. The orientation of stadium's site layout can be arranged according to those favourite slopes in order to save athletes

being blinded by the sun. The favourable/appropriate orientations which are recommended/accepted for the positioning of playing fields in stadiums are summarized in Table 2.2 in relation to the climate zone. The recommended playing field orientation range for Rugby, Football, and track and field games as well as best common axis for Playing Field orientation for many sports is shown in Figure 2.1.

Table 2.2 Orientation of playing field recommended by guidelines and technical recommendations.

Guidelines / Recommendations	Appropriate axes recommended for the orientation of playing field	Sports type	Recommended Zone	Reference
DIN 18035-1:2003	North-South $\overrightarrow{NS}$	All sports	Northern/ Southern hemisphere	DIN, 2003
FIFA Football Stadiums Technical Recommendations and Requirements	North-South $\overrightarrow{NS}$	Football	Northern/ Southern Hemisphere	FIFA, 2007
Stadium Atlas – Technical Recommendations for Grandstands in Modern Stadia	15° deviation from North to West (*) 15°N-to-W	Many sports	Northern Europe	Nixdorf, 2008
	Range between 20° deviation from North to East and 45° deviation from North to West <(20°N/E–45°N/W) = 60°	Athletics (Track and Field)		
	Range between 20° deviation from North to East and 75° deviation from North to west <(20°N/E–75°N/W) = 95°	Football and Rugby		

Table 2.2 (Continued).

UEFA Guide to Quality Stadiums	North-South ($\overrightarrow{NS}$)	Football	Northern Hemisphere	UEFA, 2011
Stadia The Populous Design and Development Guide	15° deviation from North to West (*) 15°N-to-W	Many sports	Northern Europe	Geraint <i>et al.</i> , 2013
	Range between 20° deviation from North to East and 45° deviation from North to West <(20°N/E–45°N/W) = 65°	Athletics (Track and Field)	Northern Europe	
	Range between 20° deviation from North to East and 75° deviation from North to west <(20°N/E–75°N/W) = 95°	Football and Rugby	Europe	
(*) Recommended as “best axis” for the orientation of stadiums ‘playing fields				

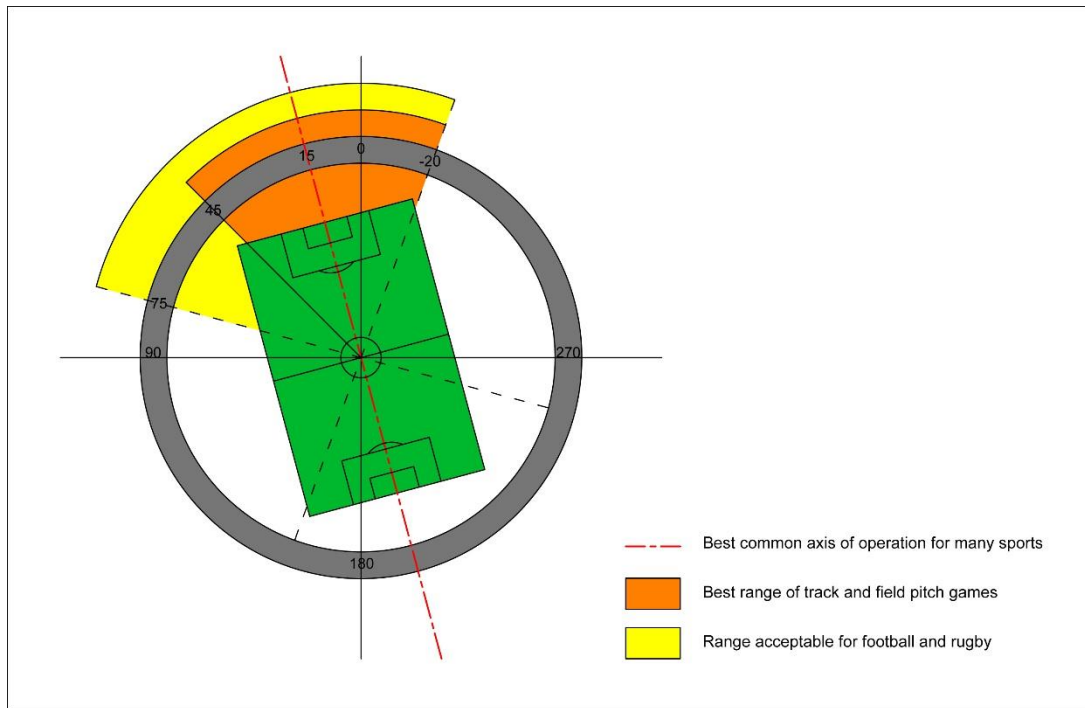


Figure 2.1 Recommended playing field orientation in northern Europe for principle sports types (Geraint *et al.*, 2013, p.30, Redrawn by Author).

According to the recommendations given for the best positioning of a stadium's playing field related to the sun exposure can be summarized as below:

- For many sports, best axis of operation is defined as 15° deviation from North to West
- For all types of sports played in stadiums, favourable direction is mentioned as N/S axis ($\overrightarrow{NS}$).
- For football games, N/S axis is also mentioned as acceptable direction.
- For athletics, in other words track and field pitch games, the best for the orientation of playing fields is defined between 20° deviation from North to East and 45° deviation from North to West.
- For football and rugby games, the acceptable range is defined between 20° deviation from North to East and 75° deviation from North to West.

2.2.3 Recommended and acceptable viewing distance

Once the use of the stadium is specified, a decision should be made about the organization of stands around the playing field in order that the spectators have a clear view of the event. Viewing comfort of spectators depends on their distances from the playing field, therefore viewing distances should be well-arranged to provide optical comfort. Here, viewing distance is an important parameter for examining the efficiency of the spectators' stands. In respect to clear view of the playing field from all seats, "optimum viewing distance" and "maximum viewing distance" are defined or recommended in regulations/standards (BSI, 2003, FIFA, 2007, Nixdorf, 2008, and Geraint *et al.*, 2013) for different sports to provide optical comfort for spectators. Those distances are set out from the extreme viewing positions to the diagonally opposed corners of the playing field by drawing a circle with a compass from each extreme point at the field which also corresponds with "optimum viewing circle (OVC)" and "maximum viewing circle (MVC)" at the playing field centre (Figure 2.2). The obtained circles define the spectator area with optimum and maximum distances. The layout of the stands areas can be arranged according to those defined optimum and maximum viewing circles thus enhancing the efficiency of the spectators' stands. The recommended "optimum viewing distance" and "maximum viewing distance" for Soccer, Rugby, and athletics are summarized in Table 2.3.

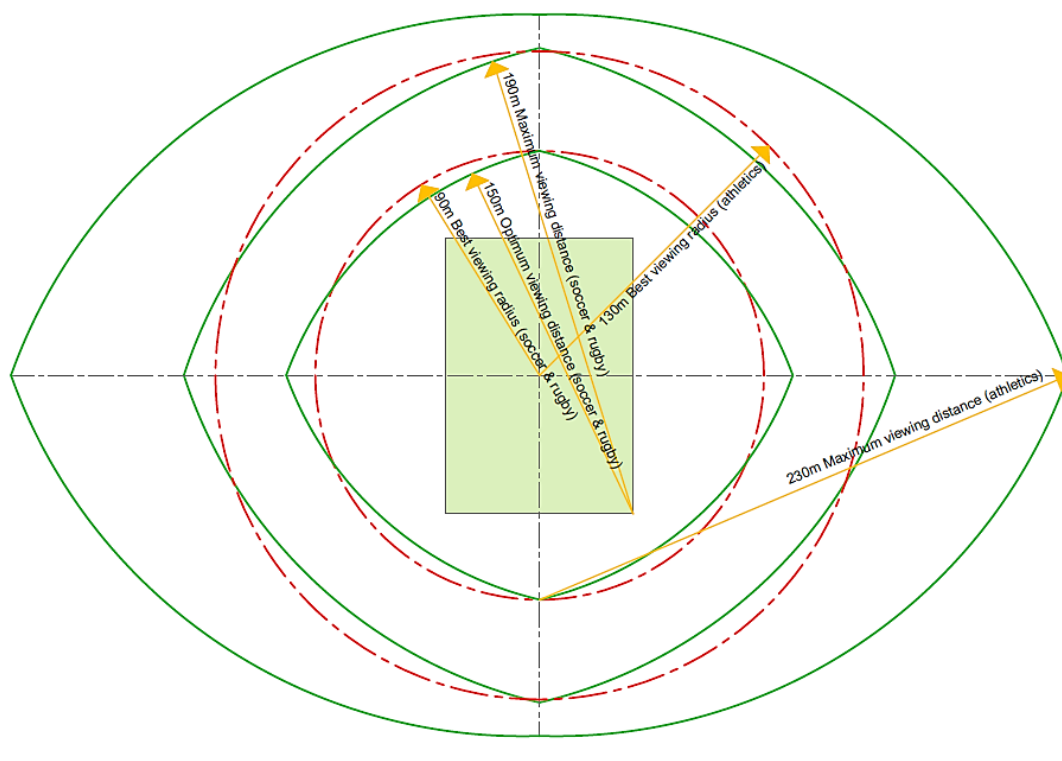


Figure 2.2 Definition of “optimum viewing distance”, “maximum viewing distance”, “optimum viewing circle”, and “maximum viewing circle” for positioning spectators’ stands area for soccer, rugby and athletics (drawn and adapted by author from sources BSI, 2003; Nixdorf, 2008; Geraint *et al.*, 2013).

Table 2.3 Recommended optimum and maximum viewing distances and optimum viewing circles for Soccer, Rugby, and Athletics.

Event Type	Optimum viewing distance	Maximum viewing distance	Optimum viewing circle (OVC)	Reference
Soccer, Rugby	150 m	190 m	90 m	BSI, 2003; FIFA, 2007; Nixdorf, 2008; and Geraint <i>et al.</i> , 2013
Athletics	190 m	230 m	130 m	BSI, 2003; Nixdorf, 2008; and Geraint <i>et al.</i> , 2013

2.2.4 Regulations on stand design

The stand also known as Auditorium, is slopping structure with standing or seating areas for spectators to watch the event (Nixdorf, 2008). The stand structure is divided into tiers depending on concept and its capacity. Nixdorf (2008) defines nine types of basic grandstands layout which are used in design of stadiums. Those layouts are geometric transformation of extreme forms of rectangles or circles (Figure 2.3) (Nixdorf, 2008).

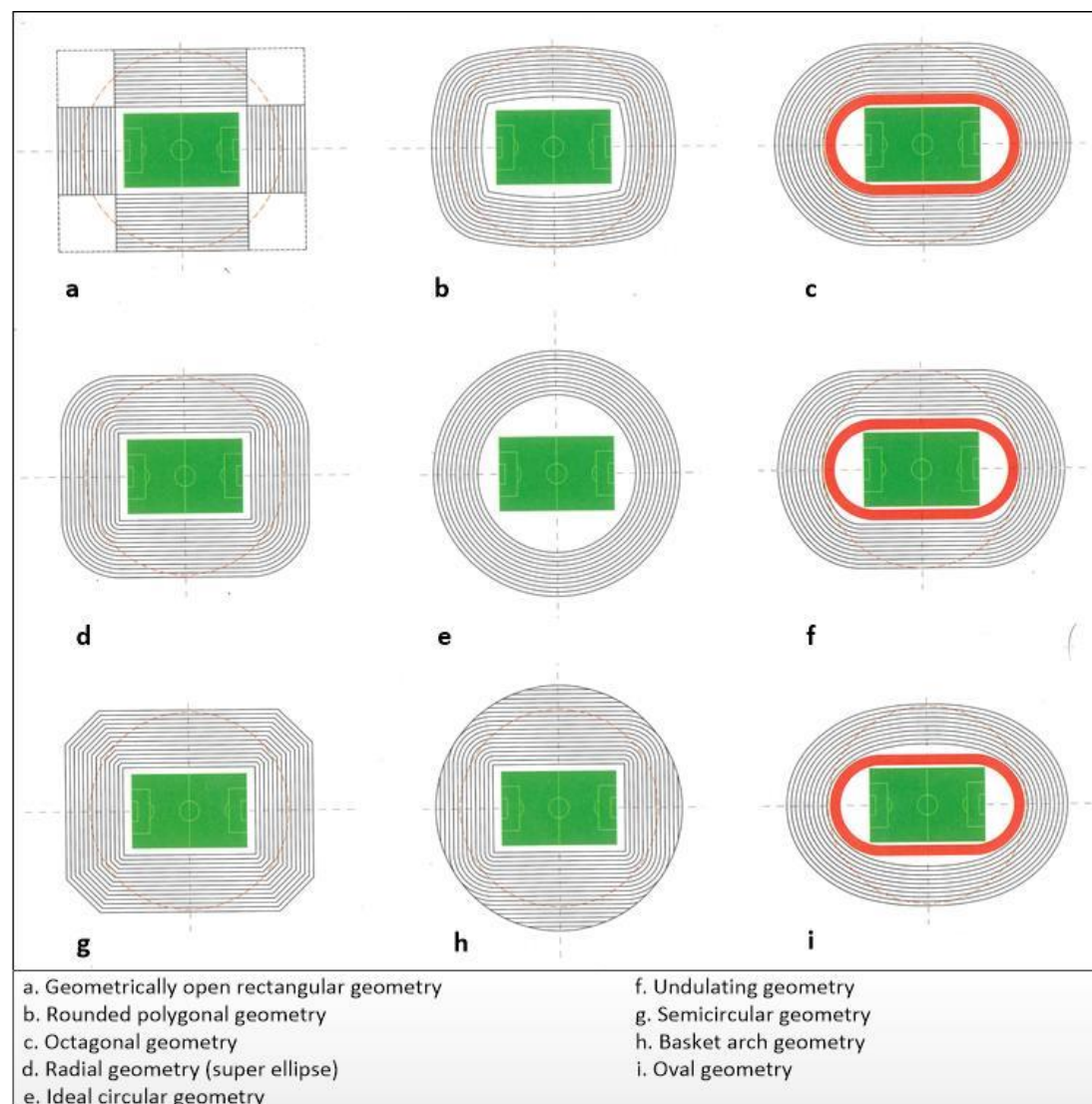


Figure 2.3 Basic types of stands layouts for stadiums (Nixdorf, 2008, p.143).

As it is mentioned in IOC Technical Manuals on Competition Venues, in the design of stand areas consideration should be given to a safe and functional movement to and from the seating areas. Seating areas should be divided into sections to allow for safe and functional entry and exit for constituents (IOC, 2005). For this purpose, stands areas are divided into seating area, stairs, gangways, and ramps (Nixdorf, 2008).

According to FIFA regulations, seats are required to be fireproof and capable of withstanding the rigours of the prevailing climate without undue deterioration or loss of colour (FIFA, 2007). Regulations have been established for seat dimensions in order to provide comfort for spectators. The regulation on places of assembly defines the 40 cm for minimum depth of the seat and 40 cm for tread thus results in 80 cm for total seating/standing width (MVStattV, 2005). Similarly, FIFA regulated 40 cm for minimum depth of the seat and 40 cm for tread (Figure 2.4) (FIFA, 2007). In addition, FIFA regulated the minimum width as 45cm and recommended a minimum width as 47 cm for each seat (Figure 2.4). On the other hand, Nixdorf (2008) recommends the following grids for seating places:

- Regular seat: 50 x 80 cm
- Executive seat: 60 x 90 cm
- Wheelchair: 90 x 150 cm
- Media / press: 50 x 150 cm
- Commentators: 160 x 180 cm

The minimum width and depth for seats determined by IOC Technical Manual on Venues – Design Standards for Competition Venues are given below:

- Minimum seat width: 46 centimetres
- Minimum depth : 80 centimetres (total depth for seat and tread)
- Minimum depth for temporary seating systems (recommended): 75 centimetres (total depth for seat and tread).

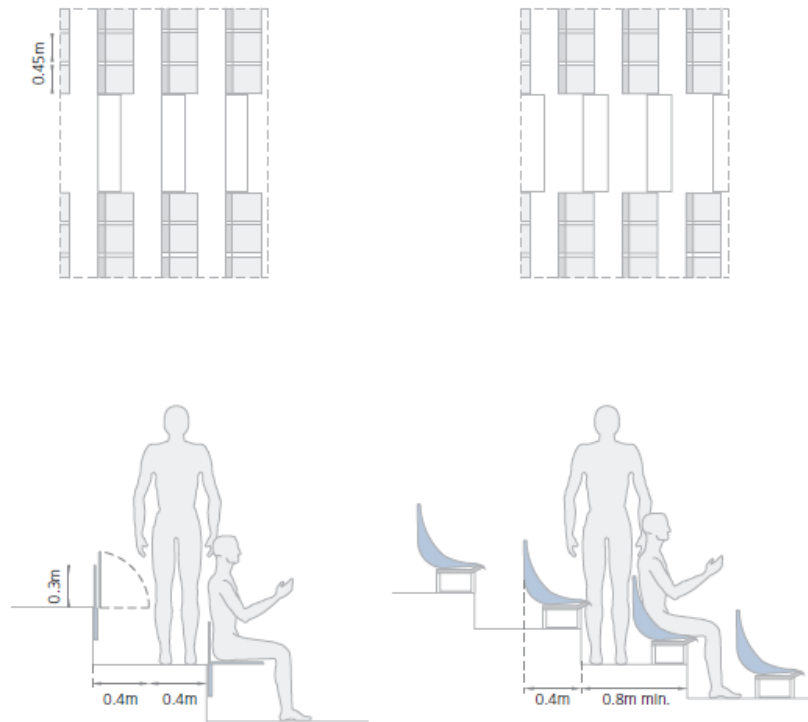


Figure 2.4 Diagram illustrating the required width and depth for seats by FIFA (FIFA, 2007, p. 106).

As defined in Regulations on the Construction and Operation of Places of assembly, the maximum block size for seating places is 30 rows x 40 persons and. In addition, in the case of uncovered areas, there should be maximum of 20 seats in each side of gangway (MVStattV, 2005).

As it is stated in EN/DIN 13200-1 in item 8.0 on walking length /distance there should be exit system inside buildings at a maximum of 30 m and in the open at a maximum of 60 m (BIS, 2003). Similarly, Regulation on the construction and operation of places of assembly, regulates that the distance of each spectator seat to the next exit leading out of the place may not exit 30 m. In addition distance to the next exit should not exceed the 60 m (MVStattV, 2005).

Moreover, Regulations on the construction and operation of places of assembly, defines width of flight routes as 1.2 m for every 600 person in the open and sport stadia (MVStattV, 2005) (Figure 2.5). The flight route is measure as follow:

- Minimum Width: 1.20 m
- Maximum Width: 240 m (straight flight width for two people using the hand rail)

According to DIN 18065 rules and principle dimension, a landing is required after a maximum of 18 steps (DIN, 2000).

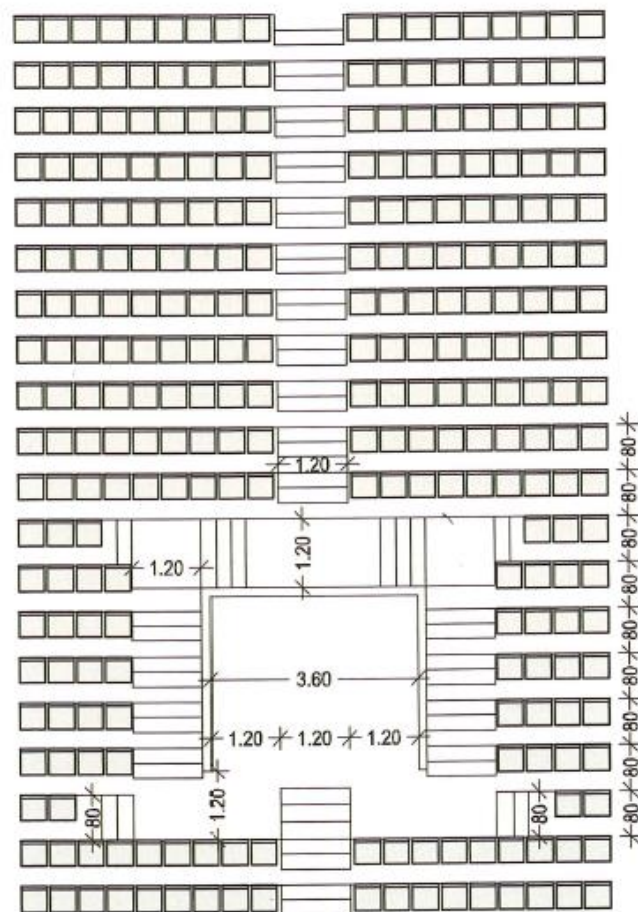


Figure 2.5 Diagram illustrating minimum requirement of 1.20 meters for every 600 seats in stand design of flight routes (Nixdorf, 2008, p. 114).

Consideration on viewing distances is the first step in determining the shape of the stadium but in order to transform this into a three-dimensional plan the viewing angles need to be determined (Geraint *et al.*, 2013). Sight lines and viewing perspectives are critical for spectators to be considered in stands design. Spectators must be able to see over the person in front of them, but at the same time not block the view of the person behind them. Many mathematical calculations are used to design adequate seating accordingly for the sightline (Nixdorf, 2008; Geraint *et al.*, 2013).

Engineers use what is referred to as the C-value in determining sightline quality and requirements within seating areas of a stadium. The C-Value is a variable that defines the quality of the spectator's line of vision over the head of the person in front of them, commonly known as 'the sightline' (UEFA, 2011) (Figure 2.6). Simply put, a higher C-value means a clearer sightline for that spectator, and resulting in a better view of the playing field. In a well-designed stadium high C-values will be incorporated for spectators through the entire stadium (Nixdorf, 2008). Graubner (1968) defines the sightline as an imaginary line from eye of the spectator to the reference point on the field. 'Sightline elevation' or 'C' value is defined as the vertical distance between the sightlines of two consecutively seated spectators (Nixdorf, 2007; Geraint *et al.*, 2013). The C value in fact defines the angle of rake which affect the viewing angles of spectators (Figure 2.7). To calculate the C-value, the following formula is used:

$$C = \frac{D(N+R)}{D+T} - R \quad (\text{Eq 2.1})$$

Where

C = the C-value

D = the horizontal distance from the eye to the point of focus (usually near the touchline)

R = the vertical height from the eye to the point of focus (usually near the touchline)

N = the riser height of each individual seating row

T = the tread depth (i.e. the depth of the individual seating row)

According to the regulations established by FIFA, UEFA, IAAF and EN/DIN 13200-1, the minimum 'C' value is determined as follow (Nixdorf, 2005):

- Optimum / Recommended C value: 12 cm
- Acceptable / admissible C value: 9 cm
- In exceptional cases: 6 cm

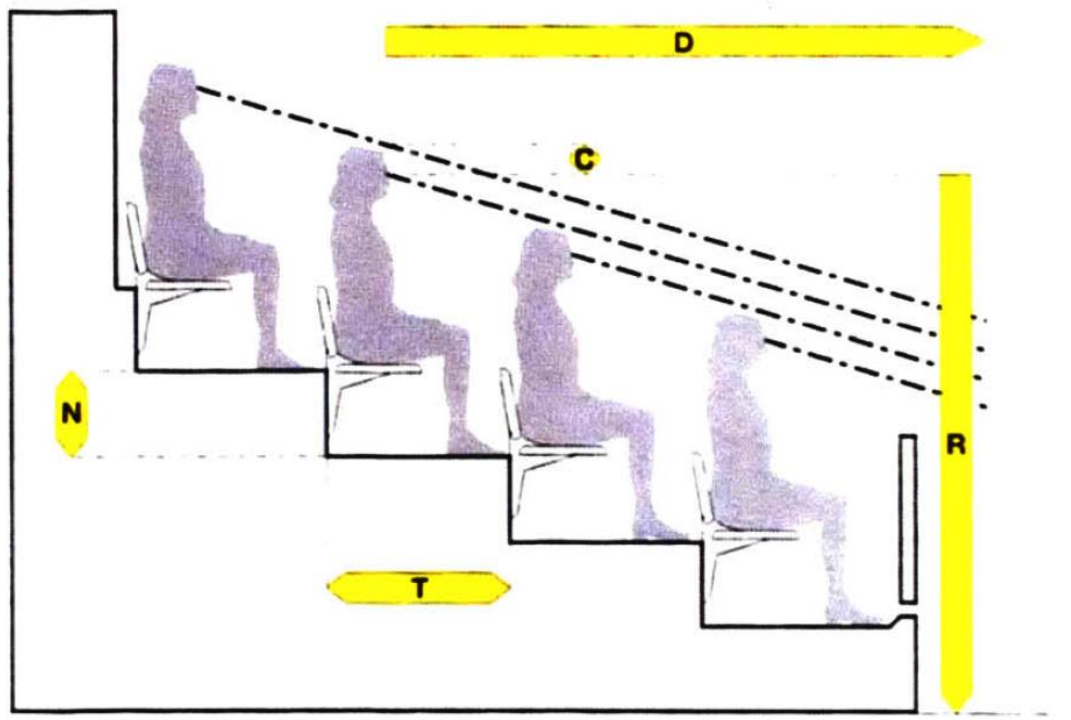


Figure 2.6 Diagram illustrating the variables to be considered for sightline calculations (Geraint *et al.*, 2007, p.133).

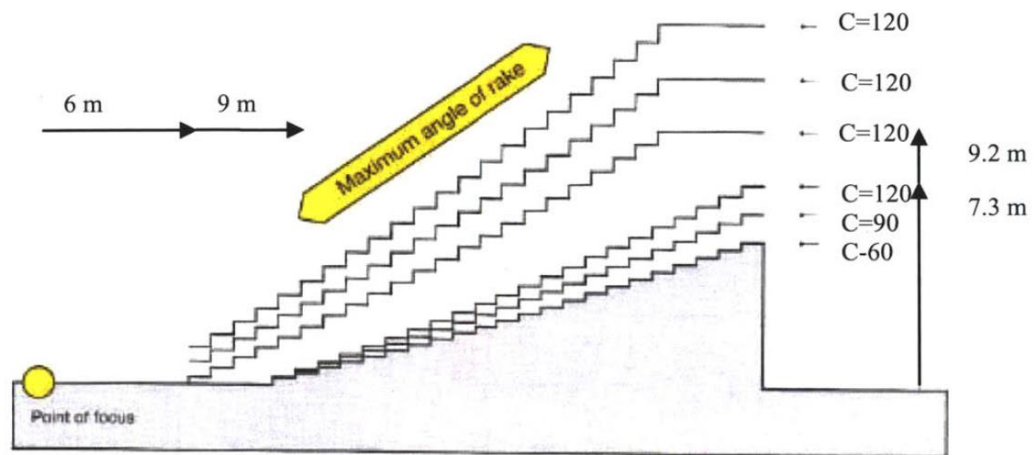


Figure 2.7 Diagram illustrating varying C-value for sightline (Geraint *et al.*, 2007, p.134).

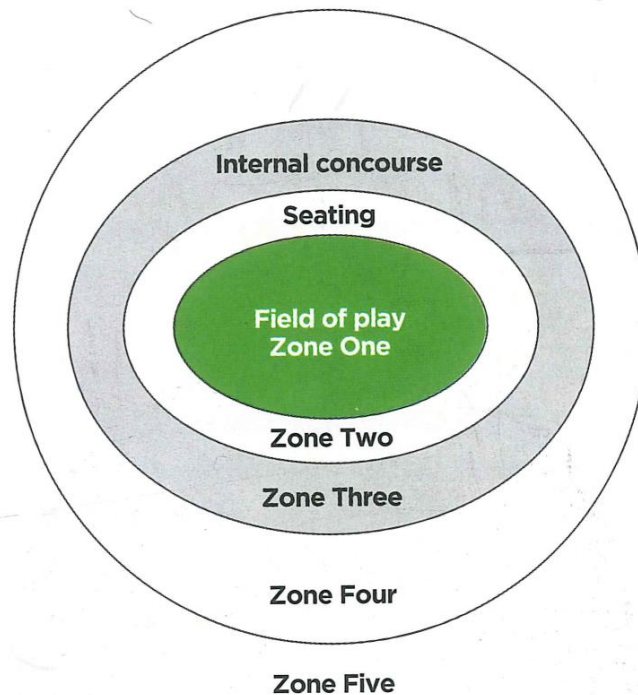
2.2.5 Planning Safety Zones for Stadium

During the preliminary design stage of stadium, it is important to plan the position of stadium on the site and understand the relationships between its main areas. In this respect, five safety zones dividing the stadium in five main parts are recommended in the form of a plan layout (Geraint *et al.*, 2013; Nixdorf, 2008). Here, the term zone refers to ring shaped layout of security belts and defined in Figure 2.8 as a schematic drawing (Geraint *et al.*, 2013).

The regulations emphasize mainly seven issues to form the basis for a safe stadium considering those five safety zones:

- Identification of five zones (Figure 2.8) to allow spectators including disabled spectators, particularly those in wheelchairs, to escape from their seats in emergency situations towards safety zones: Here, the principal is to escape in an emergency to intermediate safety zones, and then to places of permanent safety outside.

- Providing a belt of space in the case of zone 4 and 5 to allow easy access for spectators from their cars in zone 5 to the appropriate gate in zone 4 to reach zone 3 thus find their seats in zone 2; here Zone 4 and 5 should provide easy circumnavigation of stadium for the spectators from one gate to another considering that mistakes will be made by those spectators in finding the appropriate gate.
- Providing a vehicle-free and permanent safety zone which is called Zone 5 where direct an easy access should be provided and its effective area should be enough for accommodating most of stadium population. Including the surrounding roads the recommended density for the Zone 5 is 4 to 6 people per square meter.
- Providing perimeter zone as a security line called Zone 4 across which no one can pass without a valid ticket as well as serving as a temporary safety zone between Zone 3 and Zone 5 to which spectators can escape from the stadium and then go forward the permanent safety zone 5.
- Providing a zone consisting of internal concourses and social areas called zone 3 with a good level of fire safety to allow large number of spectators pass through it without risk and reach the final places of safety (zone 4 and 5).
- Providing relatively safe zone called Zone 2 containing viewing terraces which is separated from performance area by barriers; here design of barriers must consider both crowd control and easy movement to allow spectators scape from fire or other emergency and reach to the Zone 1.
- Providing the centre zone called Zone 1 to serve as both performance area and temporary safety place by properly designing the scape routs and barriers to allow spectators reach to the playing field area during an emergency.



- Zone 1:** *The applying field* of the activity area where sport events occur.
- Zone 2:** *The spectator stand/seating area* where spectators watch the events taking place on playing field.
- Zone 3:** *The stadium's service area* composed of internal concourses, restaurants, bars and other social areas.
- Zone 4:** *The exterior circulation area* surrounding the stadium structure and separating it from outer perimeter fence.
- Zone 5:** *The open space outside* the perimeter fence.

Figure 2.8 Diagram showing five safety zones providing a simple framework for stadium design (Geraint *et al.*, 2013, p. 31).

2.2.6 Basic options recommended for Stadiums roofs

As an architectural and structural element, roof is an important part of the stadium which protects spectators against rain, snow, hail, and sunshine and it can also bring a name for stadium as an intriguing part of the whole stadium structure. The decision on the roof type is made considering climate and spectators' demands for comfort. Modern stadia are incorporated with roofing systems in order to provide comfort for

spectators and fulfil the requirements and regulations established by different sport federations (Nixdorf, 2007). For instance, according to the FIFA World Cup 2006™ it is required to cover all VIP and media seats and it is also recommended to cover all spectator seats. In addition to this, according to UEFA Technical Recommendation 2008, all seats had to be covered for EURO 2008 (Nixdorf, 2007; UEFA, 2008). Similar to UEFA regulations, according to Technical Regulations for IAAF World Athletics Series 2014, championships all seats had be covered for international athletics (IAAF, 2014).

According to Geraint *et al.*, (2013), nine principle structural forms are defined for stadiums roof structures:

- Goal Post structures
- Cantilever structures
- Concrete shell structures
- Compression/Tension Ring
- Tension Structures
- Membrane structures
- Air-supported roof
- Space Frames
- Opening/retractable Roofs

Post and Beam structure is the simplest structural type as a roof to cover stands comprising series of beams and trusses supported by row of columns parallel to the playing field. The structure is economically sound but it has a disadvantage of obstructing the spectators' sightlines by a row of columns (Pitts & Hanwen, 2009; Geraint *et al.*, 2013). The roofs over the East and West stands of White City Stadium can be mentioned as an example for this structural type (Figure 2.9).



Figure 2.9 Post and Beam roof structures cover the East and West stands of White City Stadium, London, England (Olympic Games, 1908).

Goal Post structures are the improved version of Post and Beam structures with columns only on two ends of the roof. Therefore there is no viewing obstruction for spectators and entire length of the roof is spanned by a single girder. Goal Post structures can be executed over the rectangular stands with little or no corner seating part such as Ibrox Stadium (Pitts & Hanwen, 2009; Geraint *et al.*, 2013) (Figure 2.10). A variant of this structural type is replacing the girder with arched truss, such as Galpharm stadium (Figure 2.10) (Geraint *et al.*, 2013).



Figure 2.10 Examples of Goal Post structures. A: Goal post roof structure of Ibrox Stadium, Glasgow, Scotland. B: Goal post roof structure of Galpharm stadium, Huddersfield, United Kingdom. (Rangers, 2015; johnsmithsstadium, 2015).

Cantilever Structures are one of the most commonly used structural type which is fixed at one end and hang freely over the stands. The major advantage of this roof type is the unobstructed view it guarantees spectators (Pitts & Hanwen, 2009). Such a structure can be erected on any length of stand while it spans depth of 45m or even more (Geraint *et al.*, 2013). There are several types of Cantilever systems which can be erected over different type of stand layouts. Allianz Arena in Munich is an example of Simple Cantilever System (Figure 2.11). The roof over the Berlin Olympic stadium is cantilever structure with support/holding (Figure 2.11). In addition, the roof over the Frankenstadion in Nuremberg is another type of cantilever structures which is called cantilever structure with tie-back or restraining cables (Nixdorf, 2009).



Figure 2.11 Examples of Cantilever roof structures. A: Cantilever roof structure of Allianz Arena, Munich, Germany. B: Cantilever roof structure of Berlin Olympic Stadium, Berlin, Germany (Allianz Arena, 2015; Olympiastadion, 2015).

Concrete shell structures are thin surface structures which curve in one or two directions. The strength and stability of those structures is due to their geometric shape rather than the firmness of material (Geraint *et al.*, 2013). The roof over the grandstand of Zarzuela racecourse is an example of this type of roof structure (Figure 2.12)



Figure 2.12 Concrete shell structure over the grandstand of Zarzuela Racecourse, Madrid, Spain (Michavila, n.d).

Compression tension ring structure is doughnut-shaped structure consisting of an inner tension ring and outer compression ring and radial elements between them (Pitts & Hanwen, 2009). Such a roof system is a suitable option both technically and aesthetically to be erected on existing bowl stadium (Geraint *et al.*, 2013). The roof over the Rome Olympic stadium is an example of compression tension ring structure (Figure 2.13).



Figure 2.13 Compression Tension ring structure over Rome Olympic stadium, Rome, Italy (Zennit, 2015).

Catenary cable structure is another system for roof structures which consists of a compression arch (or arches) supporting cables hanging in catenary shape. The Twin gymnasia designed by Kenzo Tange for the 1964 Olympic Games is an example of this type with concrete slabs hung from steel cable which create one of the dramatic architectural forms of 20th century (Figure 2.14)(Geraint *et al.*, 2013).



Figure 2.14 Catenary Cable Structures built for Twin gymnasias designed by Kenzo Tange for the 1964 Olympic Games, Tokyo, Japan (Whiting, 2014).

Cable net structures consist of two parts; a three-dimensional net of steel cables and the fabric covering normally of plastics such as acrylic, PVC or polycarbonate (Geraint *et al.*, 2013). The 1972 Munich Olympic stadium designed by Frei Otto is an excellent example of cable net structures (Figure 2.15).



Figure 2.15 Cable net roof over Munich Olympic Stadium 1972, Munich, Germany (Mojtahedi, 2008).

Membrane structures are another type of roof systems for stadiums in which roof covering of membrane provides both the structure and enclosure. PVC-coated polyester fabric and Teflon-coated glass fibre (PTFE) are suitable fabrics for membrane structures (Geraint *et al.*, 2013). The latter is expensive option but has a much longer lifespan. The PVC coating tends to get sticky with time and requires frequent cleaning while Teflon provides a somewhat self-cleaning surface. Some countries have banned the use of PTFE-coated glass fibre because it produces toxic fumes if a fire occurs; for this reason expert designers and fire engineering is required for such roof systems (Pitts & Hanwen, 2009; Geraint *et al.*, 2013). The Mound Stand at Lord's Cricket Ground in London is an example of membrane structure (Figure 2.16).



Figure 2.16 The membrane roof structure over the Mound Stand at Lord's Cricket Ground, London, England (Hogg, 2006).

Air supported roof structures form an enclosure from plastic membrane with the help of internal pressure created by electric fans. This type of roof structure can only be applied for indoor stadiums which are commonly PVC polyester. In the case of

covering larger areas those roofs are sometimes reinforced by cables (Geraint *et al.*, 2013). Although air supported roof structures are relatively low in capital costs, large amount of energy is needed to continuously run the fans to keep the roof up. Therefore, such a roof structure is not considered as being environmentally friendly (Pitts & Hanwen, 2009; Geraint *et al.*, 2013). The RCA Dome, formerly the Hoosier dome, in Indianapolis which was built in 1972 is an example of air supported roof structure (Figure 2.17).

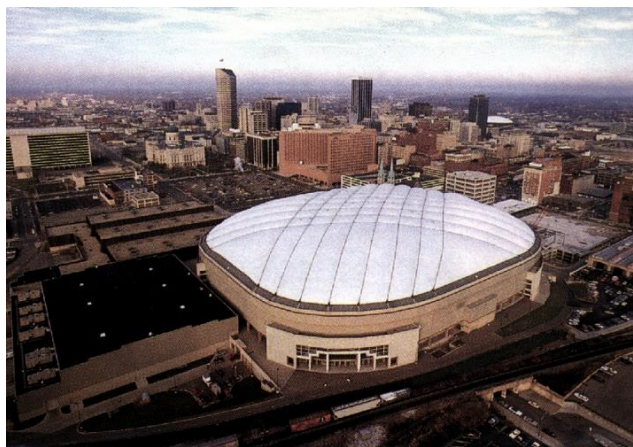


Figure 2.17 Air supported roof structure over the RCA Dome (Ludwig, 1988).

Space frames are three dimensional grid of structural members which are stable in three dimensions. Large spans can be covered by those structural types with only perimeter supports. Space frames are efficient only if spanning in two directions (Geraint *et al.*, 2013). Therefore, such a roof system is not appropriate to cover stadium stands unless the sections of roof between structural supports can be in a form of space frame (Mungan & John, 2011; Geraint *et al.*, 2013). The San Siro stadium in Milan is an example for space frame roof structure which is an aluminium deck supported from steel lattice beams (Figure 2.18) (Geraint *et al.*, 2013).



Figure 2.18 Space frame roof over the San Siro stadium, Milan, Italy (Vittorio, 2014).

Retractable roof structures are capable to be opened or closed that make it possible to convert outdoor stadium to indoor stadium. Those roof systems provide a protection from weather thus allowing numerous types of indoor events to be taken place (Geraint *et al.*, 2013). Retractable roof structures can be divided into two types namely “Rigid retractable roof” and “Flexible retractable Roof”. In the case of rigid retractable roof a frame structure is used for roof parts to be retracted, and materials such as glass, plastics, fabrics, and metal plates are stretched on the frame structure. An example of rigid retractable roof is Civic Arena (Figure 2.19) in Pittsburgh which was the first large scale structure with a roof that could be opened and closed based on crane technology (Mungan & John, 2011). Flexible retractable roofs are made of fabric materials, and the roofs are opened and closed by folding the fabric membrane. The roof over the 1976 Montreal Olympic stadium (Figure 2.19) is an early example of flexible retractable roof structure which is a gigantic fabric roof over the central arena (Mungan & John, 2011; Geraint *et al.*, 2013).



Figure 2.19 Retractable roof structures. A: Rigid Retractable roof of Civic Arena 1964, Pittsburgh, Pennsylvania, USA. B: Flexible Retractable roof of Montreal Olympic stadium 1987, Montreal, Canada (Dave, 2009; Julius, 2009.).

2.2.7 Standard dimensions required for major sport types

Here, the main sport types included in Olympic Games are Archery, Athletics, Badminton, Basketball, Cycling, Diving, Soccer, Hockey, Rugby, etc. while soccer and athletics among all are the types of outdoor sports, only played in main stadium structures.

The acceptable dimensions required for each some sport types organized as being part of international sport games or competitions, such as Olympic Games, FIFA World Cup or UEFA Competitions are given below together with their sketches.

- The IAAF standard dimensions required for an *Athletics (track and field) Arena* are 92.52m x 176.91m (Figure 2.20) (Nixdorf, 2008; Geraint *et al.*, 2013).
- The FIFA/UEFA standard dimensions required for a *Football playing field*⁸⁰ are 68m x 105m (Figure 2.21) (Nixdorf, 2008; Geraint *et al.*, 2013).
- The MLB standard dimensions required for *baseball playing field* are 120m x 160m (Figure 2.22) (Nixdorf, 2008; Geraint *et al.*, 2013).
- The NFL Europe standard dimensions required for *American football playing field* are 117m x 56m (Figure 2.23) (Nixdorf, 2008; Geraint *et al.*, 2013).

- The IRB standard dimensions required for *Rugby playing field* are 70m x 100m (Figure 2.24) (Nixdorf, 2008; Geraint *et al.*, 2013).
- The ICC standard dimensions required for *Cricket playing field* are 130m x 150m (Figure 2.25) (Nixdorf, 2008; Geraint *et al.*, 2013).
- The AFL standard dimensions required for *Australian Football playing field* are 145m x 165 (Figure 2.26) (Nixdorf, 2008; Geraint *et al.*, 2013).
- The FIH standard dimensions required for *Hockey playing field* are 60m x 100m (Figure 2.27) (Nixdorf, 2008; Geraint *et al.*, 2013).

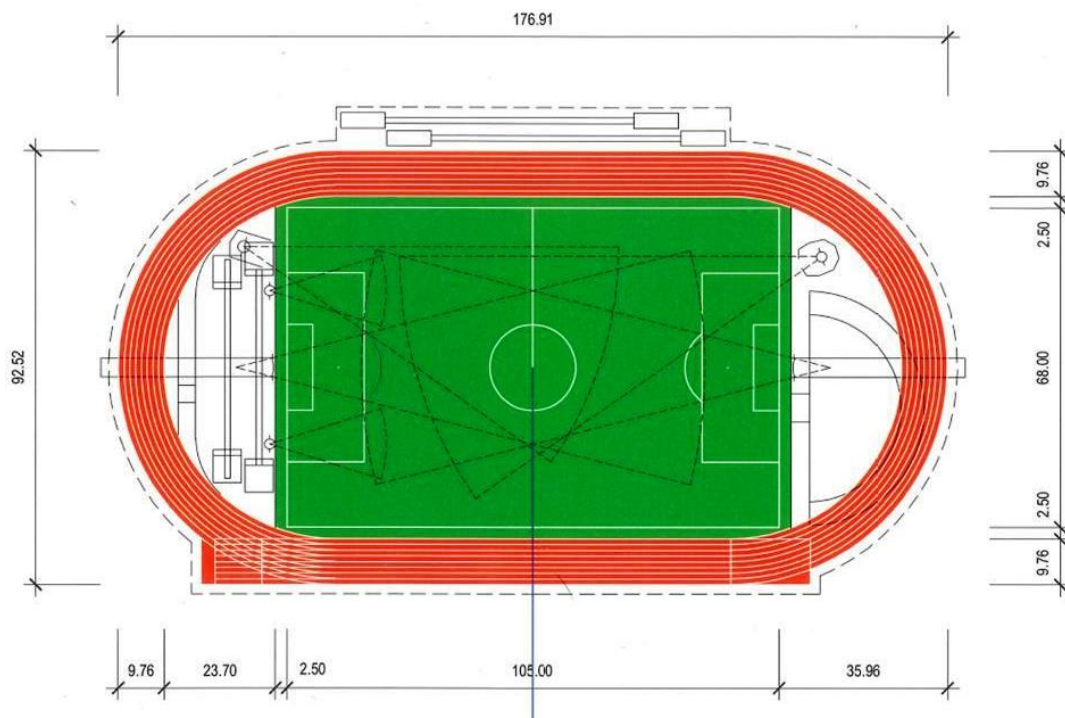


Figure 2.20 IAAF Standard dimensions for International Track and Field competitions (Nixdorf, 2008, p. 181).

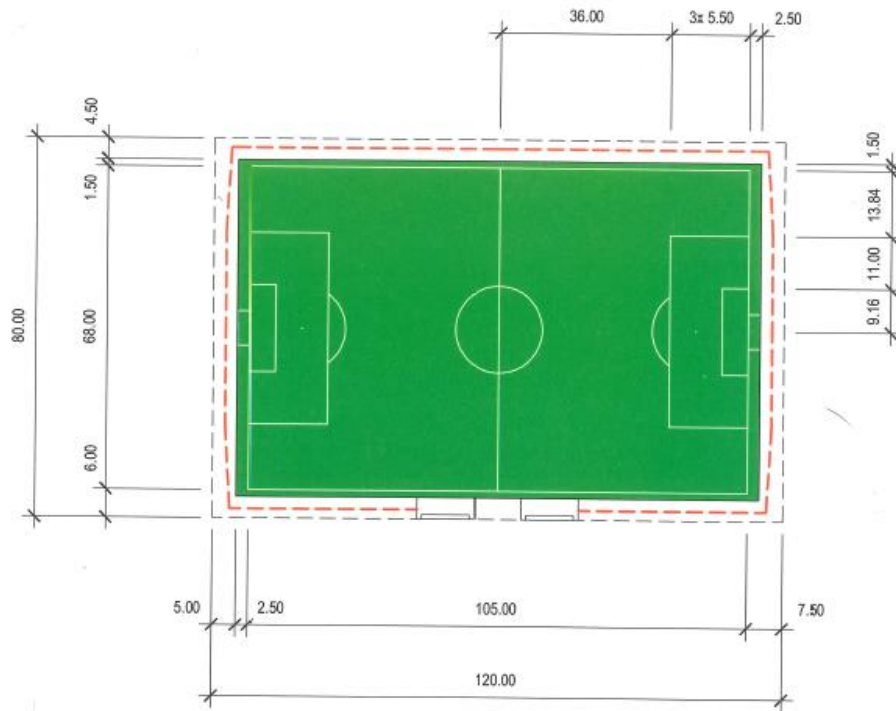


Figure 2.21 FIFA/UEFA standard dimensions for Football playing field (Nixdorf, 2008, p. 184).

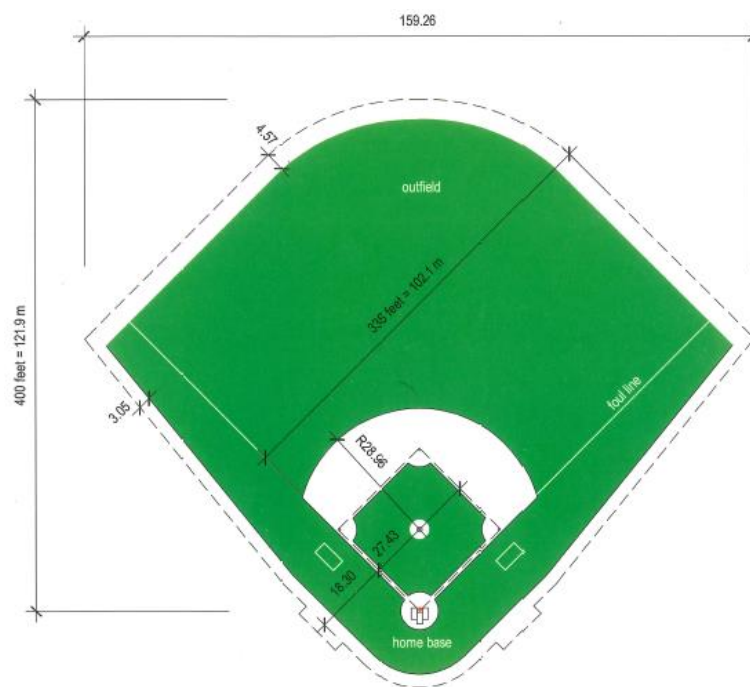


Figure 2.22 MLB standard dimensions for baseball playing field (Nixdorf, 2008, p. 185).

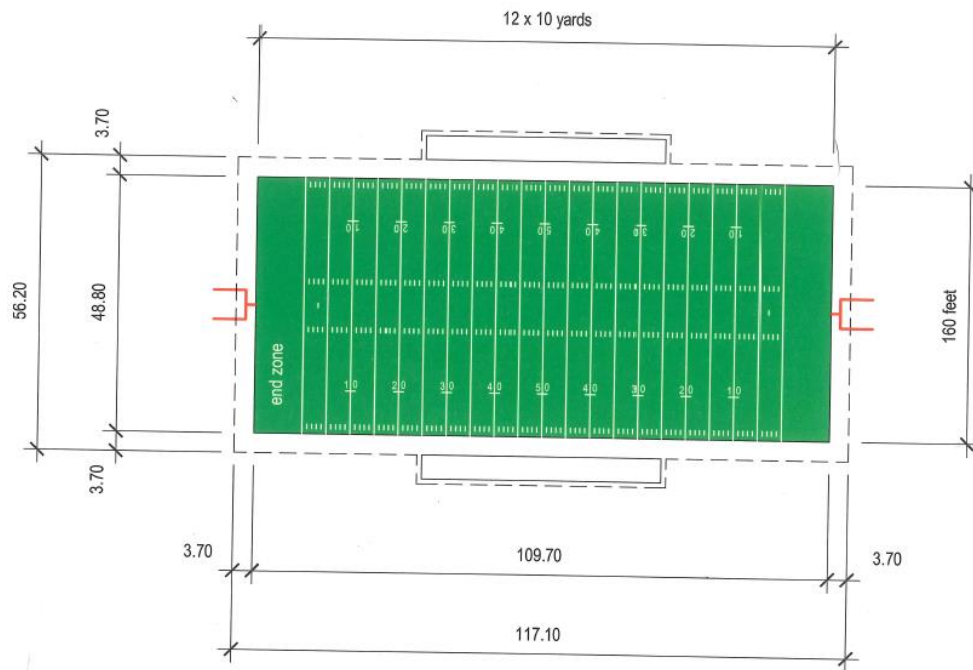


Figure 2.23 NFL Europe standard dimensions for American football playing field (Nixdorf, 2008, p. 186).

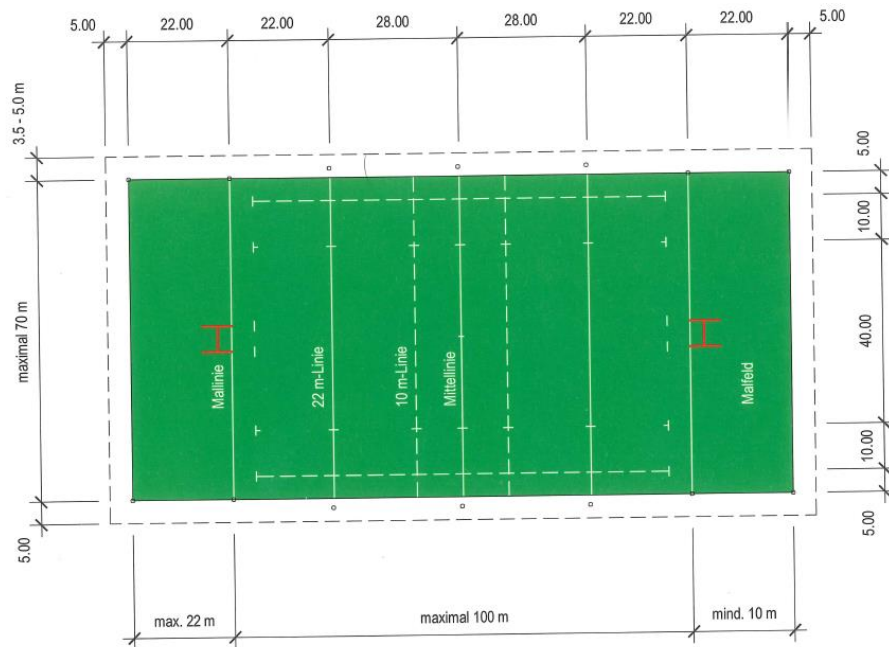


Figure 2.24 IRB standard dimensions for Rugby playing field (Nixdorf, 2008, p. 187).

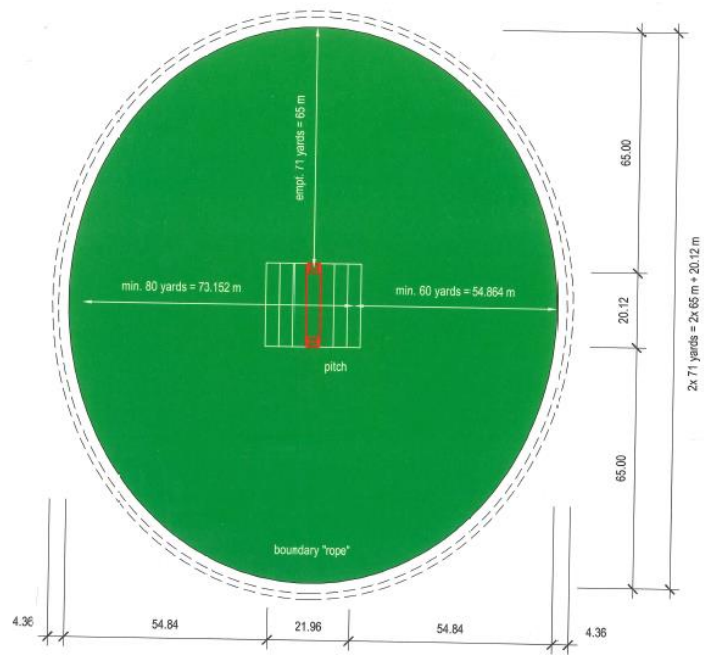


Figure 2.25 ICC standard dimensions for Cricket playing field (Nixdorf, 2008, p. 188).

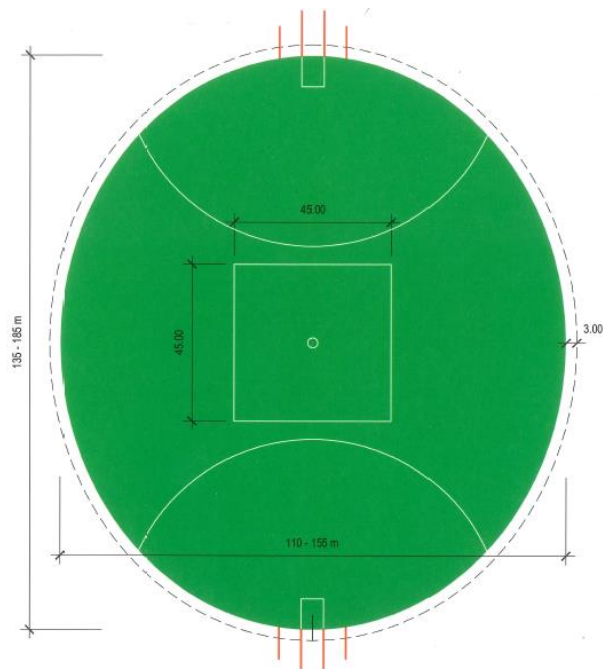


Figure 2.26AFL standard dimensions for Australian Football playing field (Nixdorf, 2008, p. 189).

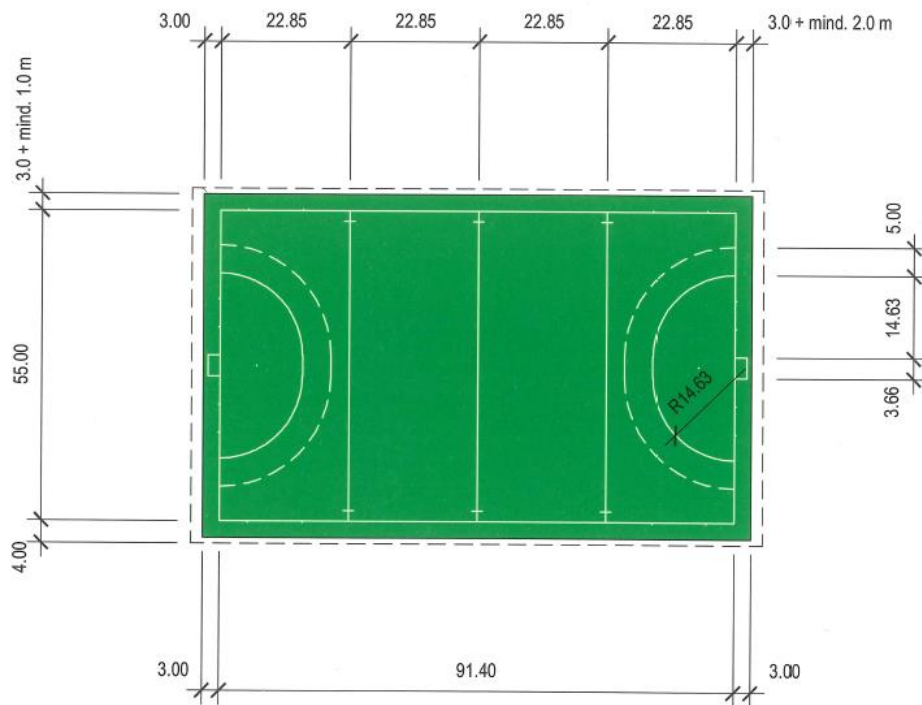


Figure 2.27 FIH standard dimensions required for Hockey playing field (Nixdorf, 2008, p. 190).

2.2.8 Recommendations and Guidelines Related with the Sustainability Issues of Olympic stadiums

The importance of environment and sustainable development was recognized by International Olympic Committee (IOC) following the declarations of Brundtland report (WCED, 1987) and Rio Earth Summit Agenda 21 (UNCED, 1992). The Olympic Movement's Agenda 21 was then established in 1999 in order to encourage the members of the Olympic Movement including the International Sports Federations (IFs), the National Olympic Committees (NOCs), the Organising Committees for the Olympic Games (OCOGs), all other recognised federations, institutions and organisations, as well athletes, judges/referees, coaches and other sports technicians, for integrating sustainability principles into their operations (IOC, 1999; 2014). Similar to IOC, Sport Federations such as; Fédération Internationale de Football

Association (FIFA) and Union of European Football Associations (UEFA) promoted sustainable development issues by including them into their Technical Manuals (FIFA, 2007; UEFA, 2011).

The parameters for sustainable development are listed in Table 2.4 by reviewing some criteria mentioned/defined in manuals, recommendations and guidelines for buildings and stadiums (Table 2.4). Those parameters can be guiding for environmentally sensitive designs as well as useful to involve architectural and technological features of stadiums for protecting the environment and ecological life during their construction and service life.

Table 2.4 Some sustainability criteria mentioned/recommended for building and stadium design in Technical manuals and Guidelines related with site preservation, water and energy efficiencies, efficient material use and long-term use.

Guideline / Manual	Site Preservation / Issues	Water efficiency	Energy Efficiency	Efficient material use	Long term use
Sustainable Building Technical Manual	- Developing previously disturbed sites such as urban lots and commercial sites in order to improve immediate community, creating jobs and increasing values of lands with abandoned and blight properties. - Preserving site by minimum interventions to the nature earth during construction and by using porous materials for arrangement of buildings periphery and site. - Protecting soil during and after construction by providing amendment and stabilization, and carefully designing for grading and excavation, as well as controlling soil erosion.	- Allowing soils to absorb the water runoff to protect watersheds by designing more pervious surfaces and minimizing pavements. - Integrating recycling / reusing process by well-designed water collection and purifying system to efficiently reuse/recycle rainwater and greywater. - Integrating waste water reclamation systems by treatment/purifying to reuse blackwater on a source permitted by local regulations.	- Integrating well-designed daylighting and natural ventilation systems by appropriate decisions on building shape, orientation, location, openings placement, and materials. - Integrating thermal storage strategies using thermal mass to absorb solar heat for use over diurnal cycle and avoid overheating by “Direct” or “Diffuse” thermal storage.	- Using materials to be reused or recycled thus reduce cost and waste such as Steel, aluminium, gypsum, glass, carpet, and disassembled components. - Integrating domestic wood which has been produced through sustainable forest management as well as using low-grade fibre, small diameter trees, fast growing trees, and less-utilized tree species for engineering wood products such as wood joists and trusses. - Integrating durable, recyclable, and adaptable to climate materials for cladding and roofing considering the longevity of the building.	Determining proper operation and maintenance for building to provide cost-effective, healthy environment.

Table 2.4 (Continued).

Sustainable Building Technical Manual			• Integrating energy-efficient fixtures and controlling light systems. • Integrating active solar collector systems considering climatic conditions and solar radiations to decide on type of collector and appropriate location for it thus providing energy for water heating, pool heating, ventilation air preheat, and space as well as generating electricity to be used in building or be sold back into the main electricity grid.	• Using salvaged building materials such as steel and aluminium beam and bar sections and architectural metal works.	
Source: USGBC, 1996					

Table 2.4 (Continued).

Guideline / Manual	Site Preservation / Issues	Water efficiency	Energy Efficiency	Efficient material use	Long term use
Olympic Movement's Agenda 21: Sport for Sustainable Development	• Redeveloping / renovating existing sport facilities and improving them by increasing safety and reducing their environmental impact. • Constructing new sports facilities when demand is not satisfied by redevelopment of existing facilities. • Preserving site by minimum interventions to the nature as well as protecting plants and animal species. • Arranging sports facilities in such a way as to protect conservation areas, countryside, cultural heritage, and natural resources as well as siting the facilities in a way as to minimize environmental impact of the infrastructures associated with them such as housing, traffic arteries, communication, electricity supplies, water and food supplies, and waste disposal and processing.	• Avoiding any practice which contaminates the underground and surface waters. • Using water resources economically as well as integrating water supply systems to reduce water waste. • Integrating waste water reclamation systems to process the waste water generated by sport activities.	• Using energy resources economically as well as integrating renewable energy sources such as electricity supplies and heating, air conditioning and ventilation systems.	• Using recyclable and non-pollutant materials.	
Source: IOC, 1999					

Table 2.4 (Continued).

Guideline / Manual	Site Preservation / Issues	Water efficiency	Energy Efficiency	Efficient material use	Long term use
FIFA Football Stadiums Technical Recommendations and Requirements	Minimizing negative environmental impacts of stadium for surrounding neighbourhood by building the stadium into the ground to lower its height, conducting traffic and crowd management plans, using noise and lighting control baffles, and designing extensive landscaping that respects the environment and its neighbourhoods.	Integrating rainwater collection system to use recycled water instead of potable water for irrigation.	Conducting energy saving activities to the design such as using photovoltaic energy sources, insulating and protecting glass on the outside of the building to reduce the use of air conditioning, as well as using building energy control systems.	Minimizing the generated waste by recycling and reusing materials.	Integrating effective stadium design in terms of future maintenance, cleaning, operation and management in a straightforward and cost-effective manner.
Source: FIFA, 2007					
Guideline / Manual	Site Preservation / Issues	Water efficiency	Energy Efficiency	Efficient material use	Long term use
IOC guide on Sport Environment and Sustainable development		Integrating waste water reclamation systems to treat the waste water thus to be reused.	Preferring day time competitions and events if renewable energy is not available for lighting the stadium at night.	- Using products conform to environmental and sustainable criteria. - Recycling and destroying the solid waste without risk to environment.	
Source: IOC, 2008					

Table 2.4 (Continued).

Guideline / Manual	Site Preservation / Issues	Water efficiency	Energy Efficiency	Efficient material use	Long term use
Sustainable Olympic Design and Urban Development	- Integrating remediation for contaminated and degraded land to be used as a site for stadium while protecting natural habitats and threatened native species. - Redeveloping existing venues for Olympic Games or building new venues if existing structures do not satisfy the demands.	- Protecting existing watersheds, watercourse, and ground water levels on site as well as specifying sustainable drainage systems by permeable surfaces to allow water infiltration into the soil. - Integrating rain water collection systems using large roof areas of stadiums as run off platforms to use water for non-potable purposes such as irrigation and toilet flushing. - Integrating grey water reclamation systems to recycle and reuse grey water for non-potable purposes such as irrigation and toilet flushing.	- Integrating renewable energy sources such as solar thermal collectors and photovoltaic panels on roof and canopy of the stadiums as well as using ground source heats pumps on site. - Integrating daylighting strategies by well-designed fenestration on external façade for indoor spaces as well as translucent canopy over spectators' area for turf growth. - Integrating efficient light fittings and controlling systems as well as movable and individually switched light that allow adaption of stadium for different events - Integrating passive heating, cooling, and ventilation strategies by stadium's orientation, landscaping, and its surroundings to minimize the demands on HVAC systems.	- Integrating waste management system to promote reduction, recycling, and reusing waste during and after construction. - Using wood as renewable organic material if it has been procured from sustainable sources rather than tropical rainforest. - Integrating light weight structures for the stadiums which will provide saving opportunities in terms of amount of materials. - Minimizing the use of new materials by reusing and recycling existing building products and avoiding the use of harmful substances as well as selecting materials in reference to local green materials guide.	Using the venues as multi-function spaces after Olympic Games by careful arrangement of their dimensions, layouts, and movable partition and stands or integrating venues with temporary sections during Olympic Games thus to be adapted for specific functions in the after Olympic Games.

Table 2.4 (Continued).

Sustainable Olympic Design and Urban Development				• Integrating screws and bolts instead of adheres and welds in order to provide easy disassembly as well as designing the stadium as modular systems which provide the opportunity to replace the building components if necessary. • Integrating pre cast concrete techniques by use of pre-stressing and post-tensioning instead of in-situ concrete as well as integrating concrete for structural parts which need lower ratio of cement for concrete composition. • Integrating steel hollow sections for long-span structures due to its high strength to weight ratio as well as using steel for seating structures which can be dismantled for further demands.	
Source: Pitts & Hanwen, 2009					

Table 2.4 (Continued).

Guideline / Manual	Site Preservation / Issues	Water efficiency	Energy Efficiency	Efficient material use	Long term use
UEFA Guide to Quality Stadiums	• Selecting the appropriate site for stadium taken into consideration the possible future use of stadium.	• Integrating rain water collection systems to collect rainwater from roofs and ground to be reused for pitch irrigation. • Integrating grey water recycling process in order to be reused in the toilets.	• Integrating well-designed facades to provide thermal insulation which will reduce heating and cooling costs. • Integrating roof structures and coverings as sun-shade protection that prevent surfaces from overheating and provides natural cooling opportunity. • Integrating solar collector systems to heat the water used for sinks and showers. • Integrating photovoltaic panels on stadium roof to generate electricity for use in the stadium or be sold back into the main electricity grid. • Integrating energy efficient lighting systems throughout the general building areas.	• Using local materials for stadium construction to reduce transport cost. • Using materials that have been recycled or materials with environmentally friendly certification. • Integrating waste-conscious site management to recycle materials.	• Integrating flexible stadium design by creating different and multifunctional spaces to expanding public appeal and increasing revenue.
	Source: UEFA, 2011				

2.3 MAIN STADIUMS OF MODERN SUMMER OLYMPIC GAMES

Throughout this section main stadiums of summer Olympic Games are pointed out for their success and important contributions to the field of stadium design. The purpose is to unravel the development of those stadiums as an engineering achievement. Among twenty seven Olympic stadiums hosted the Olympic Games, the stadium of 1900 Olympics in Paris is eliminated due to the lack of information in published literature considering the parameters aimed to be assessed for the study. It is important to be mentioned that the Games of II Olympiad were held as part of the “International Physical Exercise and Sport Competitions” of the World’s Fair in 1900, with the result that the Olympic Events were lost among these competitions. There was no distinction between the Olympic competitions and the other sporting competitions. Also there was no official opening for the Games of II Olympiad (IOC, 2011). The relevant information about all Olympic stadiums from 1896 to 2012 are described under respective subheadings.

2.3.1 The 1896 Panathenaic Stadium, Athens, Greece

Greek stadium, the Panathenaic in Athens has roots that date back 2300 years into antiquity. Although the stadium corresponds with the ancient Olympic Games which were held in Olympia in western Greece, it never hosted an ancient Olympics (Easton & Weinberg, 2006). The stadium was built by famous orator Lycurgus in 329 BC as a place for Panathenean Games. It was located on the left shore of Ilissos where a ravine laid between two hills. The ground was raised to level of hilltops by which ravine was closed in on three sides and finally formed a horseshoe shaped slope (OCHOA, 1896).

The stadium was entirely restored and decorated by Athenian sophist, Herodes Atticus in AD 139. As a glorious part of restoration, the stadium was entirely covered with marble. In the former construction of the stadium, slopes were not covered and the spectators had to sit on the ground (OCHOA, 1896). U shaped layout of the stadium

as two seating sides were protruded in the centre and inclined towards where they met semicircle section of the seats (Figure 2.28). These two sides were considered as part of circle with radius of 2000 meters. This was determined in order that the audience on both sides might get a better view. The Theatron, the space for spectators, was divided into two zones by diazoma 2.75 meters wide. Each zone constituted twenty three rows of marble benches laid on a foundation of limestone (OCA, 1896).

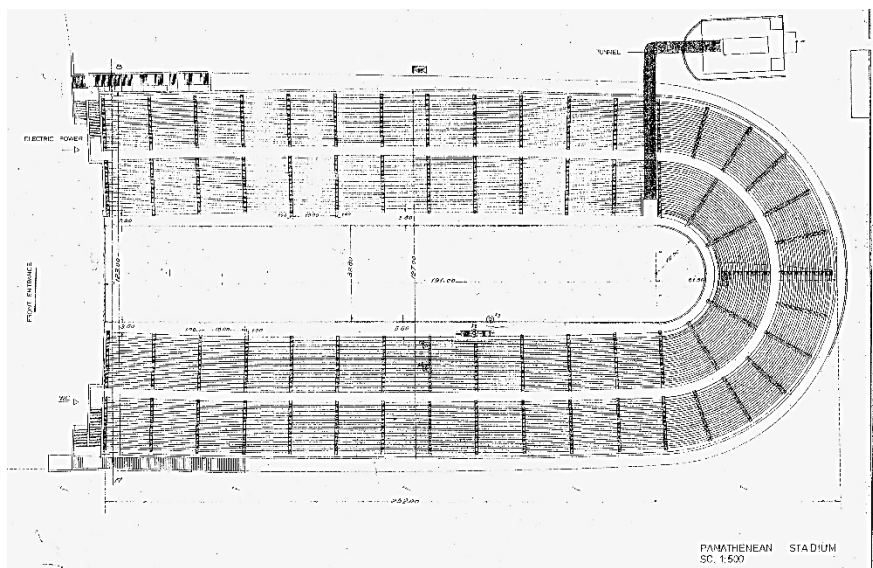


Figure 2 28 The plan of Panathenaic stadium in 1896 based on excavations executed in 1896 (Hellenic Olympic Committee, 1896).

The Panathenaic stadium was chosen as a main venue for the first modern Olympic Games in 1896. In this respect the reconstruction project of the stadium was progressed by the direction of architect Anastassios Metaxas. The excavations executed by Ernst Ziller from 1869 provided comprehensive information about the stadium which led to reconstruction of the stadium with same plan as the stadium of Herodes Atticus (OCA, 1896; Easton & Weinberg, 2006). It is important to be

mentioned that except ornamentations and stoas, all the indications of former construction was followed for the reconstruction project. Figure 2.29 shows the sketch of Herodes Atticus's stadium according to the excavations carried out in 1869. The general view of Panathenaic Stadium during 1896 Olympic Games and its current situation are shown in Figure 2.30. The overall spectator capacity of the stadium for 1896 Olympic Games was counted as 50000 seats (Geraint *et al.*, 2010).

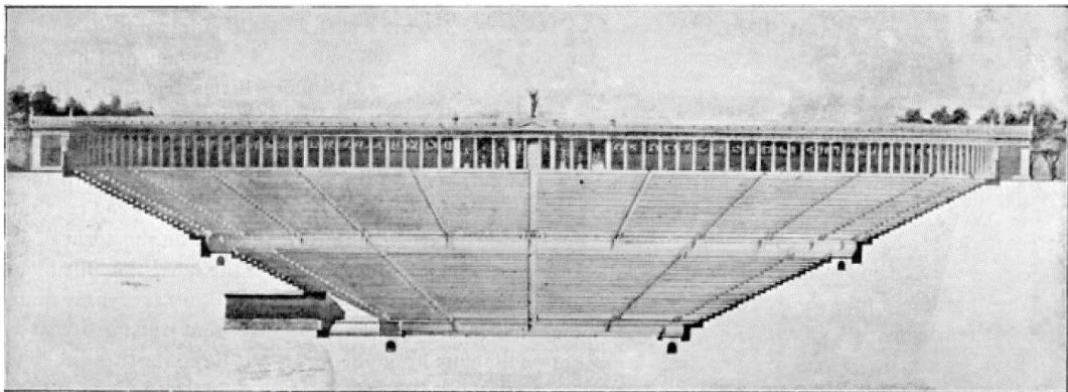


Figure 2 29 The Theatron and Stoa of Panathenaic stadium constructed by Herodes in AD 139 (OCO A, 1896, p. 33).

After Olympic Games Panathenaic stadium continued to host variety of events and it was declared as a National Architectural Monument in 1999 (Kiuri & Teller, 2015). In 2004 the Panathenaic stadium was used for the Olympic Games for the second time and archery, one of the World's oldest sports had been held at the one of the most ancient sports stadia (Mallon & Ture, 1997).



Figure 2.30 The Panathenaic Stadium during 1896 Olympic Games and at current state. A: The general view of Panathenaic stadium during 1896 Olympic Games
B: The general view of Panathenaic stadium at present (Olympic Games, 1896; Hellenic Olympic Committee, 2011).

2.3.2 The 1904 Francis Field, St. Louis, USA

The first American Summer Olympic Games held in St. Louis in 1904 which were later decided to be held in conjunction with Louisiana Purchase Exposition. Upon the desire of Department of Physical Culture which organized the Exposition, all Games were decided to be announced as Olympic championships in different sports (Lucas, 1905).

In 1902, the Washington University constructed a stadium in order to lease it for initial use by the Louisiana Purchase Exposition. Upon the decision to merge the Olympic Games and Exposition, the stadium served as the main stadium for both competitions. The stadium now called Francis Field, originally had 10,000 spectator capacity with reinforced concrete seating tiers in three sides; East, West, South. Figure 2.31 shows the part of South stand during Olympic Games in 1904. The stadium which was firstly planned to be dismantled after the Games, became a permanent part of the Washington university campus (Wuest, 2004; Gold & Margaret, 2012).

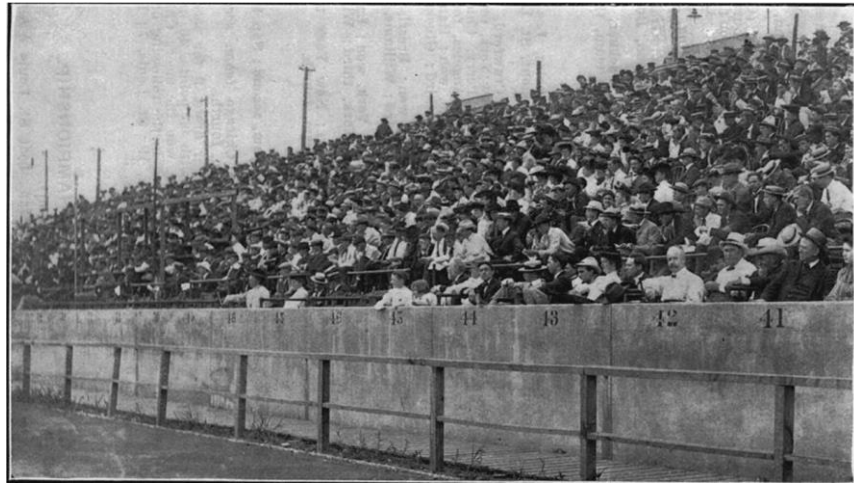


Figure 2.31 Section of South reinforced concrete stands filled with spectators during 1904 Olympic Games (Olympic Games, 2015).

Following the 1904 Summer Olympic Games, the stadium became the home for Gridiron contests for which the original clay running track has been replaced by a synthetic material track (Lennartz, 2004). Moreover, major college Footballs have been held in the stadium for which wooden stands erected on the North side of the field to increase the spectator capacity up to 20,000 in 1940s (Washington University, 2015). In 1983, the stadium underwent a major renovation when east and west reinforced concrete stands were demolished and the spectator capacity reduced to 4,000 seats (Figure 2.32). Moreover a new press box, a concession stand and ticket window, and a synthetic, eight-lane, 400-meter track were added. Following the renovation, the stadium continued to host soccer and athletics games (Wuest, 2004; Washington University, 2015).

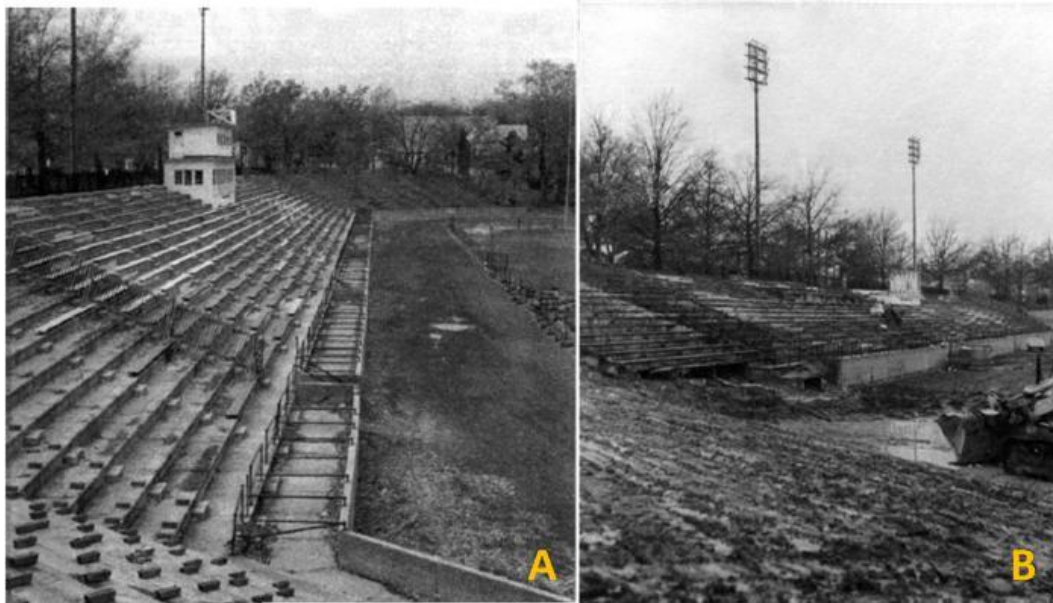


Figure 2.32 The views of Francis Field before and after renovation in 1983. A: Shot of South stands the day before bulldozers arrived to remove the concrete stands. B: the shot of removed East stand (Wuest, 2004, p. 21).

In 2003, the Francis Field renovated for the second time when existing seating tiers were resurfaced with concrete in order to improve its appearance. Moreover, in order to make the stadium accessible for disabled people two ramps and disabled persons seating area were added. Also, Press box was expanded and its roof was repaired. In 2004, Artificial Turf was installed for the games of Bears' Football and men's and women's soccer team. Recently in 2012, the stadium was resurface again (Washington University, 2015).

2.3.3 The 1908 White City stadium, London, England

The White city stadium was constructed for 1908 Summer Olympic games. It was the first time that a stadium was specially built for Modern summer Olympic Games. The stadium designed by James Fulton was a building with steel frame structure providing seats for 63,000 spectators and standing room for another 30,000 spectators in the

grandstands (BOC, 1908; Geraint *et al.*, 2013). One of the significant aspects of stadium was designing a swimming pool in playing field which was 100 meters in length (Mallon & Buchanan, 2009) (Figure 2.33). There was a large room inside the running track which was suitable to serve as field for Hockey, Rugby, Soccer, and Lacrosse matches. There were also platforms for wrestling, and gymnastics, as well as grass area for archery competitions. Therefore, spectators could watch the all Athletics, cycling, Gymnastics, Swimming, and Wrestling competitions at the same time (Mallon & Buchanan, 2009). The stadium was named as White City due to the white plaster buildings in the adjoining Exhibition during the Games. The Olympic Stadium of 1908 become a model for construction of Berlin stadium to host 1916 Olympic Games which were unfortunately cancelled due to the First World War (BOC, 1908; Mallon & Buchanan, 2009).



Figure 2.33 White City Stadium during Olympic Games, 1908 (Olympic Games, 2015).

After Olympic Games the magnificent stadium of its time fell into disuse when surrounding exhibition buildings were demolished. Although spectator capacity was reduced, major events were not held in the stadium for many years (Mallon & Buchanan, 2009). The stadium started to be used when it was taken by Greyhound Racing Association in 1927. Following this the stadium became the centre of British athletics in 1932. In this respect, a new 440 yard cinder running track was replaced the old one and swimming pool was filled. In addition, stands area was fully-sheltered by covering both ends of the stadium (Mallon & Buchanan, 2009; Geraint *et al.*, 2013) (Figure 2.34).



Figure 2.34 White City Stadium after renovation in 1933 (Petersen, 1933).

The Amateur Athletic Association moved their championships to a new athletics centre at Crystal Palace in 1971. This was the end of White city which was centre for british athletics for many years. However, the stadium continued to host Greyhound

racing competitions until 1984. The stadium finally demolished in 1984 and the land was used as a site for the headquarters of BBC (Mallon & Buchanan, 2009).

2.3.4 The 1912 Stockholm stadium, Stockholm, Sweden

The Stockholm stadium was constructed for the fifth summer Olympic Games in 1912 which was designed by architect Torben Grut. The stadium was good example of Swedish national Romantic Movement which represented a union of reinforced concrete with brick construction (Schmidt, 1988). The stadium had 22,000 spectator capacity during Olympic Games. The rows of horseshoe-shaped stands having 10,500 seat capacity were constructed with reinforced concrete in upper part and timber construction in lower part. All upper seats were covered by roof supported by timber masts. In addition, temporary stand was constructed at the North of the stadium consisting of 3,050 wooden seats and standing area for 8,450 spectators (Figure 2.35) (SOCOG, 1912; Schmidt, 1988).

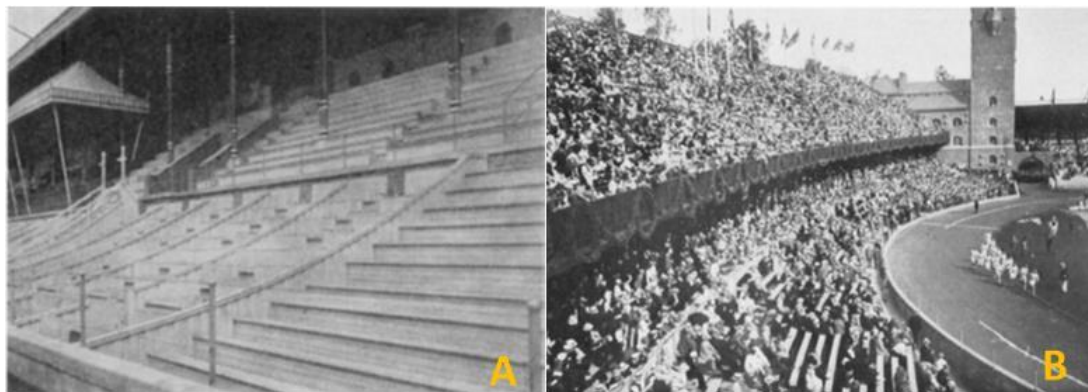


Figure 2.35 Permanent and temporary stands of Stockholm stadium during 1912 Olympic Games. A: section of West permanent stand consisting of upper reinforced concrete fully-covered stand and lower uncovered timber stand. B: temporary North stand consisting of Seating and standing areas (SOCOG, 1912, p. 138,p. 186).

After Olympic Games Stockholm stadium continued to host major events such as Ice Hockey World Championships, Swedish Bandy finals, and national football matches (Stockholms Stad, 2015). In 1958 Northern concrete stand was constructed for European Championships. The equestrian events of 1956 Olympic Games were taken place in Stockholm stadium due to the quarantine regulations which made it impossible to take horses to Australia. In 1990 the North stand was demolished and a new stand was built in the same style of stand constructed in 1958 (Stockholm Marathon, 2015; Stockholms Stad, 2015). The Stockholm stadium was declared as the Local Historical Building in 1990 (Kiuri &Teller, 2015). Spectator capacity of the stadium at current state is 14,500 seats (Figure 2.36) (Stockholms Stad, 2015).

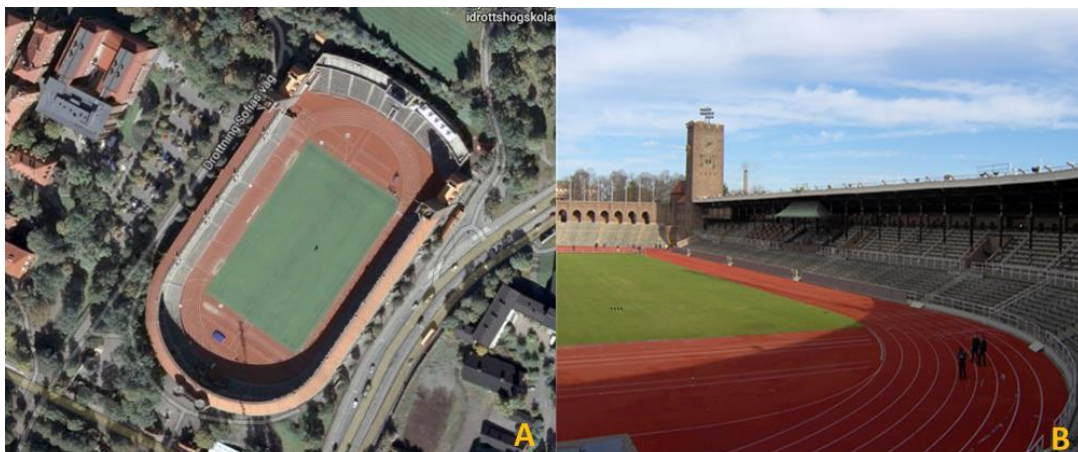


Figure 2.36 Stockholm stadium at current state. A: google earth image of Stockholm stadium. B: Stockholm stadium uncovered North stand and partially covered East stand (Google Earth image, 2015; Scherman, 2007).

2.3.5 The 1920 Olympisch Stadium, Antwerp, Belgium

The 1920 Olympisch stadium was originally an Athletics stadium built in 1914 by Somers and Montigney (Renson & Marijke, 1997). The stadium was expanded to be used for the 1920 Olympic Games. In this respect, the existing grandstands were enlarged and a small grand stand was built thus spectator capacity raised to 30,000. The spectator capacity consisted of 10,000 seats and standing spaces for another 20,000 spectators. Two longitudinal grandstands at North East and South West were covered by roofs in the form of saddle structures supported by steel columns. In addition, a new running track was replaced with the old one for the Olympic Games (Figure 2.37) (Schmidt, 1988; Renson & Marijke, 1997).

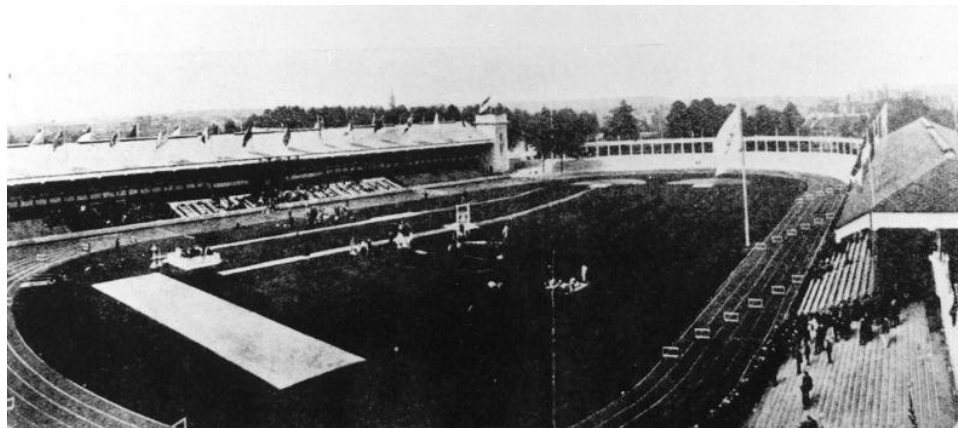


Figure 2.37 General view of the Olympisch stadium in 1920 (COF, 1924, p.29).

After Olympic Games, stadium became a home ground for Beerschot Soccer team (Renson & Marijke, 1997). Over the years, some parts of stands were demolished and spectator capacity reduced to 25,000. In 2000, the stadium was renovated by Beerschot that resulted in a smaller stadium with four separate stands and seat capacity

for 12,771 spectators (Schmidt, 1988; Renson & Marijke, 1997). Figure 2.38 represents the current state of the Olympisch stadium after major renovation in 2000.



Figure 2.38 Olympisch stadium with four separate stands in 2015 (Google earth, 2015).

2.3.6 The 1924 Stade Yves-du-Manoir, Paris, France

The Stade Yves Du Manoir was originally built for horse racing consisting of terrain track and wooden grand stands in 1883. In 1924 the stadium was completely converted to be used as the main stadium for summer Olympic Games. In this respect, the spectator capacity increased to 60,000 people, including 20,000 seats and area for 40,000 people (COF, 1924). Figure 2.39 represents general view of the stadium during 1924 summer Olympic Games.



Figure 2.39 General view of the Stade Yves Du Manoir during 1924 summer Olympic Games (Collection G.G., n.d).

The seats were distributed in two parallel parts at East and West, each 144 meters in length and 26.73 meters in width. Those two parts at East and West were covered by roofs supported by metal frames. Figure 2.40 shows the section of West grandstand covered by roof.

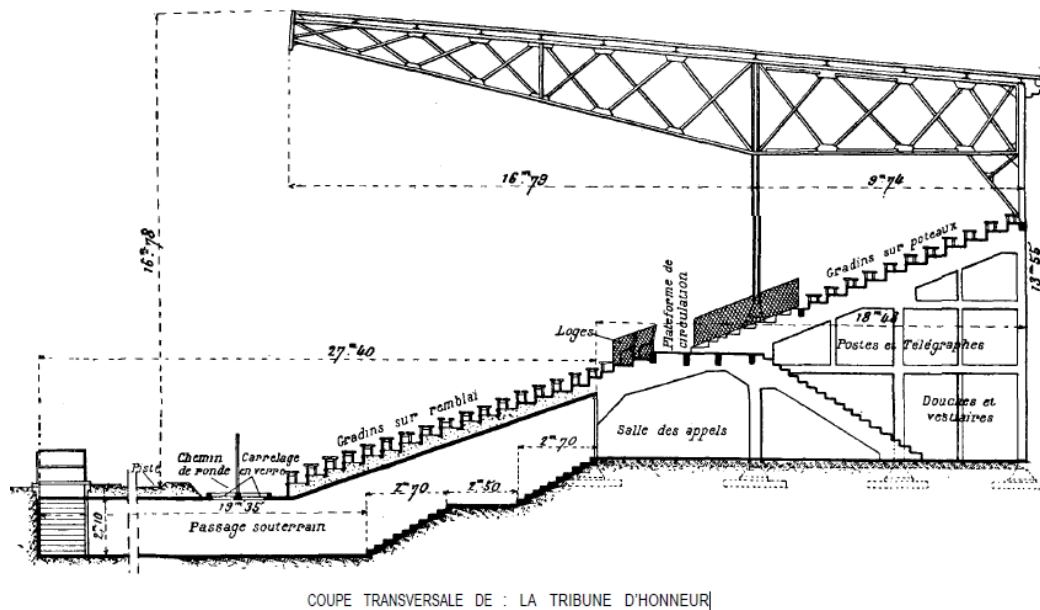


Figure 2.40 Stade Yves Du Manoir, section of West grandstand covered by roof (COF, 1924, p.54).

After Olympic Games, stadium was renovated and enlarged to be used for 1938 World Cup and European Athletics with the spectator capacity over 60,000 people. In addition, stadium was used for many soccer and rugby games. However, inauguration of new Parc des Princes in 1972 affected life of the Stade Yves Du Manoir severely. The major events of football and rugby started to be taken place in the Parc des Princes (Racing 92, 2015). After 1972, the stadium underwent several renovations that turned the stadium from an international stadium into the regional stadium. Finally, in 2000 the stadium became a home ground for national rugby and soccer teams which were succeeded in bringing spectators back to Yves Du Manoir. In this respect, the stadium renovated and was ready with the capacity of 14,000 seats in 2009 (Racing 92, 2015).

2.3.7 The 1928 Olympisch Stadium Amsterdam, Amsterdam, Netherlands

The Olympisch Stadium Amsterdam, designed by Jan Wils, was built in 1928 to be used as the main stadium for summer Olympic Games. The stadium had a spectator capacity of 31,600 including about 21,600 seats and standing area for about 10,000 people (TNOC, 1928; Pauuw, 2000). Stadium is a reinforced concrete skeleton covered externally by a brick façade which represents the architectural style of the architect Frank Lloyd Wright (Schmidt, 1988). Two longitudinal stands at East and West with seating accommodation were covered by the roof structures. The Figure 2.41 represents the Olympisch stadium during 1928 summer Olympic Games.



Figure 2.41 General view of the Olympisch Stadium Amsterdam during the 1928 Summer Olympic Games (TNOC, 1928, p. 297).

After Olympic Games, it was decided to renovate the stadium to accommodate more spectators when International Federation of Association Football (FIFA), announced a new tournament: the Football World Cup. In this respect, spectator capacity increased to 60,000 people in 1937 by a concrete superstructure on top of the red bricks which made the stadium to lose its beauty (Pauuw, 2000). After renovation, stadium continued to host major events and was the home ground for national Soccer and American football clubs until 1990's. In 1990's the municipality of Amsterdam which was not interested in the historical meaning of the building decided to demolish the stadium and use the place to build houses. Fortunately, Piet Kranenberg, a commissioner of the stadium succeeded in scheduling the stadium for preservation and finally, in 1992 stadium was listed as National Architectural Monument (Kiuri & Teller, 2015; Olympisch Stadion Amsterdam, 2015). In this respect, a renovation plan was conducted by Architect Andre van Stigt. During renovation in 2000, concrete stand of 1937 was pulled down and spectator capacity was reduced to 22288. As a result, the stadium gained same look as in 1928 (Figure 2.42) (Olympisch Stadion Amsterdam, 2015).



Figure 2.42 General view of the stadium after renovation in 2000 (Reuters, 2014).

2.3.8 The 1932/1984 Los Angeles Memorial Coliseum, Los Angeles, USA

The Los Angeles Memorial Coliseum designed by John and Donald Parkinson was constructed in 1923 which was the largest Stadium in Los Angeles at its time (Los Angeles Memorial Coliseum, 1984). It is the only stadium in the world which was used as the main stadium for the summer Olympic Games two times in 1932 and 1984. In order to host the 1932 summer Olympic games, 25 stepped tiers were added on top of the stands that increased the seating capacity from 75,000 to nearly 101,574 (OCLA, 1933; Los Angeles Memorial Coliseum, 1984; Lacoliseum, 2015). In addition, VIP Tribune for members of international and national committees, presidents, special guests and juries were provided that was not thought in the previous construction (Lacoliseum, 2015). The stadium is a reinforced concrete, cast in place structure on a sloped bank of a sand and gravel pit (OCLA, 1933; Los Angeles Memorial Coliseum, 1984). Figure 2.43 shows the general view of the stadium in 1932.



Figure 2.43 General view of the Los Angeles Memorial Coliseum after renovation in 1932 to host Summer Olympic Games (OCLA, 1933, p.37).

In 1964 stadium underwent a renovation and old benches were replaced by theatre-type chairs were. The spectator capacity was reduced to 93,000 seats (Lacoliseum, 2015).

For the second time stadium hosted the summer Olympic Games in 1984. In order to host the Games, new track was installed and first row of seats on the north side of the stadium was removed (LAOOC, 1985). The day before the opening ceremony of 1984 Olympic Games, Los Angeles Memorial Coliseum was declared as National Historic Landmark for its contribution to the history of California (Figure 2.44) (Kiuri & Teller, 2015; Lacoliseum, 2015).

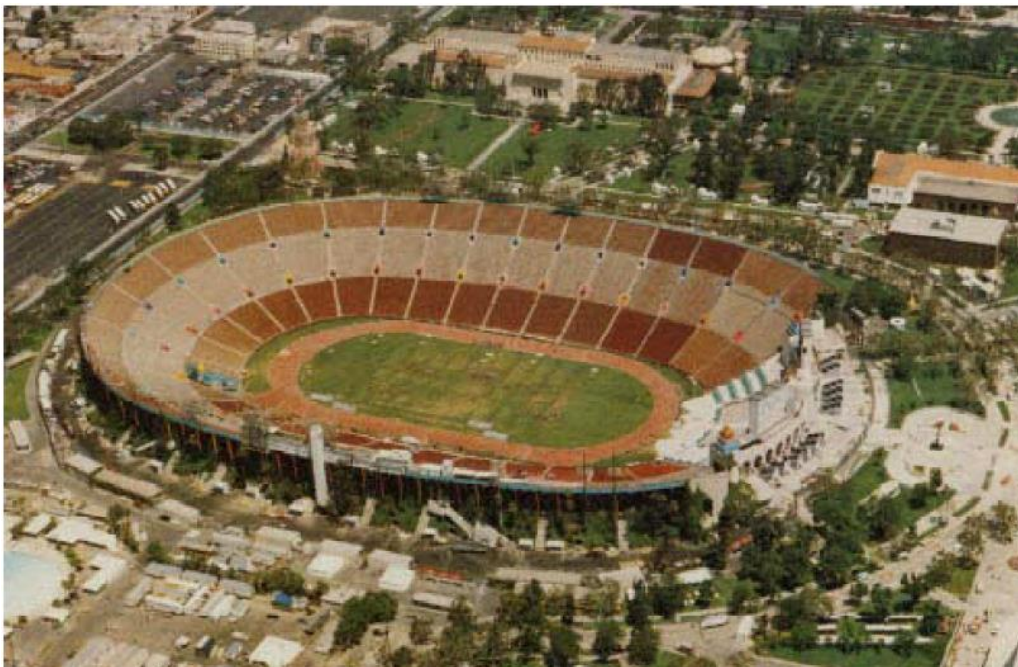


Figure 2.44 General view of the Los Angeles Memorial Coliseum the day before opening ceremony of 1984 summer Olympic Games (LAOOC, 1985, p.74).

During its lifetime stadium has hosted many major events and has been a home ground for several national clubs for American football, Soccer, Baseball, Basketball and Hockey (Lacoliseum, 2015).

In 1993 Los Angeles Memorial Coliseum underwent another renovation. During renovation, running track was removed and the floor was lowered to about 3.35 meters in order to create a more imitate stadium (USC, 2015). As a result, 8,000 seats were added down low that led spectators to be closer to the playing field (USC, 2015). After the last renovation in 2008, the stadium has a present spectator capacity of 93,607 seats. Figure 2.45 shows the view of Los Angeles Memorial Coliseum during Baseball games in 2008 after renovation.



Figure 2.45 View of Los Angeles Memorial Coliseum during Dodgers exhibition Baseball game in 2008 (USC, 2015).

2.3.9 The 1936 Olympiastadion Berlin, Berlin, Germany

The Olympiastadion Berlin, formerly German stadium, had been designed for 1916 summer Olympic Games by Architect Otto March with the capacity of 32,000 seats. Unfortunately, due to the First World War the games of 1916 were cancelled (OKOB, 1936). For the second time summer Olympic Games were awarded to Berlin for which the German Stadium was remodelled and enlarged by Werner March son of original Architect Otto March to be used as main stadium (OKOB, 1936, Nixdorf, 2008). As a result, the stadium had a spectator capacity of 110,000 including seating capacity for 85,000 people and standing area for 35,000 people (Gammon, *et al.*, 2014). The stands were constructed with reinforced concrete consisting of prefabricated step units and cast-in-place radial frames. The 1936 summer Olympic Games were the first games with television transmission by 25 giant screens all over the Berlin. In addition, for the first time Olympic movie was provided as film Olympia in 1938 by Leni Riefenstahl (Gammon, *et al.*, 2014). Figure 2.46 shows general view of the Olympia stadion Berlin during the 1936 summer Olympic Games.



Figure 2.46 General view of the Olympia stadion Berlin during 1936 summer Olympic Games (Olympic Games, 2015).

After Olympic Games, the stadium annually hosted 20 to 25 major events and from 1963 stadium became a home ground for national soccer team (Olympiastadion Berlin, 2015). In 1974 a steel frame roof was erected over the East and West stands covering the 26,000 seats in order to use the stadium for the football world cup competitions (Figure 2.47) (Constantinescu, 2005; Nixdorf, 2008).



Figure 2.47 Olympia stadion Berlin roof erected over the West grandstand in 1974 (Constantinescu, 2005, p.2).

Olympia stadion Berlin was declared as Local City Landscape in 1996 (Kiuri & Teller, 2015; Olympiastadion Berlin, 2015) and following this the spectator stands were fully sheltered in 2000 (Nixdorf, 2008). The continuous roof is a spatial truss supported by inner and outer columns (Constantinescu, 2005) (Figure 2.48). The multipurpose stadium today is used for athletics, football and open-air concerts with a seating capacity of 79,200 (Nixdorf, 2008).



Figure 2.48 General View of Olympia stadion Berlin after erection of continues roof in 2000 (Busam, n.d.).

2.3.10 The 1948 Empire Stadium, London, England

Empire stadium, designed by architects Simpson and Ayrton, was built in the mid-1920s as one of the several structures to be used for British Empire Exhibition of 1924-1925 (Pretty & Alison, 2012). At the beginning, the stadium with the capacity of 129,000 spectators including 35,000 seats and stand area for 91,500 people, was decided to be demolished after the exhibition. Upon the efforts of Sir James Stevenson, chairman of the organizing committee of the exhibition, it was decided to keep the stadium alive (Pretty & Alison, 2012). In 1948, Empire stadium was used as the main stadium for summer Olympic Games. In this respect, a running track was added and the spectator capacity was reduced to 82,000 including 72,000 seats and standing area for 10,000 spectators (LOCOG, 1948; Pretty & Alison, 2012). Figure 2.49 shows the general view of the Empire stadium in 1948.



Figure 2.49 General view of Empire stadium in 1948 (Stadiumdb, 1948).

After Olympic Games, Empire stadium continued to host major games and became world renowned football centre. In 1963 a new roof made of aluminium and translucent glass was erected which covered all spectators' stands area and in 1967 the stadium was registered as national monument (Pretty & Alison, 2012; Clarke, 2012; Kiuri & Teller, 2015). The spectator capacity of stadium was slightly decreased to 80,000 in 1990 (Pretty & Alison, 2012). Unfortunately, Empire stadium started to show signs of severe decline at the end of twentieth century and became an uninviting facility (Pretty & Alison, 2012). By 1995 the sport council was looking into alternatives for an English National stadium to retain a name recognized world-wide and finally selected site of the Empire stadium for construction of new stadium (Clarke, 2012). Following this decision, Empire stadium was demolished in 2002 to make a way for new Wembley Stadium with the spectator capacity of 90,000 seats (Pretty & Alison, 2012). Figure 2.50 shows the general view of Empire stadium in 1999 before its demolition.



Figure 2.50 General view of the Empire stadium in 1999 (English heritage, 1999).

2.3.11 The 1952 Olympia-stadion Helsinki, Helsinki, Finland

The Olympia stadion Helsinki designed by Yrjö Lindegren and Toivo Jäntti was built in 1938 in order to host 1940 Summer Olympic Games which were cancelled due to the World War II (OCOH, 1955; Olympiastadion, 2015). The stadium was later used as a main stadium for 1952 summer Olympic Games. In this respect, temporary wooden stands were added at the South and North bends, and along East side which increased the spectator capacity to around 70,000 people. The stadium had a roof over its West grandstand and at south end of the stadium there was a narrow white tower 72 meters in height (Figure 2.51) (OCOH, 1955). As a result of modernization between 1990 and 1994 the stadium today got the capacity of 39,000 seats and the East stand was covered by roof (Olympiastadion, 2015). The stadium building has the dimensions of 234m long and up to 159m wide (Olympiastadion, 2015). The Olympia stadion Helsinki will renovate in 2016 to cover all stands area and reduce the spectator

capacity to around 36,000 seats (Olympiastadion, 2015). Figure 2.52 shows the Olympia- stadion Helsinki in in 2013 with roofs sheltering East and West stands.



Figure 2.51 General view of Olympia-stadion Helsinki in 1952 (OCOH, 1955, p.44).



Figure 2.52 General view of Olympia stadion Helsinki in 2013 (Sefutbol, 2013).

2.3.12 The Melbourne Cricket Ground, Melbourne, Australia

The Melbourne Cricket Ground designed by architect Arthur Purnell was built in 1953 and became the home of Australian football since 1859. The stadium was the birthplace of test cricket in 1877 (MCG, 2015). The spectator stands had been built in several sections over the years. The 1956 summer Olympic Games were awarded to Melbourne which were the first games to be held in Southern Hemisphere (OCOM, 1958). In order to host the summer Olympic Games, the oldest stand of Melbourne Cricket Ground dismantled and replaced with a three tiers concrete stand with 40,000 spectators capacity. This resulted in the stadium with spectator capacity of 104,000 including 99,000 seats and standing area for 5,000 spectators (OCOM, 1958). The Northern stand of the stadium was covered by a roof structure (Figure 2.53). After Olympic Games, the stadium continued to host major national and international sporting events specially Cricket and Australian football games (COA, 2005).



Figure 2.53 General view of Melbourne Cricket Ground during 1956 Summer Olympic Games (Olympic Games, 1956).

The stadium underwent several redevelopments throughout the years and it was registered as National Place in 2005 (Kiuri & Teller, 2015). The latest redevelopment of stadium was accomplished between the 2003 and 2005. As a result of this redevelopment, the 1928 Members' stand (Southern stand) and 1956 Olympic Stand (Northern stand) were demolished and replaced with new stands for 2006 Commonwealth Games (Nixdorf, 2008; Melbourne Cricket Ground, 2013). Moreover, a new hybrid roof structure of metal and glass was erected which covered 80 percent of spectators' stands area. Today, Melbourne Cricket Ground has a capacity of around 100,024 including 95,000 seats and standing area for 5,000 spectators (Figure 2.54) (Melbourne Cricket Ground, 2013; MCG, 2015).



Figure 2.54 General view of the Melbourne Cricket Ground in 2010 (Sheko, 2010).

2.3.13 The 1960 Stadio Olimpico, Rome, Italy

The Stadio Olimpico, designed by architect Mario Moretti was constructed as the centrepiece of the Foro Italia sports complex which was the project started by the regime of Mussolini. Construction of the stadium started in 1928 and first tier of stands

was completed in 1932. The work of second tier was interrupted by Second World War and as a result the stadium officially opened in 1953 with the spectator capacity of 100,000 (Brennan, 2010). Stadio Olimpico was used as the main stadium for 1960 summer Olympic Games. The main stadium for the games was uncovered oval shaped three-story seating structure with the spectator capacity of 90,000 including 65,000 seats and standing area for 25,000 people (Figure 2.55) (CONI, 1960; Brennan, 2010). The main axis of the oval was 319 meters and the minor axis was 186 meters. In 1990, Stadio Olimpico renovated and a roof called bicycle wheel system was erected to cover all stands which was designed by Massimo Majowiecki (Mungan & John, 2011; Geraint *et al.*, 2013). In addition, the stadium was later renovated in 2008, with improvements for security, adjustment of dressing rooms, and refurbishment of seats. As a result, spectator capacity was reduced to current capacity of 70,634 (Figure 2.56) (Brennan, 2010).

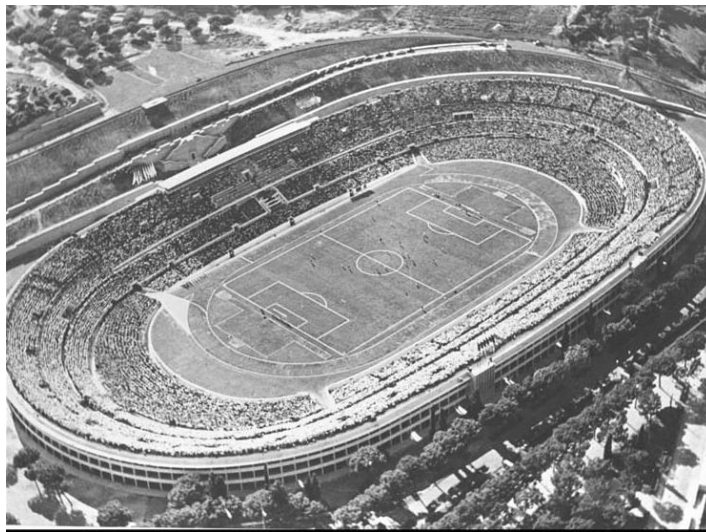


Figure 2.55 General view of stadio Olimpico Rome during 1960 summer Olympic Games (Olympic Games, 1960).

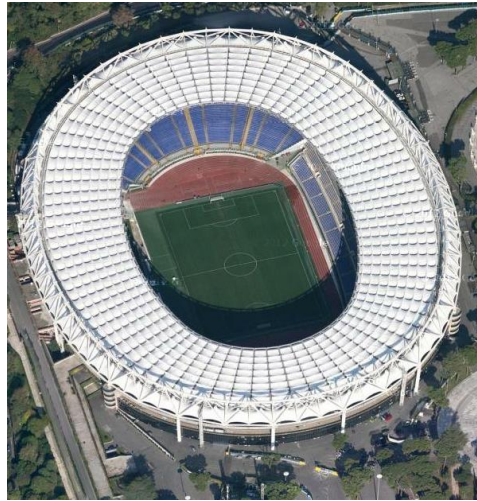


Figure 2.56 General view of Stadio Olimpico in 2010 (Meier, 2010).

2.3.14 The 1964 Tokyo National Stadium, Tokyo, Japan

The Tokyo National stadium, designed by architect Mitsuo Latayama, was built for the third Asian Games in 1958 with the spectator capacity of 52,000. The stadium, later was enlarged and remodelled in order to host 1964 summer Olympic Games. As a result of redevelopment, the seating capacity was increased to 75,000 people. The structure of the stadium consisted of Ferro-concrete and steel frame structures in some parts (TOCOG, 1964). Figure 2.57 shows the general view of National Stadium in 1964. At current state the stadium has the spectator capacity of 57,363. However, Tokyo National Stadium will be demolished in order to build National Olympic Stadium with 80,000 spectator capacity which will be the main stadium for 2020 Summer Olympics and Paralympic Games (Japan Sport Council, 2015). Figure 2.58 shows the general view of Tokyo National Stadium in 2013.



Figure 2.57 General view of Tokyo National stadium in 1964 (TOCOG, 1964, p.25).



Figure 2.58 General view of Tokyo National stadium in 2013 (Tomura, 2013).

2.3.15 The 1968 Estadio Olímpico Universitario, Mexico City, Mexico

The Estadio Olímpico Universitario, designed by architects Augusto Perez, Raul Salinas, and Jorge Bravo Moro, was built in 1953. The stadium, having 70,000

spectator capacity in origin was a site for opening closing ceremonies, athletics competition and equestrian team jumping events (OCOM, 1969). It is important to be mentioned that this stadium was the first in the world which had a house of press for radio and television, known as Palomar (Palacios *et al.*, 1968). In 1966 Estadio Olímpico Universitario was modified in order to host 1968 summer Olympic Games. As a result of modification, new track and light towers were added. In addition, seating stands were redesigned and spectator capacity was increased to 83,700. The stands were designed as asymmetric geometry to locate most seats at West (Figure 2.59) (OCOM, 1969). Stadium was constructed on embankment as two levels of stands with reinforced concrete. The upper level of stands was cantilevered nine meters on the lower level of stands covering the total 14,000 seats (Palacios *et al.*, 1968). After Olympic Games stadium continued to host Athletics, Soccer and Gridiron games and it was registered as UNESCO world cultural heritage in 2007 (Kiuri & Teller, 2015; Estadio Olímpico Universitario, 2015). The stadium is part of the main campus of National Autonomous University of Mexico. At current state Estadio Olímpico Universitario has 68,945 seat capacity (Figure 2.60) (Estadio Olímpico Universitario, 2015).



Figure 2.59 General view of Estadio Olímpico Universitario during 1968 summer Olympic Games (Olympic Games, 1968).

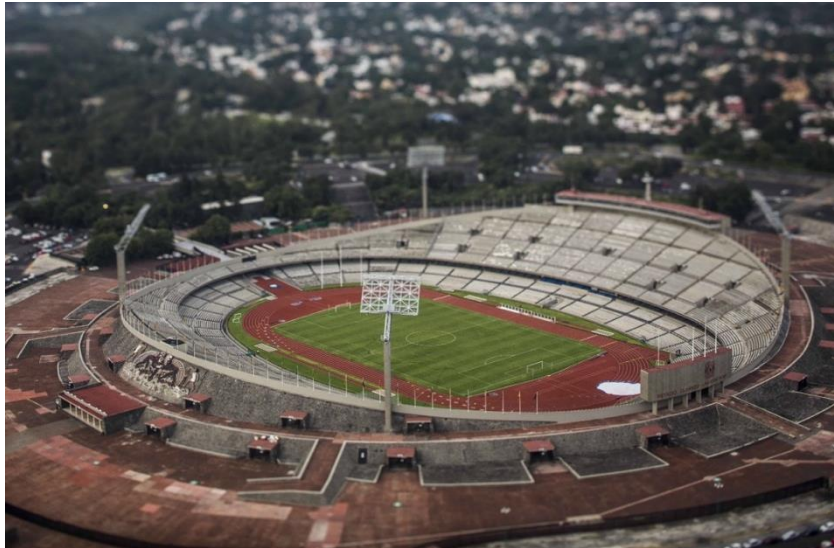


Figure 2.60 General view of Estadio Olímpico Universitario in 2014 (Betansoz, 2014).

2.3.16 The 1972 Munich Olympic Stadium, Munich, Germany

The Munich Olympic Stadium, designed by Behnisch and Associates was built in 1972 to be used as the main stadium for summer Olympic Games. The stadium had the spectator capacity of 80,000 including 69,000 seats and standing area for 11,000 people (OCOM, 1972). The East grandstand was uncovered stand constructed on embankment. The West grandstand was constructed partially on embankment and concrete work for seating and standing area was completed following the embankment part (Figure 2.61) (OCOM, 1972). A cable net roof structure designed by structural engineer Frei Otto was erected covering the 65% of spectators (Figure 2.62). The roof, was constructed with PVC-coated polyester fabric panels supported by web of steel cables (Mungan & John, 2011; Geraint *et al.*, 2013). The stadium was equipped by fully automatic irrigation system for playing field. In addition, warm water heating installation was erected below the playing field surface to protect the field from weather conditions such as snow and ice (Olympic Park Munich, 2015). The main

axis of the stadium structure was 260 meters and the minor axis was 250 meters. After Olympic Games, Munich Olympic Stadium was used for many sport events and it was used as a home ground for soccer teams. At current state, it has the, spectator capacity of 69,250 including 57,450 seats and standing area for 11,800 people. The stadium now has ten to fifteen major events each year (Olympic Park Munich, 2015).

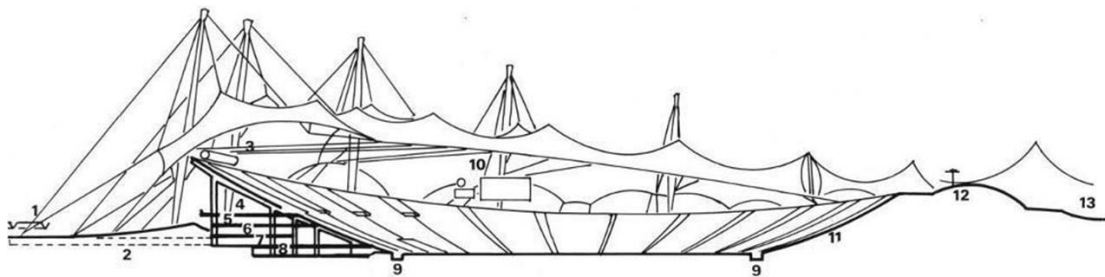


Figure 2.61 Section of East and West grandstands of Munich Olympic Stadium (OCOM, 1972, p.50).



Figure 2.62 Cable net roof structure over the Munich Olympic Stadium in 1972 (Mojtahedi, 2008).

2.3.17 The 1976 Montreal Olympic Stadium, Montreal, Canada

The Montreal Olympic Stadium, designed by Roger Taillibert, was constructed in 1976 in order to host the summer Olympic Games. The stadium was designed with 60,000 permanent seats and 10,000 temporary seats to be removed after Olympic Games (COJO'76, 1976). The basic structural system for the stadium was composed of 34 prefabricated concrete consoles which were arranged on an ellipse (Figure 2.63). A retractable roof structure was designed for the stadium in order to make it possible to use the stadium in all weather conditions. However, the roof was not completed for the Games (Figure 2.63) (COJO'76, 1976). When completed, the Montreal Olympic Stadium was 305 meters long and 250 meters wide and 55 meters high above the ground (COJO'76, 1976).

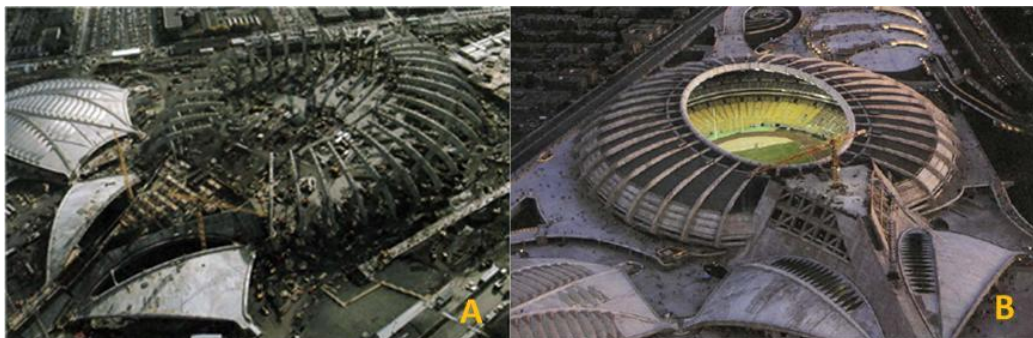


Figure 2.63 Montreal Olympic Stadium: A. Stadium during construction. B. Stadium during 1976 summer Olympic Games (COJO'76, 1976, p.47; Olympic Games, 1976).

After Olympic Games, natural turf of the playing field was replaced with synthetic surface laid over an asphalt base. In addition, two sections of mobile stands constructed of steel and resting on rails, were installed on the longitudinal axis of the stadium in order to make the stadium adaptable for baseball and football games

(COJO'76, 1976). The retractable roof of the Montreal Olympic Stadium was completed in 1988. The folding retraction method was applied for roof made of PVC-Coated Kevlar fibre Fabric. However, the roof was suffered from failures of the fabric (Mungan & John, 2011). In 1991, stadium underwent a renovation and as a part of renovation 12,000 seats were eliminated to make the stands closer to the field for baseball games. As a result, stadium had the capacity of 56,000 permanent seats which was expandable by temporary seats (Park Olympique la stade, 2015). Between the 1995 and 1998 stadium was used all year long with about 37 events each year.

As result of roof failure, in 1992 it was decided to fit the foldable part of roof closed at all the times. Following this, in 1998 a previous roof was replaced with opaque blue roof. Due to the failure of the new roof, it was removed and another roof was later applied (Figure 2.64) (Advisory Committee, 2011). Today Montreal Olympic Stadium has the spectator capacity of 56,000 seats. The stadium is closed from December to March due to the state of its roof. The seasonal use of the stadium reduces the number of shows and events which can be hosted (Advisory Committee, 2011).



Figure 2.64 General view of Montreal Olympic Stadium in 2009 (Julius, 2009).

2.3.18 The 1980 Luzhniki Stadium, Moscow, Russia

The Luzhniki stadium, formerly Central Lenin stadium, was built in 1956 in order to host First USSR Summer Spartakiade (OCOG-80, 1980). The stadium was designed to accommodate 100,000 spectators in 73 to 78 seat rows. The grandstands structure was cast-in-situ self-stressing concrete. The upper rows of the stands were covered by a steel frame roof 10 meters in depth. (OCOG-80, 1980). Figure 2.65 shows the Luzhniki stadium in 1980.



Figure 2.65 General view of the Luzhniki stadium in 1980 (OCOG-80, 1980, p. 85).

After Olympic Games, the Central Lenin stadium continued to be the home ground for soccer team as well as hosting athletics and rugby games. The Central Lenin stadium was renamed to Luzhniki Stadium in 1992. As a result of extensive renovation in 1996, a roof was applied over the stands and seating area were refurbished which led to the spectator capacity reduction to 78,360 seats (Olympic complex Luzhniki, 2015). Figure 2.66 shows the general view of the Luzhniki stadium in 2010.



Figure 2.66 General view of the Luzhniki stadium in 2010 (Muehlbradt, 2010).

2.3.19 The 1988 Jamsil Olympic stadium, Seoul, Korea

The Jamsil Olympic stadium, designed by architect Kim Swoo-geun, was built in 1984 with the spectator capacity of 100,000 seats (Schmidt, 1987; SLOOC, 1988). The longitudinal axis of stadium was 208 meters and transverse axis was 145 meters (Schmidt, 1987). Although stadium hosted 10th Asian Games in 1986, it was constructed with the purpose of hosting 1988 summer Olympic Games (Schmidt, 1987). The roof of the stadium was curved wave-like form composed of reinforced concrete consoles. At current state, Jamsil Olympic stadium has spectator capacity of 69,841 seats (Jamsil stadium, 2015). Figure 2.67 shows the general view of Jamsil Olympic Stadium during 1988 summer Olympic Games.



Figure 2.67 General view of Jamsil Olympic Stadium during 1988 summer Olympic Games (Olympic Games, 1988).

2.3.20 The 1992 Barcelona Olympic Stadium, Barcelona, Spain

The Barcelona Olympic stadium, designed by architect Domènech i Roure, was built in 1929 for the Barcelona International Exposition (COOB'92, 1992). The stadium was used for second Mediterranean Games in 1955, but after the games it was fallen into disuse. The 1992 summer Olympic Games were the impulse for rebuilding the stadium to be used for sport and for musical and cultural events (COOB'92, 1992). In this respect, the playing field was lowered eleven meters which made it possible to increase the spectator capacity to 60,000 seats. In addition, a roof structure was erected over the west grandstand which was 150 meters long and 30 meters deep. As it was planned at the beginning, after Olympic Games stadium used for soccer, athletics and cultural musical events. At its current state Barcelona Olympic stadium has spectator capacity of 54,000 (Estadi Olímpic, 2015). Figure 2.68 shows the general view of Barcelona Olympic Stadium in 1992.



Figure 2.68 General view of the Barcelona Olympic Stadium in 1992 (COOB'92, 1992, p.162).

2.3.21 The 1996 Centennial Olympic stadium, Atlanta, USA

The Centennial Olympic stadium, designed by architects Williams Russell and Johnson Ellerbe Becket, was built in 1996 to host summer Olympic Games (OCOG, 1996). The 1996 Centennial Olympic Stadium can be mentioned as the first Olympic stadium which initiated to include technical sustainable features to its design. The main focus of the design was on post-Olympic functioning of the stadium which was designed to be converted to baseball stadium after games in order to sustain its service life (OCHOA, 1896). In this respect, the stadium was designed to have spectator capacity of 85,000 seats during the games and spectator capacity of 45,000 seats after the games (Figure 2.69). In addition, materials and construction techniques were selected in such a way to ease the demount ability of the stadium after games. For instance; precast sections were used and slab-on-grade construction was conducted to the design (OCHOA, 1896; French & Mike, 1997).



Figure 2.69 General view of the Centennial Olympic stadium in 1996 (Olympic Games, 1996).

After the Olympic Games, the stadium was converted to baseball stadium and renamed to Turner Field which became the home ground for the Atlanta Braves in 1997 (Figure 2.70) (French & Mike, 1997).

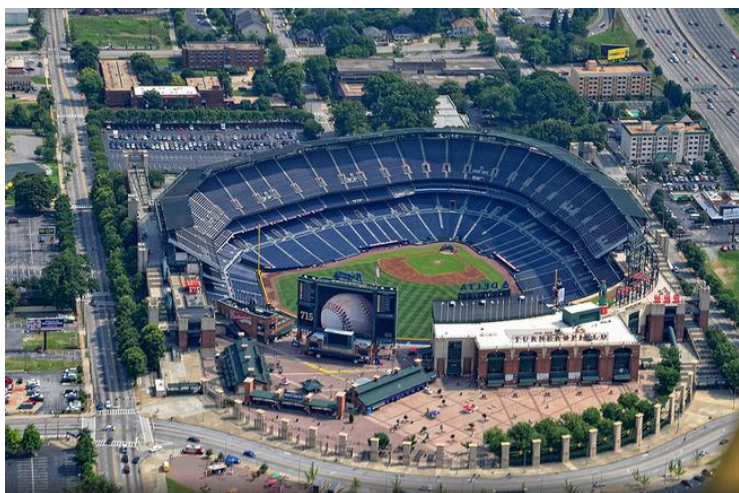


Figure 2.70 General view of Turner Field in 2013 (Foster, 2013).

2.3.22 The 2000 ANZ stadium, Sydney, Australia

The ANZ stadium, also known as Stadium Australia, was designed by Populous and Bligh Voller Nield to host 2000 summer Olympic Games (OCA, 2000). The Sydney 2000 Olympic Games were the first games for which environmental guideline was established in order to construct the venues with the environmentally sensitive approach (OCA, 2000). The 2000 ANZ stadium can be mentioned as a successful stadium in terms of conducting sustainable features mentioned/defined in manuals recommendations and guidelines. The stadium was registered as local object in 2000 (Kiuri & Teller, 2015). Figure 2.71 shows the general view of ANZ stadium during 2000 summer Olympic Games.



Figure 2.71 General view of the ANZ stadium during 2000 summer Olympic Games (Olympic Games, 2000).

The construction site was a suburb formerly home to abattoirs, factories and an industrial dump which turned into recreational land for Olympic Games (OCA, 2000).

The most important and intriguing part of the design was two temporary stands at North and South to be removed after games thus reducing the capacity of the stadium for future uses from 110,000 to 83,500 seats (Figure 2.72). In this respect, those temporary stands were constructed with steel to be recycled or reused after removing. On the other hand, the field was converted to rectangular field, and movable seats were located around the playing field which would provide the opportunity to add the track around the field in future. In addition, in order to minimize the shadow and patches of sunlight translucent polycarbonate was used for roof covering (OCA, 2000; Traganou, 2008). Moreover, Water efficiency issues such as rainwater collection for pitch irrigation as well as water recycling and purifying systems for toilet flushing and landscape irrigation was conducted to the design. The design was also integrated with natural ventilation, cooling and heating strategies for interior spaces of stadium (Traganou, 2008; Georgoulas & Patramanis, 2009).



Figure 2.72 General view of the ANZ stadium in 2014 (Pope, 2014).

2.3.23 The 2004 Athens Olympic stadium, Athens, Greece

The Athens Olympic Stadium, was built in 1982 with spectator capacity of 70,000 order to host 13th European Athletics Championship (OAKA, 2015). The stadium was used as the main stadium for 2004 summer Olympic Games. In this respect, the stadium was redeveloped to be an urban centre of athletics and culture for continuous operation (Georgoulas & Theodoros).

Developing an existing structure to be used for new purposes can be mentioned as sustainable feature that has been recommended by different manuals. In developing the existing non-roof stadium, a roof was erected over the most of the stands area for which stainless steel and Polycarbonate panels were used (Figure 2.73) (Traganou, 2008). The special additive in polycarbonate panels keeps the spectators cool despite the summer heat and reflects the majority of the radiant heat from natural sunlight, but still allows the visible part of the light to pass through (Georgoulas & Patramanis, 2009). In addition, playing field was designed with 6.000 plastic cap in which lawn is grown thus allowing the movement of lawn outside of the stadium to use the field for different events. Moreover, programmed irrigation system by 35 automatically elevated water launchers for lawn was implemented (OAKA, 2005).

The Athens Olympic Stadium in current state has the spectator capacity of 70,000 seats and it is the home ground for national soccer team (OAKA, 2015). Figure 2.73 shows the Athens Olympic stadium during 2004 summer Olympic Games.



Figure 2.73 General view of Athens Olympic Stadium in 2004 (Olympic Games, 2004).

2.3.24 The 2008 Beijing National stadium, Beijing, China

The Beijing National stadium, designed by Herzog & de Meuron Architekten AG, was built in 2008 in order to host summer Olympic Games (BOCOG, 2008). The Stadium can be mentioned as one of the successful structures in terms of integrating technical sustainable features to its design. Similar to 1996 and 2000 stadiums, capacity reduction after games was planned in preliminary design stage. In this respect, 11000 temporary stands were designed in upper parts of the stands area to be removed after games (Figure, 2.74) (BOCOG, 2008). In addition, similar to 2000 ANZ Stadium, rainwater collection system was conducted to the design. Beijing Olympic stadium is the first Olympic stadium which integrated solar photovoltaic panels on roof. The stadium also integrated ground source heat pump in order to produce energy for cooling purposes in summer and heating purposes in winter (BOCOG, 2008). On the other hand, outer part of the roof was covered with transparent ethyl tetrafluoro ethylene (ETFE) which functions as weather proof protection and inner part of roof was covered with translucent poly tetrafluoro ethylene (PTFE) which serves as the

acoustic ceiling and provides shade for the spectators (BOCOG, 2008; Choi & Michael, 2009; Parrish, 2009).



Figure 2.74 Seating bowl of Beijing National stadium with red line showing the margin for temporary seats to be removed after games (Parrish, 2009, p. 10).



Figure 2.75 General view of the Beijing National Stadium in 2008 (Olympic Games, 2008).

2.3.25 The 2012 London Olympic Stadium, London, England

The London Olympic stadium, designed by Rod Sheard, was built in 2012 with the spectator capacity of 80,000 seats in order to host summer Olympic Games (Knight & Sybil 2012; Cole & Hulme, 2011). The most important part of the design was temporary stands to make the stadium adaptable and demountable after games which allowed major capacity reduction from 85000 to 54000 for future uses (Knight & Sybil 2012; The stadium, 2015). In this respect, temporary stands were constructed with steel sections to be recycled or reused after removing. The stadium stands was built in two main tiers. The lower tier surrounded the playing field had the spectator capacity of 25,000 seats. The upper tier which was designed as temporary stand to be removed after the games had the spectator capacity 55,000 seats (Civil engineering, 2011).

The spectator stands were partially sheltered with roof structure called Bicycle wheel' cable net roof (Cole & Hulme, 2011). It is important to be mentioned that much parts of the roof trusses were constructed using surplus stock wastage from the steel industry. On the other hand, prefabricated concrete sections with 36% recycled concrete aggregate were used and 98 percent of materials from the buildings demolished were recycled or reused for construction. In addition PVC-coated polyester roof covering was used to be recycled after games (Knight & Sybil 2012; Cole & Hulme, 2011).

From 2016, London Olympic Stadium will be the home ground for West Ham United FC (football club) and it will be National competition Centre for Athletics in England. The stadium will be also used for cultural events, concerts and conferences (The stadium, 2015). Figure 2.76 shows the general view of the London Olympic stadium in 2012.



Figure 2.76 General view of London Olympic Stadium in 2012 (Knight & Sybil 2012, p.8).

CHAPTER 3

MATERIAL AND METHOD

This study was conducted on the main structures of modern summer Olympic Games built or renovated between 1896 and 2012. These stadiums have been used for Olympic athletics games, final football matches of Olympic Games, and opening/closing ceremonies during the Olympic Games. The examination of the modern Olympic Stadiums were done in terms of some measurable or descriptive variables/parameters.

Measurable and/or numerical parameters used for the analyses were listed below:

- “Olympic date”, as well as “construction date”, “renovation date” after Olympic Games, “demolished date” of stadiums;
- “overall spectator capacity” including seating and standing spectator capacities of main stadium structures;
- “current spectator capacity”, in other words the overall capacity renovated for post-Olympic use of stadiums;
- “seating capacity” referring only to the seats allocated in stands area;
- “dates of major post events” hosted by each stadium during their service life;
- “host city population” based on the population officially-declared for the host city on Olympic date;
- “orientation/slope of playing field axis” which is the deviation of central longitudinal axis of the stadium’s playing field in degrees in accordance with N/S axis;

- “viewing comfort zones of stands area” based on “best viewing radius”, “optimum viewing distance” and “maximum viewing distance” for international athletics and soccer games;
- “geometrical layout of stands area” based on two-dimensional geometrical patterns classified in technical manuals.

Descriptive/verbal parameters were listed below:

- “types of post-Olympic events” held in Olympic stadiums after Olympic Games including both many sports types and non-sports activities,
- “climate zone” of host cities,
- “presence of roof” covering the stands area, mainly in terms of “fully-sheltered stands area” or “partially-sheltered stands area”
- “presence of any technical feature” contributing to the sustainable use of stadiums related with site preservation, water and energy efficiency and long-term use.

Those main stadium structures of Summer Olympic Games were examined in terms of those descriptive and measurable parameters mentioned above. A focus was given on some basic features of stadiums’ plan layout, mainly in terms of minimum seating capacity, sheltered seat capacity, ideal positioning of stands and playing field areas, which are major criteria to assess efficiency of their physical capacity/performance for both Olympic and post-Olympic uses. Here, fulfilling of those features in acceptable ranges and positioning were investigated for each stadium to better understand their efficiencies and/or potentials for post-Olympic uses, especially for hosting international many sports competitions. The methods for data acquisition and their analyses are described under respective subheadings.

Some parameters, such as “viewing angle of stands area”, “density of stands area” and “maximum escape distance”, cannot be included in the analyses since it was not possible to achieve accurate data on those parameters and scaled architectural drawings, specifically the scaled section drawings of stands area, although direct contacts with the official websites of stadiums were provided.

3.1 STADIUMS EXAMINED

Twenty six stadiums hosted the summer Olympic Games from 1896 to 2012 were examined for the study. Namely, they are listed in Table 3.1 together with data on the Olympic date, host city and country, continent, architect(s). Known as modern Olympic Games, twenty seven Summer Olympic Games have been held in this period but stadium of 1900 Olympics in Paris is eliminated due to the lack of information in published literature considering the parameters aimed to be assessed for the study. The quantity of host Countries by continent are shown in Figure 3.1. The host cities of Olympic Games are shown in world map in Figure 3.2.

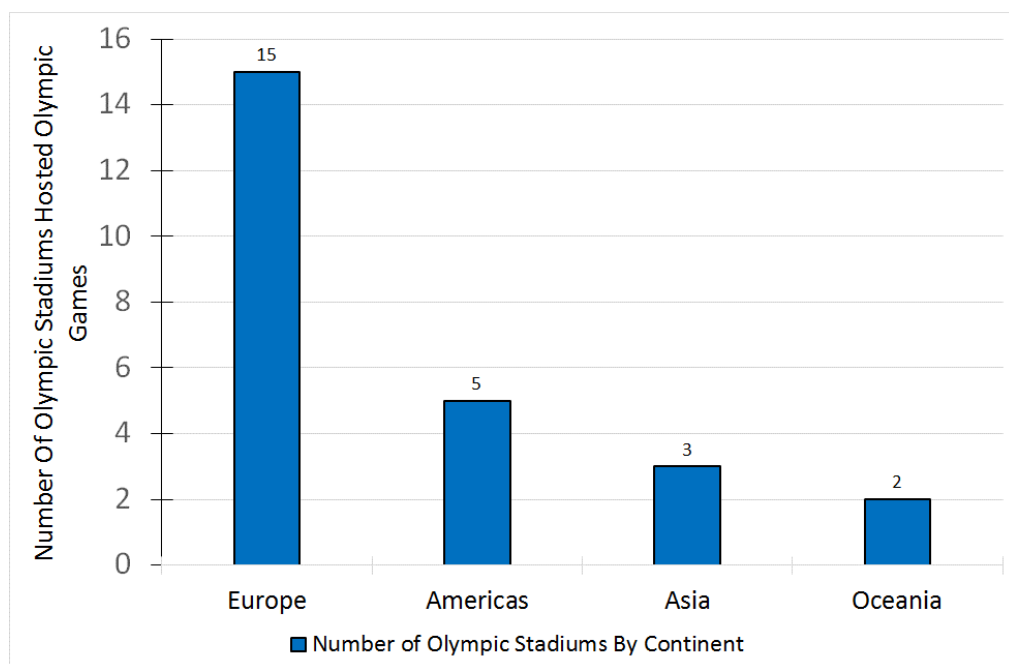


Figure 3.1 # of main summer Olympic Stadiums in Europe, Americas, Asia, and Oceania.

Table 3.1 List of main stadiums of summer Olympic Games from 1896 to 2012 in terms of their name, date of Olympic Games, city and country, architects and relevant reference where the information taken.

Name	Olympic Date	City/ Country	Continent	Architect(s)	Reference(s)
Panathenaic Stadium	1896	Athens/ Greece	Europe	Ernest. Ziller	OCO A, 1896
Francis Field	1904	St. Louis/ USA	Americas	NA	Lucas, 1905
White City Stadium	1908	London/ England	Europe	James Fulton	BOC, 1908
Stockholm Stadium	1912	Stockholm/ Sweden	Europe	Torben Grut	SOC, 1913
Olympisch Stadium	1920	Antwerp/ Belgium	Europe	Somers and Montigny	Schmidt, 1988; Renson & Marijke, 1997
Stade Yves-du-Manoir	1924	Paris/ France	Europe	Faure-DUJARRIC	COF, 1924;
Olympisch Stadium Amsterdam	1928	Amsterdam/ Netherlands	Europe	Jan WILS	TNOC, 1928
Los Angeles Memorial Coliseum	1932	Los Angeles/ USA	Americas	John and Donald PARKINSON	OCLA, 1933
Olympia stadion Berlin	1936	Berlin/ Germany	Europe	Werner March	OKOB, 1936
Empire Stadium	1948	London/ England	Europe	John SIMPSON, Maxwell AYRTON	LOCOG, 1948
Olympia-stadion Helsinki	1952	Helsinki/ Finland	Europe	Yrjö Lindegren and Toivo Jäntti	OCOH, 1955; Olympi astadion, 2015
Melbourne Cricket Ground	1956	Melbourne/ Australia	Oceania	Arthur W. Purnell	OCOM, 1958;
Stadio Olimpico	1960	Rome/ Italy	Europe	Mario Moretti	CONI, 1960
National Olympic Stadium	1964	Tokyo/ Japan	Asia	Mitsuo Katayama	TOCOG, 1964
Estadio Olimpico Universitario	1968	Mexico City/ Mexico	Americas	Augusto Perez, Raul Salinas, and Jorge Bravo Moro	OCOM, 1969
Munich Olympic Stadium	1972	Munich/ Germany	Europe	Behnisch and Associates	OCOM, 1972

Table 3.1 (Continued).

Montreal Olympic Stadium	1976	Montreal/Canada	Americas	Roger Taillibert	COJO'76, 1976
Luzhniki Stadium	1980	Moscow/Russia	Europe	NA	OCOG-80, 1980
Los Angeles Memorial Coliseum	1984	Los Angeles/USA	Americas	John and Donald Parkinson	LAOOC, 1985
Jamsil Olympic stadium	1988	Seoul/South Korea	Asia	Kim Swoo-Geun	SLOOC, 1988
Barcelona Olympic Stadium	1992	Barcelona/Spain	Europe	Domènech i Roure	COOB'92, 1992
Centennial Olympic Stadium	1996	Atlanta/USA	Americas	Williams-Russell and Johnson Ellerbe Becket	ACOG, 1996
Stadium Australia	2000	Sydney/Australia	Oceania	Populous and Bligh Voller Nield	OCA, 2000
Athens Olympic Stadium	2004	Athens/Greece	Europe	Santiago Calatrava ;Roof design	Traganou, 2008
Beijing National Stadium	2008	Beijing/China	Asia	Herzog & de Meuron Architekten AG	BOCOG, 2008
London Olympic Stadium	2012	London/England	Europe	Road Sheard and Populus	Knight & Sybil 2012; The Stadium, 2015;

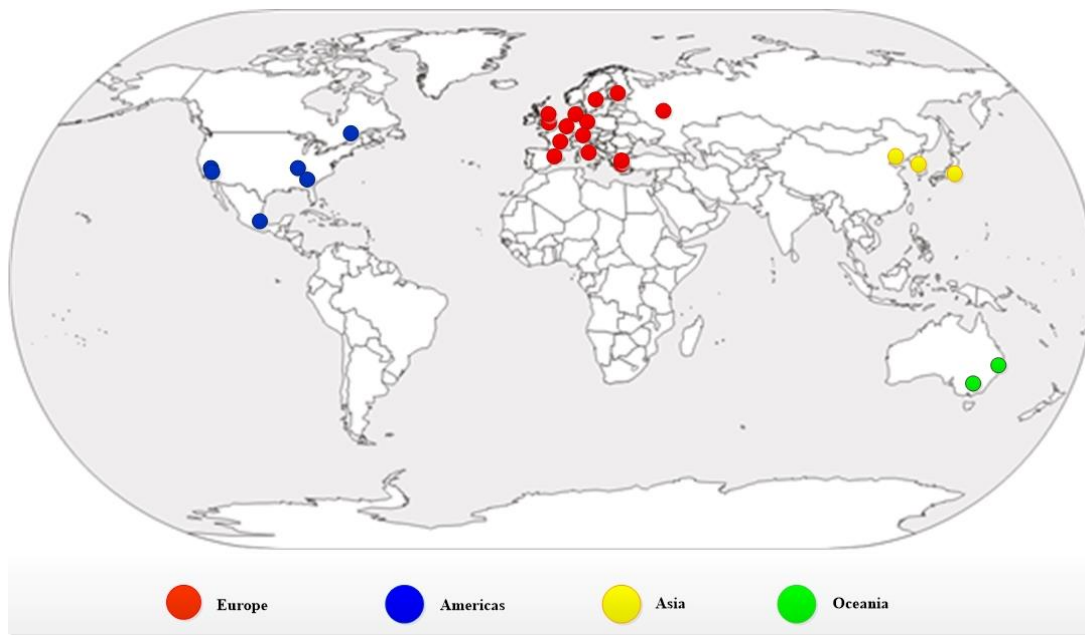


Figure 3.2 The world map showing the distribution of 26 main stadiums' locations where summer Olympic Games were held from 1896 to 2012.

The Los Angeles Memorial Coliseum is the only stadium which was used two times as the main stadium for summer Olympic Games in 1932 and 1984. Considering this, in the examinations of “playing field orientation”, “viewing comfort zones of stands area” and “post-Olympic uses” the number of examined stadiums was counted as 25 while for all other analyses the number of examined stadiums was counted as 26.

3.2 DATA ACQUISITION ON SPECIFIC FEATURES OF STADIUMS

A detailed archive research was conducted or data acquisition on specific properties and specifications of stadiums. The data were then classified, if needed processed, to be able to examine the main stadiums of Summer Olympic games in terms of some measurable/numerical and descriptive/verbal parameters. The parameters for the analyses were selected by taking into consideration some acceptances/criteria on:

- spectator capacity performance,
 - physical performance of geometrical layout (in terms of viewing comfort conditions for athletes and spectators),
 - long-term functioning of stadiums,
- all of which mentioned/defined in technical recommendations/regulations/guidelines on stadium design and sustainability issues.

The data on those assessment parameters were collected from stadium design manuals, relevant books, official reports of Olympic Games, scientific articles, conference proceedings, newsletters, and official websites of Olympic Stadiums. For instances:

- Data on host city population belonging to the Olympic date were obtained by direct communication with 22 official demographic agencies of host cities in the form of mutual correspondence via e-mail.
- Data on post-event use of main summer Olympic Stadiums in other words the types of events that have been held in those stadiums were collected from official websites of main Summer Olympic stadiums. For some cases, namely “1896 Panathenaic Stadium”, “1924, Stade Yves-du-Manoir stadium”, “1932/1984 Los Angeles Memorial Coliseum”, and “1952 Olympiastadion Helsinki” the relevant data were acquired from official websites of those stadiums by mutual correspondence via e-mail.

Data on orientation of stadiums in terms of deviation (slope) of longitudinal central axis of stadiums’ playing fields in reference to N/S axis, were extracted from scaled schematic plan drawings. Those drawings were reproduced by benefitting from the scaled sketch plan drawings, figures, sketches, google earth images given in technical manuals and books on stadium design (Table 2.1), official reports on Olympic Games (Table 3.1, see Column for References) and scientific articles (Hellenic Olympic Committee, 1896; Palacios *et al.*, 1968; Higgot, 1999; Choi & Michael, 2009; Parrish, 2009; Jonker, 2011; Yau, 2015).

- Data on climate zones for 22 host cities of stadiums were produced by juxtaposition of host cities’ locations on Köppen-Geiger World Climate

Classification Map which has been reproduced as a digital map by Kottek and friends (Kottek, *et al.*, 2006).

3.3 METHODOLOGY

The data on the measurable parameters were analysed to better-understand the changes or evolution of Olympic stadiums in time. For this purpose, the graphs were produced to examine:

- the relationship between “spectator capacities of stadiums” and “time (date of Olympic Games)”, considering regulations on seating and overall spectator capacities required for major sports competitions;
- the types of post-Olympic activities and possible use of stadiums to host those activities in order to identify the promising/favourite post-event types to sustain functioning of main stadiums and to better-understand selection criteria of post-events in relation to capacity features of stadiums and regional preferences;
- the relationship between “overall spectator capacity” of stadiums and “population of the host city” on Olympic date;
- the slope of longitudinal central axis of stadiums’ playing fields on Cartesian coordinate plane showing the deviation of that axis from N/S axis and their appropriateness for international many sports and soccer games;
- the “best”, “optimum” and “maximum” viewing zones of each stadiums’ stands area and efficiency of their plan layouts for international many sports and athletics competitions.

The data plotted in those graphs described above were evaluated by means of producing the trend lines showing the linear correlation between two parameters, analyses of distribution of data, and/or calculating the average values of the numerical data together with standard deviation. The interpretations of numerical values were done by discussing the data in accordance with the capacities/requirements defined numerically in standards/recommendations/regulations, such as IOC Technical Manual on Venues: Design Standards for Competition Venues 2005 and FIFA

Football Stadiums; Technical Recommendation and Requirements 4th edition 2007. All documents benefitted for the evaluations were listed in Table 2.1 where the relevant reference data for each assessment were mentioned under respective discussions.

In addition, the sustainability features of each stadium were assessed by checking the presence of any item/feature related with the issues of site preservation, water efficiency, energy efficiency, and long-term use, as mentioned in technical guidelines and/or recommendations. The descriptive data were gathered in documentary tables in order to determine the common sustainability features involved in Olympic stadium designs.

Some methods were also used/adapted for data acquisition and their evaluations, such for the identification and assessment of “climate zones where the stadiums constructed”, “orientation of stadiums’ playing fields”, and “optimum viewing zones of stands area” in relation to “geometrical layout of stands area”. Those methods were explained under respective subheadings.

3.3.1 Identification of Climate Zone where the stadiums are located

The climate zone of stadiums where they are located were identified according to the World Climate Classification Map defined by Köppen-Geiger (Köppen, 1900; Geiger, 1954, 1957).

Köppen has presented the first quantitative classification of world climates. This classification has been constructed on the basis of five vegetation groups. Each climate type is presented by three letters in an order (Kottek, *et al*, 2006). First letter in capitals defines vegetation groups; Equatorial zone (A), the Arid zone (B), the Warm Temperate zone (C), the Snow zone (D) and the Polar zone (E). The second letter refers to the type of “Precipitation” for the assigned vegetation zone. The third letter gives information on “Air Temperature” characteristics for the assigned vegetation

zone. The abbreviations representing the types of vegetation zone, precipitation and air temperature are listed below in Table 3.2 (Kottek *et al.*, 2006). The combination of vegetation zone, precipitation and temperature characteristics derives 31 different climate types to classify the climate any location on earth.

Table 3.2 The abbreviations that represent the types of vegetation zone, precipitation and air temperature (Kottek *et al.*, 2006).

Main climates /Vegetation Zones	Precipitation	Temperature
A: equatorial	W: desert	a: hot summer
B: arid	S: steppe	b: warm summer
C: warm temperate	f: fully humid	c: cool summer
D: snow	s: summer dry	d: extremely continental
E: polar	w: winter dry	h: hot arid
	m: monsoonal	k: cold arid
		F: polar frost
		T: polar tundra

Table 3.3 Types and descriptions of climate zones together with the specified climatic data in terms of temperature in °C and precipitation in mm (Kottek *et al.*, 2006, p. 260,262).

First and Second letters		
Type	Description	Criterion
A	Equatorial climates	$T_{min} \geq +18\text{ }^{\circ}\text{C}$
Af	Equatorial rainforest, fully humid	$P_{min} \geq 60\text{ mm}$
Am	Equatorial monsoon	$P_{ann} \geq 25(100-P_{min})$
As	Equatorial savannah with dry summer	$P_{min} < 60\text{ mm in summer}$
Aw	Equatorial savannah with dry winter	$P_{min} < 60\text{ mm in winter}$
B	Arid climates	$P_{ann} < 10\text{ Pth}$
BS	Steppe climate	$P_{ann} > 5\text{ Pth}$
BW	Desert climate	$P_{ann} \leq 5\text{ Pth}$
C	Warm temperate climates	$-3\text{ }^{\circ}\text{C} < T_{max} < +18\text{ }^{\circ}\text{C}$
Cs	Warm temperate climate with dry summer	$P_{min} < P_{Wmin}$, $P_{wmax} > 3\text{ P}_{min}$ and $P_{min} < 40\text{mm}$
Cw	Warm temperate climate with dry winter	$P_{wmin} < P_{min}$ and $P_{smax} > 10\text{ P}_{wmin}$
Cf	Warm temperate climate, fully humid	Neither Cs nor Cw

Table 3.3 (Continued).

D	Snow climates	$T_{min} \leq -3\text{ }^{\circ}\text{C}$
Ds	Snow climate with dry summer	$P_{smin} < P_{wmin}, P_{wmax} > 3 P_{smin}$ and $P_{smin} < 40\text{ mm}$
Dw	Snow climate with dry winter	$P_{wmin} < P_{smin}$ and $P_{smax} > 10 P_{wmin}$
Df	Snow climate, fully humid	neither Ds nor Dw
E	Polar climates	$T_{max} < +10\text{ }^{\circ}\text{C}$
ET	Tundra climate	$0^{\circ} < T_{max} < +10^{\circ}\text{C}$
EF	Frost climate	$T_{max} < 10\text{ }^{\circ}\text{C}$
Third letter		
Type	Description	Criterion
h	Hot steppe / desert	$T_{ann} \geq +18\text{ }^{\circ}\text{C}$
k	Cold steppe /desert	$T_{ann} < +18\text{ }^{\circ}\text{C}$
a	Hot summer	$T_{max} \geq +22\text{ }^{\circ}\text{C}$
b	Warm summer	not(a) at least 4 $T_{mon} \geq +10\text{ }^{\circ}\text{C}$
c	Cool summer and cold winter	not (b) and $T_{min} > -38\text{ }^{\circ}\text{C}$
d	extremely continental	like (C) but $T_{min} \leq -38\text{ }^{\circ}\text{C}$
<i>T_{min}</i> : The monthly mean temperature of the coldest months; <i>T_{max}</i> : The monthly mean temperature of the warmest months; <i>P_{smin}</i> : The lowest monthly precipitation values for the summer half-year; <i>P_{smax}</i> : The highest monthly precipitation values for the summer half-year, on the hemisphere; <i>P_{wmin}</i> : The lowest monthly precipitation values for the winter half-year; <i>P_{smax}</i> : The highest monthly precipitation values for the winter half-year, on the hemisphere.		

3.3.2 Identification of playing field orientation

The playing field orientation of stadiums, whether they are within the range of acceptable directions or not, were examined. The central longitudinal axis of stadium's playing field, shortly called as "the central axis of the playing field" was determined for each stadium on their schematic scaled drawings. Those plan drawings were redrawn by using AutoCAD 2013 software by benefitting from the relevant data, sketches, and figures collected from written literature.

The methods used for achieving data on the orientation of stadiums' playing field and their analyses were described below:

- The central axis of the playing field was positioned on plan layout and then its angle, in other words, deviation in degrees from $\overrightarrow{NS}$ axis was determined by using AutoCAD software.
- That plan layout was inserted in Cartesian coordinate plane by positioning the centre of the plan layout on the origin O (0, 0). The y-axis of the plane was accepted to indicate “North”, corresponding with $\overrightarrow{NS}$ direction.
- The angle of slope determined for the central axis of each stadium is then converted to a linear equation.
- The linear equation representing the direction of central axis belonging to each stadium were plot in XY graph based on Cartesian coordination system.
- The position of stadiums were checked whether they fall into the acceptable directions or not.

The stadiums examined where grouped as “properly-oriented” for many sports games, athletics games, soccer and rugby games, or “poorly-oriented” for any sports games (See Table 2.2 for acceptable ranges recommended for specific types of sports). The athletics games are performed throughout day, therefore, the period of time used for the sports activities is longer when compared with the soccer games which were mostly played in afternoons and evenings. The wider slope range (such as ‘20°N/E–75°N/W’), therefore, can be acceptable for soccer/rugby games, while narrower slope range is needed (such as 20°N/E–45°N/W’) for the games performed throughout a day. The best orientation for most sports events were accepted to be within 0°-15° deviation from North to West.

3.3.3 Identification of optimum viewing zones in stadiums

Since most stadiums host soccer games followed by athletics after Olympic Games, the stadiums were evaluated according to the recommended/accepted optimum and maximum viewing circles defined for soccer/rugby and athletics games. Those circles define recommended zones for spectators which are satisfactory for proper-viewing

and refer to the positioning of seat areas with best, optimum and maximum viewing distances. Those distances were summarized in Table 3.4. The classification of seats depending on their optical comfort features has also commercial importance. For the evaluations, the optimum and maximum viewing circles for soccer games were deduced by the “best viewing radius”, “optimum viewing distance” and “maximum viewing distance” which are 90m, 150m and 190m, respectively. The optimum and maximum viewing circles for athletics games were deduced by considering the “best viewing radius” and “optimum viewing distance” of 130m and 190m, respectively. Those values are required to provide a good spectator-player relationship during soccer/rugby and athletics games (Nixdorf, 2008; Geraint *et al.*, 2013).

The relationship between the viewing performance of stands area and their geometric layout was examined. The main forms used to shortly-define the geometric pattern of stands area are circular, semi-circular, oval, U-shaped and basket arch geometries. The efficiency of those geometries was discussed related to the recommended viewing circles and to the overall spectator capacities.

In addition, the seat area positioned to the west of playing field extends back to the limit of the optimum viewing circle is recommended more than the seats positioned to the east. Asymmetric layouts providing seat area mostly located at the south and west as well as mostly kept within the optimum viewing circle, is preferable since such layouts allow the majority of spectators have their backs to the sun during games.

Table 3.4 The best, optimum and maximum viewing distances and Radius for Soccer, Rugby and Athletics competitions.

Viewing location	Soccer/Rugby games	Athletics games	References
Best viewing radius	90m	130m	(BSI, 2003; Nixdorf, 2008; Geraint <i>et al.</i> , 2013)
Optimum viewing distance	150m	190m	(BSI, 2003; Nixdorf, 2008; Geraint <i>et al.</i> , 2013)
Maximum viewing distance	190m	230m	(BSI, 2003; Nixdorf, 2008; Geraint <i>et al.</i> , 2013)

The method used for the deduction of viewing circles was explained in Figure 3.3. Here, the best viewing circles/zones (BVC) were inserted in plan by drawing a circle with a radius of 90m for soccer games and a radius of 130m for athletics games, from the centre spot of the playing field. The edges of the optimum viewing circle/zone (OVC) for soccer/rugby games were placed in plan layout by drawing arcs running through N-W, W-S, S-E and E-N directions. Those arches were produced by drawing four circles with a radius of 150m where their centres were positioned to each corner of the playing field. The maximum viewing circle/zone (MVC) defined for soccer/rugby games corresponds with the optimum/recommended viewing zone defined for athletics games. Here, the recommended bird's eye view distance is 190m between each extreme edge of the playing field and the spectator seat. The edges of the maximum viewing zone were drawn by the same technique described for defining the optimum viewing zone while the radius of circles were taken as 190m.

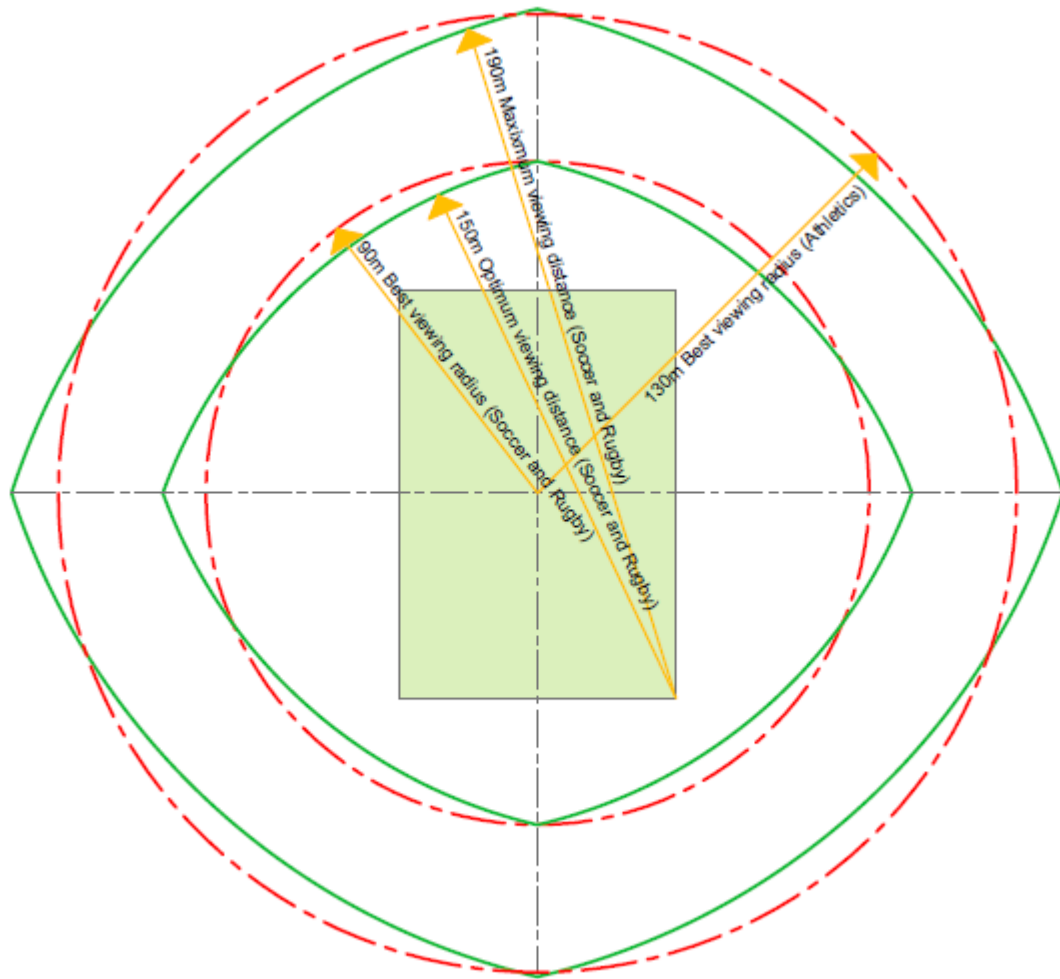


Figure 3.3 Relationships between playing field, best viewing radius, optimum and maximum viewing circles/zones for soccer/rugby and athletics games(adapted by author from sources Nixdorf, 2008; Geraint *et al.*, 2013).

The juxtaposition of recommended viewing circles and plan layout of stadiums presented:

- “the seat areas within the optimum and maximum viewing circles” which are “satisfactory” for providing optical comfort conditions for spectators”;

- “the seat area partially beyond the maximum viewing circles” which are “partially-satisfactory” for providing ideal viewing conditions, and
- “the seat areas extending the limit/borders of recommended viewing zones” which are “not satisfactory” and suffer from long distances between the playing field and spectator.

Here, the viewing comfort of stands area were examined in terms of preferred viewing comfort at stands while the optimum viewing angle of spectators stands were not included in examinations since scaled section drawings of stadiums structures were not available.

CHAPTER 4

RESULTS

The numerical data obtained from the detailed review of literature and from scaled sketch drawings of stadiums were evaluated in terms of “varieties in climate zone of stadiums”, “spectator capacity evolution in time”, “post-Olympic use of stadiums”, “relationship between the spectator capacity and host city population”, “appropriateness of stadiums’ playing field orientations”, and “efficiency of viewing comfort in stadiums’ stands area”. The sustainability features commonly observed in Olympic stadiums were also summarized which can be useful for professions interested in stadiums design. Those evaluations were explained under respective subheadings.

4.1 VARIETIES IN CLIMATE ZONES WHERE STADIUMS WERE BUILT

The climate zones and types of host cities were identified in reference to Köppen-Geiger World Climate Classification Map (Kottek *et al.*, 2006) and presented in Table 4.1. The results exhibited the climatic characteristics of the host cities, generally in terms of air temperature and precipitation, where the main stadiums were built. The reasons for fully-sheltered stands were determined in terms of precipitation and warmest temperature characteristics of those climate types. The roofs, if built in origin, and their positions were added on the schematic scaled plan drawings of stadiums (Figures C.1 – C.7). The data on the presence of roof structure in the origin of stadium structures or added later on were summarized in Table 4.2.

Table 4.1 The climate zones of host cities identified in reference to Köppen-Geiger World Climate Classification Map together with general definitions of climate zones in terms of precipitation, coldest and warmest temperature conditions.

Stadium	City/Country	Continent	Climate Classification	Temperature and Precipitation Criteria
1964 National Olympic Stadium	Tokyo/Japan	Asia	Cfa Warm Temperate/Fully Humid/Hot Summer	• $-3^{\circ}\text{C} < T_{\min} < +18^{\circ}\text{C}$; $T_{\max} \geq +22^{\circ}\text{C}$ • Constantly moist, precipitation is generally constant throughout the year
1996 Centennial Olympic Stadium	Atlanta/USA	Americas		
2000 ANZ Stadium	Sydney/Australia	Oceania	Cfb Warm Temperate/Fully Humid/Warm Summer	• $-3^{\circ}\text{C} < T_{\min} < +18^{\circ}\text{C}$; $T_{\max} \leq +22^{\circ}\text{C}$ • At least 4 months $T_{\min} \geq +10^{\circ}\text{C}$ • Constantly moist, precipitation is generally constant throughout the year
1908 White City Stadium	London/England	Europe		
1920 Olympisch Stadium	Antwerp/Belgium	Europe		
1924 Stade Yves-du-Manoir	Paris/France	Europe		
1928 Olympisch Stadium Amsterdam	Amsterdam/Netherlands	Europe		
1936 Olympiastadion Berlin	Berlin/Germany	Europe		
1948 Empire Stadium	London/England	Europe		
1956 Melbourne Cricket Ground	Melbourne/Australia	Oceania		
1972 Munich Olympic Stadium	Munich/Germany	Europe		
2012 London Olympic Stadium	London/England	Europe		
1896 Panathenaic Stadium	Athens/Greece	Europe	Csa Warm Temperate/Summer Dry/Hot Summer	• $-3^{\circ}\text{C} < T_{\min} < +18^{\circ}\text{C}$; $T_{\max} \geq +22^{\circ}\text{C}$ • $P_{\min} < P_{w\min}$; $P_{w\max} > 3 P_{\min}$ and $P_{\min} < 40\text{mm}$ • Dry season in summer when 70% or more of annual precipitation falls in winter
1932 Los Angeles Memorial Coliseum	Los Angeles/ USA	Americas		
1984 Los Angeles Memorial Coliseum	Los Angeles/ USA	Americas		
1960 Stadio Olimpico	Rome/Italy	Europe		
1992 Barcelona Olympic Stadium	Barcelona/Spain	Europe		
2004 Athens Olympic Stadium	Athens/Greece	Europe		

Table 4.1 (Continued).

1968 Estadio Olimpico Universitario	Mexico City/Mexico	Americas	Cwb Warm Temperate/Winter Dry/Warm Summer	• $-3^{\circ}\text{C} < T_{\text{min}} < +18^{\circ}\text{C}$; $T_{\text{max}} \leq +22^{\circ}\text{C}$ • At least 4 months $T_{\text{mon}} \geq +10^{\circ}\text{C}$ • $P_{\text{wmin}} < P_{\text{smin}}$ and $P_{\text{smax}} > 10 P_{\text{wmin}}$ • A noticeable difference between the dry winters and rainy summers. • Dry season in winter when 70% or more of annual precipitation falls in summer
1904 Francis Field	St. Louis/USA	Americas	Dfa Snow/fully humid/Hot Summer	• $T_{\text{min}} \leq -3^{\circ}\text{C}$; $T_{\text{max}} \geq +22^{\circ}\text{C}$; • Constantly moist, precipitation is generally constant throughout the year
1912 Stockholm Stadium	Stockholm/Sweden	Europe	Dfb Snow/Fully Humid/Warm Summer	• $T_{\text{min}} \leq -3^{\circ}\text{C}$; $T_{\text{max}} \leq +22^{\circ}\text{C}$; • at least 4 $T_{\text{mon}} \geq +10^{\circ}\text{C}$ • Constantly moist, precipitation is generally constant throughout the year
1952 Olympiastadion Helsinki	Helsinki/Finland	Europe		
1976 Montreal Olympic Stadium	Montreal/Canada	Americas		
1980 Luzhniki Stadium	Moscow/Russia	Europe	Dwa Snow/Winter Dry/Hot Summer	• $T_{\text{min}} \leq -3^{\circ}\text{C}$; $T_{\text{max}} \geq +22^{\circ}\text{C}$ • $P_{\text{wmin}} < P_{\text{smin}}$ and $P_{\text{smax}} > 10 P_{\text{wmin}}$ • Dry season in winter when 70% or more of annual precipitation falls in summer
1988 Jamsil Olympic Stadium	Seoul/South Korea	Asia		
2008 Beijing Olympic stadium	Beijing/China	Asia		
<i>Tmin</i> : The monthly mean temperature of the coldest months; <i>Tmax</i> : The monthly mean temperature of the warmest months; <i>Tann</i> : the annual mean; <i>Psmin</i> : The lowest monthly precipitation values for the summer half-year; <i>Psmax</i> : The highest monthly precipitation values for the summer half-year, on the hemisphere; <i>Pwmin</i> : The lowest monthly precipitation values for the winter half-year; <i>Psmax</i> : The highest monthly precipitation values for the winter half-year, on the hemisphere.				

The main stadiums seemed to be exposed environmental conditions of mainly “Warm Temperate Climate (C)” and “Snow Climate (D)” zones. Each host city belongs to one of seven climate types defined in Köppen-Geiger World Climate Classification for warm temperate or snow climate zones. (Table 4.1) The main features of 7 climate types are summarized below:

- Cfa – Warm Temperate/Fully Humid/Hot Summer: It refers mild mid-latitude climate having constantly moist conditions where precipitation/rainfall is consistent throughout the year; the coldest month is warmer than -3°C but colder than $+18^{\circ}\text{C}$, and the warmest month is above and equal to $+22^{\circ}\text{C}$. Three stadiums were observed to exist in that climate.
- Cfb – Warm Temperate/Fully Humid/Warm Summer: It refers mild mid-latitude climate having constantly moist conditions where precipitation/rainfall is consistent throughout the year; the coldest month is warmer than -3°C but colder than $+18^{\circ}\text{C}$ and at least 4 months warmer than 10°C but colder than $+22^{\circ}\text{C}$. Nine stadiums were observed to exist in that climate.
- Csa – Warm Temperate/Summer Dry/Hot Summer: It refers mild mid-latitude climate having dry season in summer when 70% or more of annual precipitation falls in winter; the coldest month is warmer than -3°C but colder than $+18^{\circ}\text{C}$, and the warmest month is above and equal to $+22^{\circ}\text{C}$. Six stadiums were observed to exist in that climate.
- Cwb – Warm Temperate/Winter Dry/Warm Summer: It refers mild mid-latitude climate having dry season in winter when 70% or more of annual precipitation falls in summer; the coldest month is warmer than -3°C but colder than $+18^{\circ}\text{C}$ and at least 4 months warmer than 10°C but colder than $+22^{\circ}\text{C}$. One stadium was observed to exist in that climate.
- Dfa – Snow/Fully humid/Hot Summer: It refers cold mid-latitude climate having constantly moist conditions where precipitation/rainfall is consistent throughout the year; the coldest month is colder than -3°C and the warmest month is above and equal to $+22^{\circ}\text{C}$. One stadium was observed to exist in that climate.
- Dfb – Snow/Fully Humid/Warm Summer: It refers cold mid-latitude climate having constantly moist conditions where precipitation/rainfall is consistent

throughout the year; the coldest month is colder than -3°C and at least 4 months warmer than 10°C but colder than $+22^{\circ}\text{C}$. Four stadiums were observed to exist in that climate.

- Dwa – Snow/Winter Dry/Hot Summer: It refers cold mid-latitude climate having dry season in winter when 70% or more of annual precipitation falls in summer; the coldest month is colder than -3°C and the warmest month is above and equal to $+22^{\circ}\text{C}$. Two stadiums were observed to exist in that climate.

According to the precipitation characteristics of all 7 climate zones, all stadiums need to have roof structure to shelter stands area from wetting during rainfall and/or snow. Since all stadiums are exposed to the precipitation conditions defined as “constantly moist” or “70% or more of annual precipitation falling in summer or winter months”, all require roof structures to shelter the stands area from wetting. Among 7 climate zones, 4 of them live hot summers with monthly-mean of warmest months more than 22°C . That also signals that 11 stadiums belonging to those hot summer climates have necessity of roof structure to save their stands area from sun exposure. In short, all stadiums should have been designed with a roof structure fully- covering their stands area due to the outdoor climatic conditions.

On the other hand, it was determined that only two stadiums have been fully-sheltered and one stadium mostly-sheltered in origin among 26 stadiums while the others did not have roof or had partially-roof covers (Table 4.2).

Table 4.2 Climate classification for host cities of modern summer Olympic Games according to Köppen-Geiger world climate classification map.

Name	City/ Country	Continent	Climate Zone	Roof sheltering stands on Olympic date *	Roof sheltering in current state *
1896 Panathenaic Stadium	Athens/ Greece	Europe	Csa	No roof	
1904 Francis Field	St. Louis/ USA	Americas	Dfa	No roof	
1908 White City Stadium	London/ England	Europe	Cfb	Partial stands area at NE & SW 1908	Fully sheltered stands area in 1971
1912 Stockholm Stadium	Stockholm/ Sweden	Europe	Dfb	Partial stands area at E, W, & S 1912	
1920 Olympisch Stadium	Antwerp/ Belgium	Europe	Cfb	Partial stands area at NE, & SW 1920	Fully sheltered stands area in 2000
1924 Stade Yves-du-Manoir	Paris/ France	Europe	Cfb	Partial stands area at E, & W 1924	
1928 Olympisch Stadium Amsterdam	Amsterdam/ Netherlands	Europe	Cfb	Partial stands area at E, & W 1928	
1932 Los Angeles Memorial Coliseum	Los Angeles / USA	Americas	Csa	No roof	
1936 Olympiastadion Berlin	Berlin/ Germany	Europe	Cfb	No roof	Fully sheltered stands area in 2000
1948 Empire Stadium	London/ England	Europe	Cfb	Partial stands area at N & S 1948	Fully sheltered stands area in 1963
1952 Olympiastadion Helsinki	Helsinki/ Finland	Europe	Dfb	Partial stands area at E 1952	Fully sheltered stands area in 2016
1956 Melbourne Cricket Ground	Melbourne/ Australia	Oceania	Cfb	Partial stands area at N, E, & S 1956	Fully sheltered stands area in 2006
1960 Stadio Olimpico	Rome/ Italy	Europe	Csa	No roof	Fully sheltered stands area in 1990
1964 National Olympic Stadium	Tokyo/ Japan	Asia	Cfa	Partial stands area at NW, & W 1964	
1968 Estadio Olimpico Universitario	Mexico City/ Mexico	Americas	Cwb	No roof	
1972 Munich Olympic Stadium	Munich, Germany	Europe	Cfb	Partial stands area at NW, W, SW, & S 1972	
1976 Montreal Olympic Stadium	Montreal/ Canada	Americas	Dfb	Fully-sheltered stands area in 1976	

Table 4.2 (Continued).

1980 Luzhniki Stadium	Moscow/ Russia	Europe	Dfb	Partial stands area at all directions 1980	Fully sheltered stands area in 1996
1932 Los Angeles Memorial Coliseum	Los Angeles / USA	Americas	Csa	Non-roof	
1988 Jamsil Olympic stadium	Seoul/ South Korea	Asia	Dwa	Most stands area at all directions 1988	
1992 Barcelona Olympic Stadium	Barcelona/ Spain	Europe	Csa	Partial stands area at W 1992	
1996 Centennial Olympic Stadium	Atlanta/ USA	Americas	Cfa	Partial stands area at S 1996	
2000 ANZ Stadium	Sydney, Australia	Oceania	Cfa	Partial stands area at E & W 2000	Fully sheltered stands area in 2002
2004 Athens Olympic Stadium	Athens/ Greece	Europe	Csa	Partial stands area at all directions 2004	
2008 Beijing National Stadium	Beijing/ China	Asia	Dwa	Fully sheltered 2008	
2012 London Olympic Stadium	London/ England	Europe	Cfb	Partially sheltered at all directions 2012	
LEGAND		NON-SHELTERED			(*) Year of roof construction
		PARTIALLY-SHELTERED			
		FULLY-SHELTERED			

The precipitation and warmest temperature characteristics of those identified climate zones exhibited the necessity of superstructure(s) protecting the spectators from exposed outside conditions of those climates. It should be noted that, such stadium structures bringing together ten thousands of people in their stands area, in one way or another, should be sheltered with roof(s). However, most of stadiums have been originally-built with partial covers only sheltering VIP and private seats (16 over 26 stadiums) and without any roof (7 over 26 stadiums). The exposed situation of spectators under non-sheltered conditions, definitely, is not acceptable. The stands area of 9 stadiums, later on, were fully-covered with roofs expectedly. Due to that necessity of fully-sheltered stands, “the requirement of fully-sheltered stands area” was involved in technical recommendations/guidelines for stadium design, and that requirement became an obligatory requirement especially declared for international

soccer and athletics competitions (FIFA, 1995; UEFA, 2001; Nixdorf, 2008; IAAF, 2014).

4.2 SPECTATOR CAPACITY EVOLUTION IN TIME

For Summer Olympic Games, the overall spectator capacities of main stadiums based on the Olympic date are given in Figure 4.1. “The overall spectator capacity” refers to the number of both seating and standing spectators who watch the games. Here structures originally constructed as Olympic stadium and renovated as Olympic stadium were considered for the analyses. Among the all 26 modern summer Olympic Stadiums, 12 Stadiums have been built specifically for the Olympic Games while 14 stadiums have been renovated to be used as the main stadium for the summer Olympic Games (Table A.1).

The numerical data obtained on their overall spectator capacities in terms of “original spectator capacity on Olympic date”, “the capacity renovated for Olympic Games” if the stadium is renovated for the date of Olympic Games, and “the current spectator capacity” provided for post-Olympic events were summarized in Table A.1.

The data on original and current spectator capacities of stadiums was evaluated to assess the changes in those capacities in relation to the date of Olympic Games, post-Olympic events hosted by the stadiums, types of those events, and population of the host cities.

4.2.1 Evaluation of Overall Spectator Capacities of Stadiums

The overall spectator capacity of the stadiums hosted Olympic Games was observed to vary in the range of 10,000 - 110,000 with an average of $75,203 \pm 26,802$ considering 26 stadiums examined in the study (Table A.1).

The plot of data has shown that the overall capacity of Olympic stadiums increased in time while two ranges of capacity were observed during the evolution of Olympic Games stadiums (Figure 4.1 and Figure 4.2). The overall spectator capacity data obtained from the structures originally constructed as Olympic stadiums presented the similar trend as well (Figure 4.3).

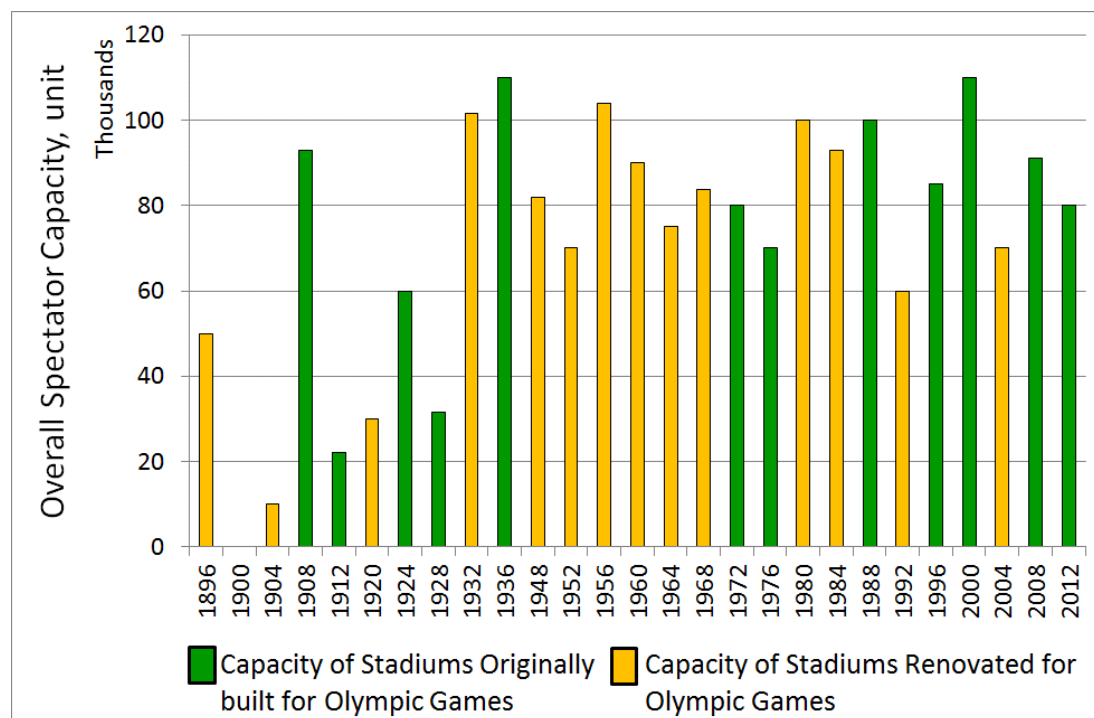


Figure 4.1 The overall spectator capacity of all main stadium structures, originally-constructed and renovated for the use of Summer Olympic Games from 1896 to 2012 in chronological order.

The analyses showed the presence of two ranges in spectator capacities for the periods between 1896-1928 and 1932-2012 (Figure 4.2 and Figure 4.3). The data obtained are explained below:

- The first range of spectator capacity is in the range of 10,000 - 93,000 with an average of $42,371 \pm 27,881$ within the period of 1896-1932 years. This period starts with the 1896 Panathenaic Stadium in Athens/Greece and ends with 1928 Amsterdam Olympisch Stadium in Netherlands.
- The second range of spectator capacity is in the range of 70,000-110,000 with an average of $87,120 \pm 14,598$ within the period of 1932-2012 years. This period started with the 1932 Stadium “Los Angeles Memorial Coliseum” in Missouri/USA with the overall capacity of 101,574 spectators which has been renovated to be used as main stadium for Olympic Games. (OCLA, 1933).
- The period of 1930’s corresponds to the sharp increase in the spectator capacities from 42 thousands before 1928 towards 87 thousands after 1932. That may be attributed to the emergence of television and TV broadcasting of sport events in 1930’s (Honre & Garry, 2012).
- In addition, within each period, before 1928 and after 1932, spectator capacities of stadiums were observed to slightly-decrease (Figure 4.2). That showed the tendency of reduction towards 40,000 spectator capacity at 1928 and towards 85,000 spectator capacity at 2012.

Among the Olympic stadiums after 1930’s, the highest spectator capacity belongs to 1936 Berlin Olympic stadium with a quantity of 110,000 spectators. In sports world history, 1936 Berlin Olympic Games marked as the first live-broadcast sport event (Honre & Garry, 2012) and that allowed people to watch the Olympic Games outside the stadium for the first time. Its capacity, then has been reduced to 79,200 in 1974 and used for other national and international sport events, particularly for football events (Nixdorf, 2008).

Among the stadiums before 1930’s the highest spectator capacity belongs to 1908 London White City Stadium with a quantity of 93,000 spectators. The White City Stadium was the first stadium built for the modern Olympic Games (OKOB, 1936). The White City Stadium demolished in 1984 (Mallon, 1999) since it was not used for sport events or any other purposes.

On the other hand, the lowest spectator capacity before 1930's belongs to the 1904 Olympic stadium with a quantity of 10,000 spectators. The Olympic Games in 1904 were held as a sport event of among the activities of Louisiana Purchase Exposition (Lucas, 1905). This situation decreases its impact among other Olympic Games. The structure itself is still in use as the permanent part of the Washington University Campus after Olympic Games and known as Francis Field (Wuest, 2004). Its capacity has been reduced to 4,000 spectators during the renovations in 1984, 2003, 2012.

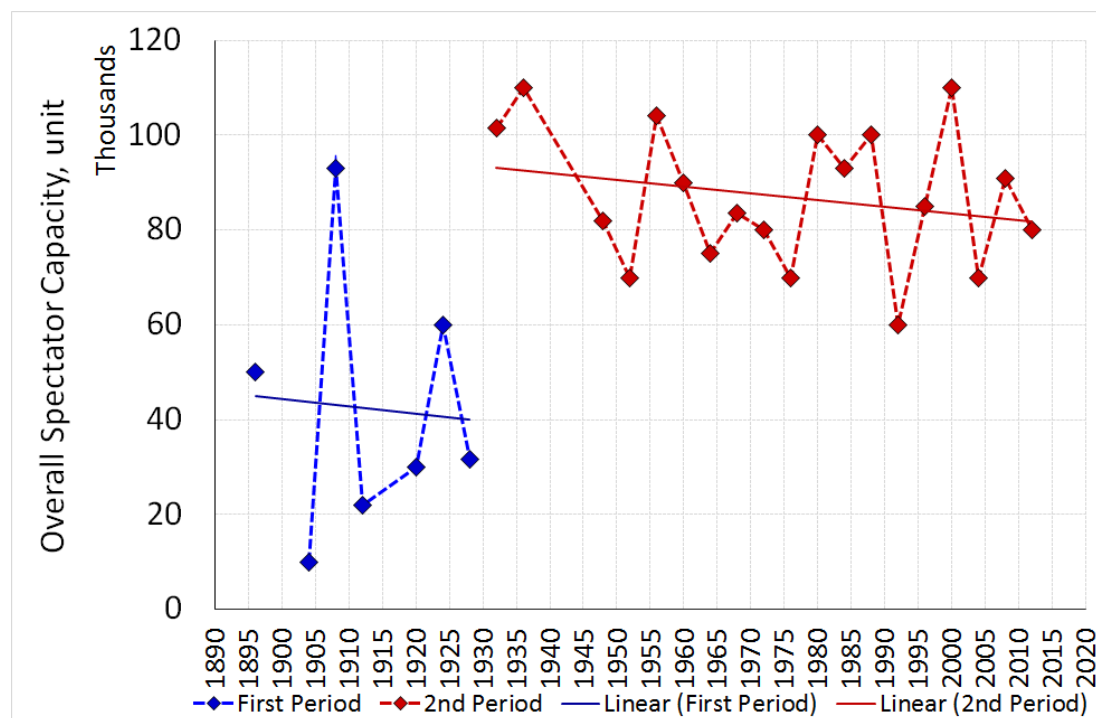


Figure 4.2 The evolution of overall spectator capacity in all main stadium structures used for Summer Olympic Games (including originally-built ones and renovated ones) from 1896 to 2012 in chronological order.

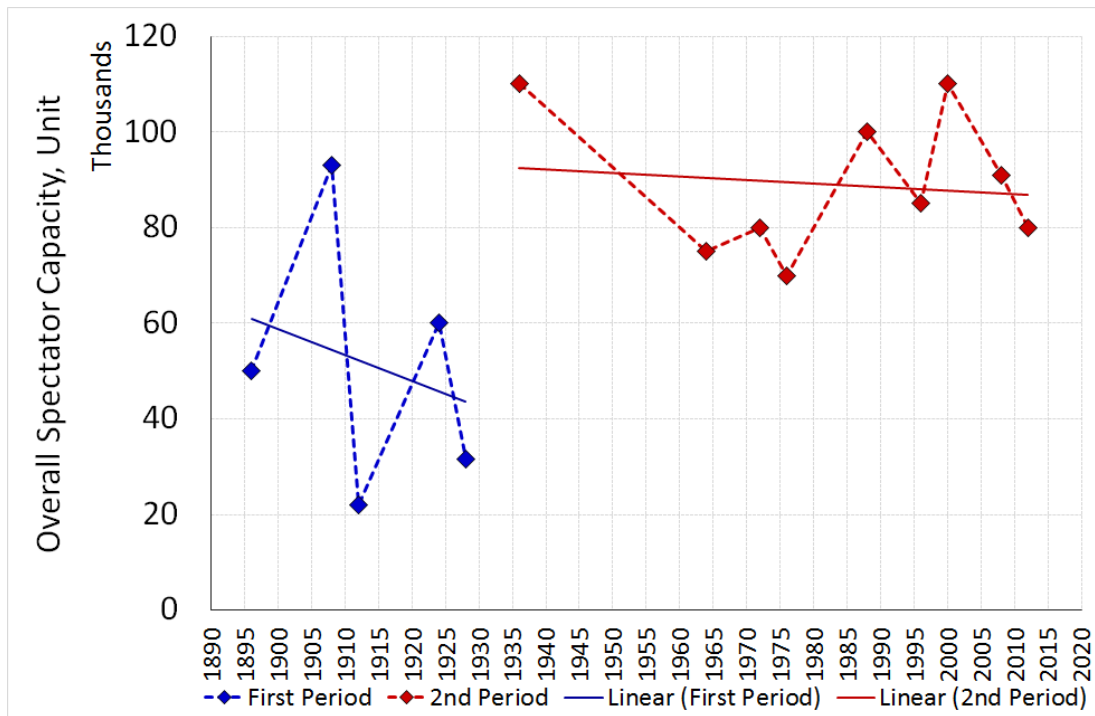


Figure 4.3 The evolution of overall spectator capacity of the originally-built main stadium structures for Summer Olympic Games from 1896 to 2012 in chronological order.

4.2.2 Evaluation of Current Overall Spectator Capacities of Stadiums

“The overall spectator capacity on Olympic date” and “their current spectator capacities after renovations” for post-Olympic uses of those stadiums were plot in a graph (Figure 4.4). Here, the changes in original spectator capacities in time for post-Olympic use were examined. The data achieved were then analysed to better-understand the reasons of renovations in spectator capacities for post-Olympic uses, in other words for sustaining their service life.

The overall spectator capacity of most stadiums were observed to have been reduced for post-Olympic uses (Figure 4.4). The current spectator capacities for all stadiums were in the range of 4,000-100,000 with an average of $59,126 \pm 26,996$. That value

showed that the overall reduction in their original spectator capacity is about 21% (Table A.1).

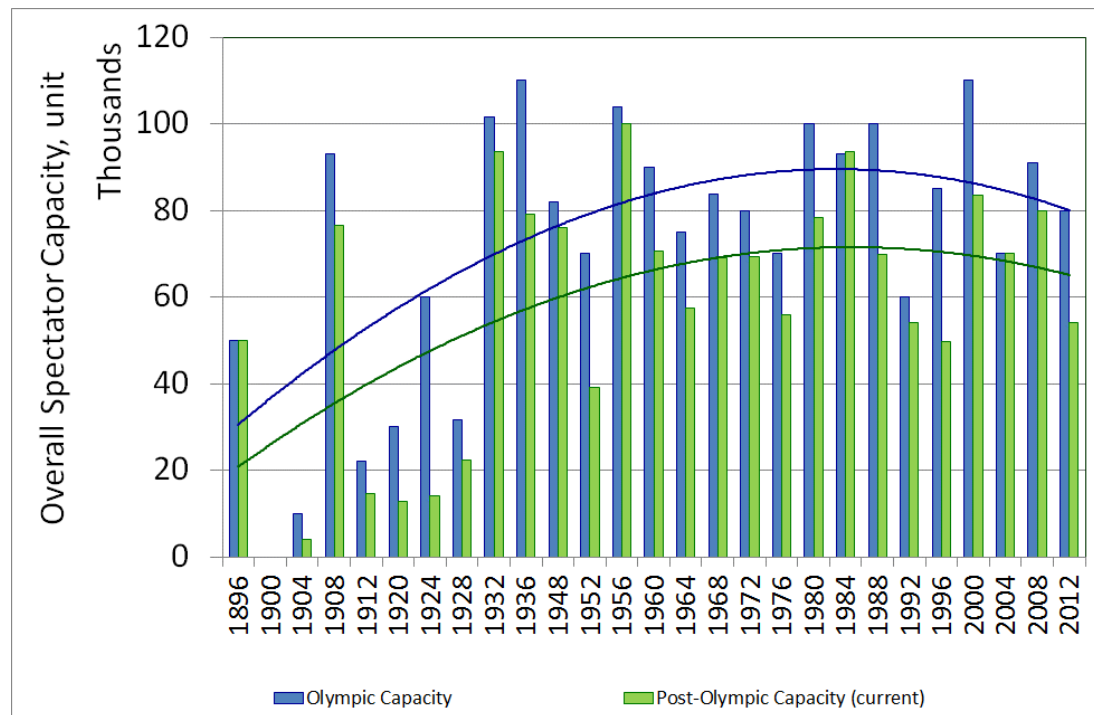


Figure 4.4 The overall spectator capacities of all main stadiums and their current spectator capacities renovated for post-Olympic events from 1896 to 2012 in chronological order.

The plot of the original and current spectator capacities of all stadiums (Figure 4.5) and only the stadiums originally-built for Olympic Games (Figure 4.6) showed that:

- there is tendency of decrease in current capacities in time, and
- this trend is similar with decrease observed in original capacities of stadiums.

Considering the two periods, 1896-1928 and 1932-2012, respectively, the comparison of original and current spectator capacities showed similar trends in time (Figure 4.5 and Figure 4.6). Those trends individually for two periods are explained below:

- The current spectator capacity of the stadiums within the period of 1896-1932 years varies in the range of 4,000-76,567 spectators with an average of $27,732 \pm 26,016$. That value showed that the current capacities are reduced in comparison to their original capacities in that period and that reduction is about 34%. The current capacities were also observed to decrease towards the end of this period to 20,000 spectators. Such a significant decrease signals the tendency for converting Olympic stadiums to low-capacity stadiums in that period and renovating stadiums for national/regional post-events.
- Within the period of 1932-2012 years, the current capacity is in the range of 39,000-100,024 spectators with an average of $70,693 \pm 16,189$. A reduction of 19% was observed in current capacities in comparison to the original capacities in this period. The current capacities were also observed to decrease from 80,000 towards 60,000 spectators towards the end of this period. That tendency can be attributed to a natural trend for achieving “acceptable capacity criterion” described officially “Design Standards on Competition Venues” (IOC, 2005) and Technical Regulations for IAAF World Championships. The renovations on spectator capacities should be considered as the efforts of using such large activity areas for many international sports events to sustain their service life.

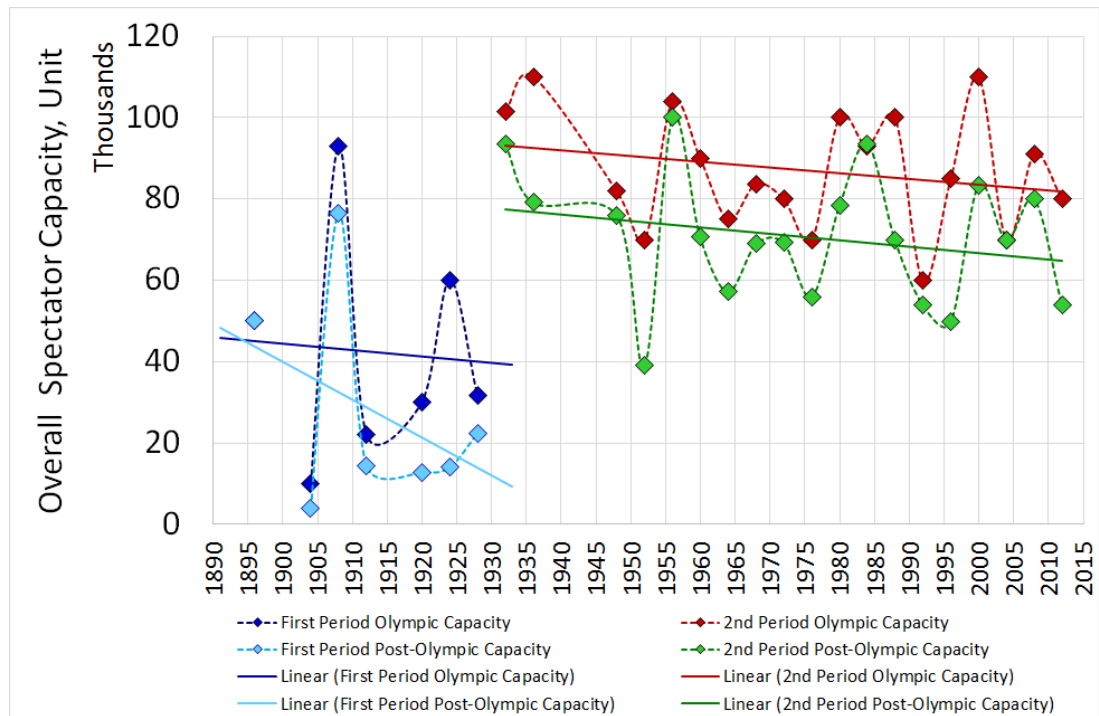


Figure 4.5 The evolution of overall spectator capacities of all stadiums and their current capacities from 1896 to 2012 in chronological order.

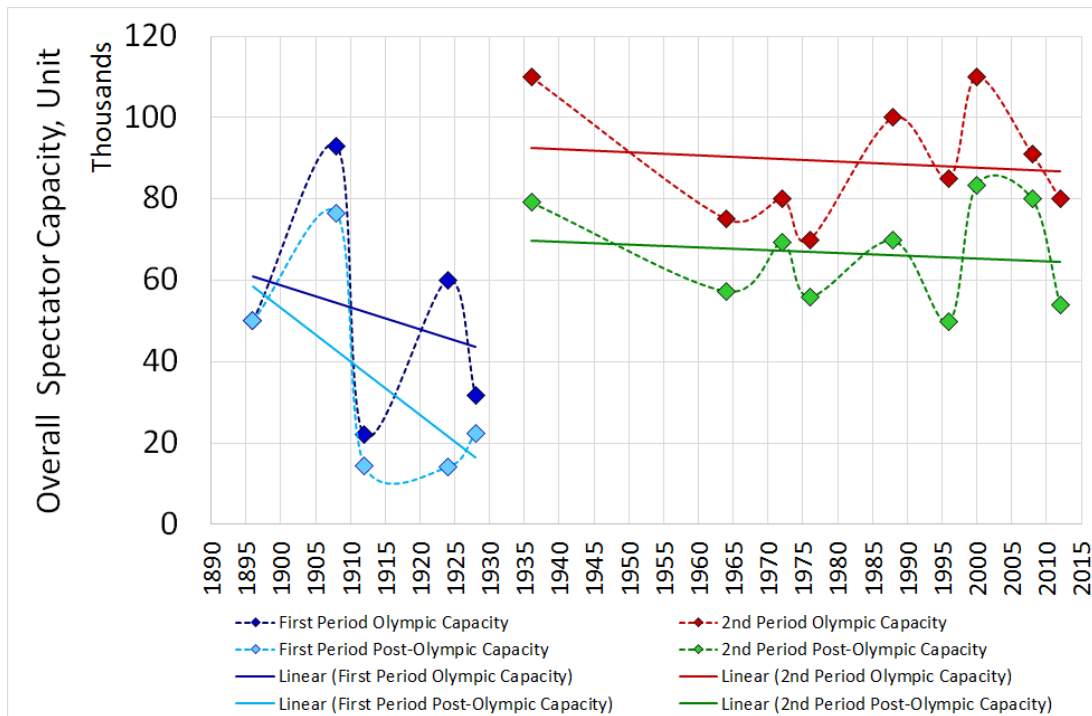


Figure 4.6 The evolution of overall spectator capacities of originally-built stadiums and current capacities from 1896 to 2012 in chronological order.

There are Olympic stadiums having very high and very low spectator capacities. Among 26 stadiums, “1908 White City Stadium” and “1948 Empire Stadium” were demolished; and “1932 Los Angeles Memorial Coliseum” was converted to “1984 Los Angeles Memorial Coliseum”. Therefore, the remained 23 stadiums, still have potential to be used in future. Depending on their current spectator capacities only, the evaluations have shown that (Table A.1):

- 11 of them have current overall capacity above 60,000 spectators, therefore those stadiums can function as main stadiums of following Olympic Games in future and international many sports competitions.
- 16 of them have current seating capacity above 50,000 spectators, therefore those stadiums are available to host final soccer matches of Olympic Games as well as FIFA and UEFA World and Cup Championships.

- 18 of them have current seating capacity above 30,000 spectators, therefore those stadiums have potential to be used for international athletics championships as well as FIFA international tournament and UEFA quarter and semi-final matches in future.
- 4 of them have current seating capacity between 10,000 and 30,000 spectators, therefore those stadiums can only host national and regional many sports including soccer games of regional divisions.
- The remained stadium with 4,000 current seating capacity seemed to be not available for international and national/regional sports games.

4.3 POST-OLYMPIC USE OF STADIUMS AND CHANGES IN SPECTATOR CAPACITY IN RELATION TO POST EVENTS

The 13 types of post-Olympic events, individually, were checked whether each was hosted by 25 stadiums or not. The relevant data obtained from literature and official web sites of those stadiums are presented in Table B.1. The checklist in Table B.2, shows the types of post-Olympic events for each stadium and presented the variety of their uses (Table B.2).

The ratios showing the number of stadiums hosted each post-Olympic event among 25 stadiums in total were plot in Figure 4.7 which presented four groups of post-events with different ratios:

- The stadiums hosted at most Non-Sport, Soccer and Athletics events among 13 types of post events. Among 25 stadiums, 24, 23 and 20 stadiums hosted non-sports events, soccer and athletics games, respectively which were represented with ratios between 96-80%. The highest use therefore, belongs to Non-Sport Events including cultural and tourism activities. The next post-event with the highest ratio was Soccer and then followed by Athletics.
- The next group of post-events mostly hosted by the stadiums was determined to include Racing, Rugby and Gridiron. The 36-40% of 25 stadiums in total were determined to host those events in time.

- The post-events of Baseball and Hockey seemed to be hosted with the stadiums in few numbers and were represented with the ratios of 16% and 12% among 25 stadiums, respectively.
- The group of post-events including Basketball, Austrian football, Bandy, Cricket and Archery are hosted rarely by the stadiums and 8% of 25 stadiums hosted those specific events in time.

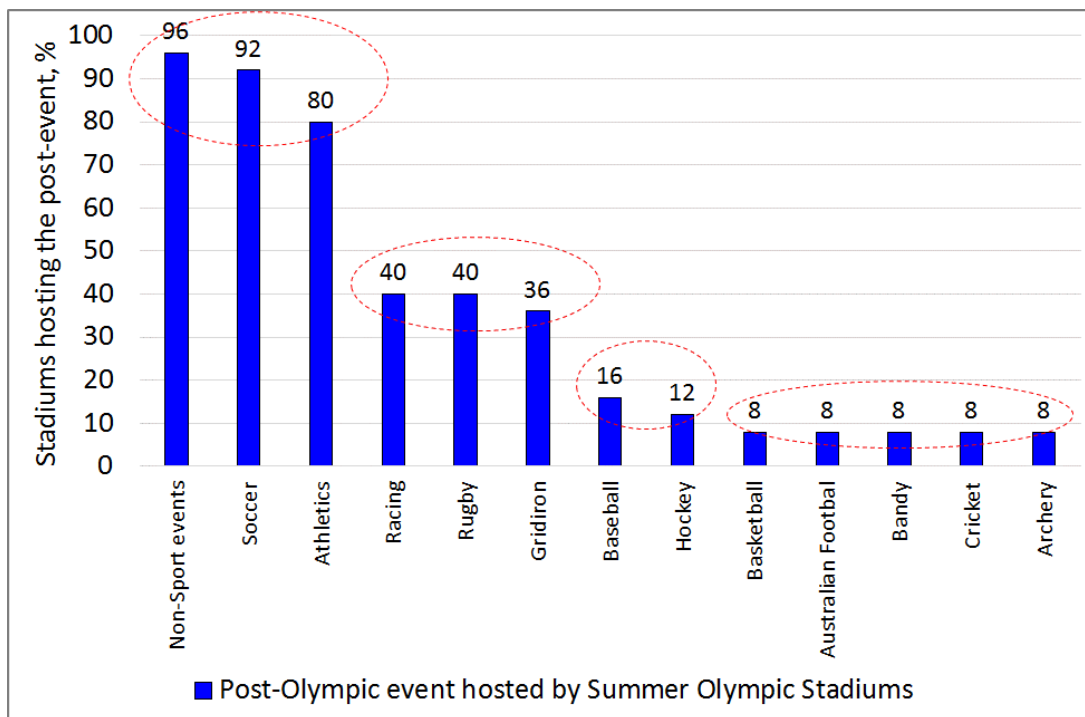


Figure 4.7 The ratio that shows “the number of stadiums hosting a specific event” to “the total number of stadiums” (25 stadiums from 1896-2012) in percentage.

It was concluded that:

- Almost all stadiums with the ratio of 96% have had “Non-Sport Events” in their post-Olympic program (Figure 4.7). That activity is composed of musical, cultural and touristic activities, ceremonies and festivals. It seemed that the existing main

stadium structures are used in time to bring together a crowded population for such activities.

- The next activity again hosted by almost all stadiums with the ratio of 92% is the “Soccer Games” (Figure 4.7). The establishment of FIFA and UEFA World Cup Games which made the soccer games favourite in the world after 1930’s together with the broadcasting of Olympic Games on television are the factors that might encourage an increase in spectator capacity.
- The other most favourite post-Olympic event with the ratio of 80% is the “Athletics Games”. The Athletics is one the main sport event that all Olympic main stadiums were originally shaped to host those activities, therefore the use of stadiums for their authentic function should be expected. On the other hand, the use of stadiums for non-sport activities and soccer games seem to be more dominant when compared with the use of stadiums for Athletics.
- The remained types of post-Olympic activities seemed to be hosted in few numbers by the stadiums. This might be due to the differences and/or preferences in regions and the nature of the stadiums.

Those results, in fact, presented the promising post-events which can be favourite in time in relation to spectator capacity and regional preferences of host countries. The possible reasons of their preference are discussed in the following subheadings.

4.3.1 Cultural Importance of Olympic Stadiums for Their Long-Term Functioning

The data on post-event use of Olympic stadiums have shown that if a stadium is part of the cultural heritage or cultural history, independent to their capacities, it is used mostly for Non-Sport activities (Table C.1). The list of stadiums showing the type of a cultural heritage classification declared by national or international associations are given below:

- The 1896 Panathenaic Stadium is a reconstruction of the ancient one, initially built in 329 BC. The present state of the structure has been declared as a National

Architectural Monument since 1999 (Hellenic Olympic Committee, 2011; Kiuri & Teller, 2015). In addition, it is positioned across the Acropolis of Athens which has been in the list of UNESCO World Heritage Site since 1987 (UNESCO, 2015). Due to such situation, it is also appreciated as a cultural landmark in the city.

- The 1912 Stockholm Olympic Stadium was listed as a Local Historical Building in 1990 (Stockholms stad, 2015; Kiuri & Teller, 2015).
- The 1928 Olympisch Stadion Amsterdam was notified as National Architectural Monument in 1992 which is still in use for many activities (Kiuri & Teller, 2015; Olympisch Stadion Amsterdam, 2015).
- The 1932 Los Angeles Memorial Colosseum was designated as a National Historic Landmark, a State Historical Landmark, and listed in the National Register of Historic Places (National Register) in 1984 (Marathon Communication, 2005; USC 2014; Kiuri & Teller, 2015).
- The 1936 Berlin Olympic Stadium which was declared as Local City Landscape in 1996 (Kiuri 2015 & Teller, 2015; Olympiastadion Berlin, 2015).
- The 1948 Empire stadium was declared as National Monument in 1967 which was then demolished in 2002 to give a place for a new Wembley Stadium (Kiuri & Teller, 2015; Klarke, 2012).
- The 1956 Melbourne Cricket Ground was part of an Olympic Complex site which was declared as National Place in 2005 (Kiuri & Teller, 2015; MCG, 2015).
- The 1968 Estadio Olímpico Universitario was declared in the list of UNESCO World Heritage Site in 2007 (Kiuri & Teller, 2015; UNAM, 2015)
- The 1980 Luzhniki Stadium was notified as national art monument in 1974 (Kiuri & Teller, 2015; Olympic Complex Luzhniki, 2015).
- The 2000 ANZ stadium was listed as Local object in 2000 (Kiuri & Teller, 2015; ANZ Stadium, 2015).

The stadiums being part of the cultural heritage of their country were determined to be used for many sports types and cultural activities (Table B.2). It seemed that the approach of citizens to lifelong use of stadium structures is to keep those structures alive if they are part of their cultural heritage.

Among those stadiums declared as a cultural heritage, four structures presented the highest variety in post-Olympic use as listed below:

- The 1932 Los Angeles Memorial Colosseum with current capacity of 93,607 seats is still in use for eight types of post-Olympic activities, namely non-sport events, soccer, athletics, racing, gridiron, baseball, hockey and basketball.
- The 1928 Stockholm Olympisch Stadium Amsterdam with current capacity of 22,288 seats is still in use for seven types of post-Olympic activities, namely non-sport events, soccer, athletics, racing, gridiron, hockey and archery.
- The 1956 Melbourne Cricket Ground with overall capacity of 104,000 spectators, then renovated to current capacity of 95,000 seats in 2006, is still in use for six types of post-event activities, namely non-sport events, soccer, athletics, rugby, Australian football and cricket.
- The 2000 Sydney Olympic Stadium with current capacity of 83,500 seats is still in use for six types of activities, namely non sport events, soccer, racing, rugby, Australian football and cricket.

4.3.2 Impact of International Soccer Competitions on post-Olympic use of stadiums

The involvement of football tournaments in Olympic Games and then the great interest of people to that game allowed the organization of football games in the form “World Cup Championship” by FIFA in 1930 (FIFA, 2015). Following this in 1954 Union of European Football Associations (UEFA) was formed as administrative body for association football (Soccer) in Europe which then defined major Soccer competitions around the world (UEFA, 2015). According to the data shown in Table B.3 and Table B.4), main Olympic stadiums have tendency to be used for the worldwide and European-wide soccer competitions organized by FIFA and UEFA.

The evaluation of the data is summarized below:

- Among 25 main stadiums, 17 structures have been used for national and international soccer games while 13 of those 17 stadiums hosted FIFA and UEFA

soccer competitions (Table B.4 and Figure 4.8). The capacity of those 17 stadiums on the dates of soccer matches vary in the range of 39,000 and 104,000 seats.

- Among 26 stadiums, 13 structures have been used for international major soccer games including FIFA and UEFA major soccer competitions. Those stadiums have current capacities of 50,000 seats or more, except 1952 Olympiastadion Helsinki stadium with current capacity of 39,000 seats.
- Those 13 stadiums hosted 89 major soccer games for FIFA World Cup competitions, 40 major soccer games for UEFA competitions; in total 155 international major soccer games (Table B.4). That exhibited the dominance of FIFA major competitions among international games and the potential use of Olympic stadiums for FIFA competitions in time.
- Among those 13 stadiums, the number of FIFA and UEFA soccer games hosted by 1948 London Empire Stadium between 1966 and 1999 (within 33 years), which is 36 in total, is remarkable (Table B.4 and Figure 4.8). That signalled the high preference of that stadium for international soccer games.
- The other mostly-used stadiums for FIFA World Cup competitions are 1960 Stadio Olimpico, 1976 Montreal Olympic stadium and 1936 Berlin Olympic Stadium (Table B.4 and Figure 4.8).

Here, 4 stadiums hosted FIFA and UEFA major competitions for many times were evaluated in terms of minimum requirements of *50,000 seating capacity* and *fully-sheltered stand*, which were defined in FIFA and UEFA technical requirements (UEFA, 2001; FIFA, 2002; Nixdorf, 2008):

- “1948 London Empire stadium” was specifically-renovated in 1963 to host the FIFA World Cup Games in 1966. During the renovations, all seats were sheltered with an additional roof structure and its overall capacity was slightly- reduced from 82,000 to 80,000 spectators in 1966 and then to current capacity of 76,000 seats in 1980’s (Pretty & Alison, 2012). On the other hand, this stadium has been demolished in 2002 to make a way for a new English National Stadium, namely Webley Stadium. The new one has been specifically-constructed in 2007 for

national and international soccer competitions with fully-sheltered stands area and original capacity of 90,000 seats (Pretty & Alison, 2012; Clarke, 2012).

- All seat area of “1960 Stadio Olimpico” was fully-covered with a complete roof particularly to host 1990 UEFA soccer games and its original capacity of 90,000 spectators was reduced to the current capacity of 70,634 seats during the renovations.
- “1936 Berlin Olympic Stadium” was specifically-renovated to host 1974 FIFA World Cup Games by addition of a roof structure on East Stand which covered 26,000 seats (Nixdorf, 2008). In the context of its complete renovation and modernization in summer period of 2000, its stands area was fully-covered by a complete roof and overall capacity of 110,000 spectators was reduced to current capacity of 79,200 seats (Constantinescu, 2005; Nixdorf, 2008).
- The 1976 Montreal Olympic stadium was used only for FIFA World Competitions and originally-had a roof structure to shelter the overall seating area, therefore no renovation was necessitated to adapt itself in accordance with 2001 UEFA Technical Recommendations. The seats capacity of 70,000 reduced to 56,000 in 1991 in order to make the stadium suitable for baseball games (Parc Olympique Le Stade, 2015).

The stadiums without roof which do not totally-shelter the spectator seat area, such as “1972 Munich Olympiastadion”, “1968 Estadio Olímpico Universitario”, “1924 Stade Yves Du Manoir”, “1928 Olympisch Stadium Amsterdam” have never been used for FIFA World Cup competitions after 2000. The two stadiums, namely “1980 Luzhniki Stadium”, and “1952 Olympiastadion Helsinki” were decided to be renovated by adding a roof for FIFA World Cup Games in 2018 and 2020, respectively.

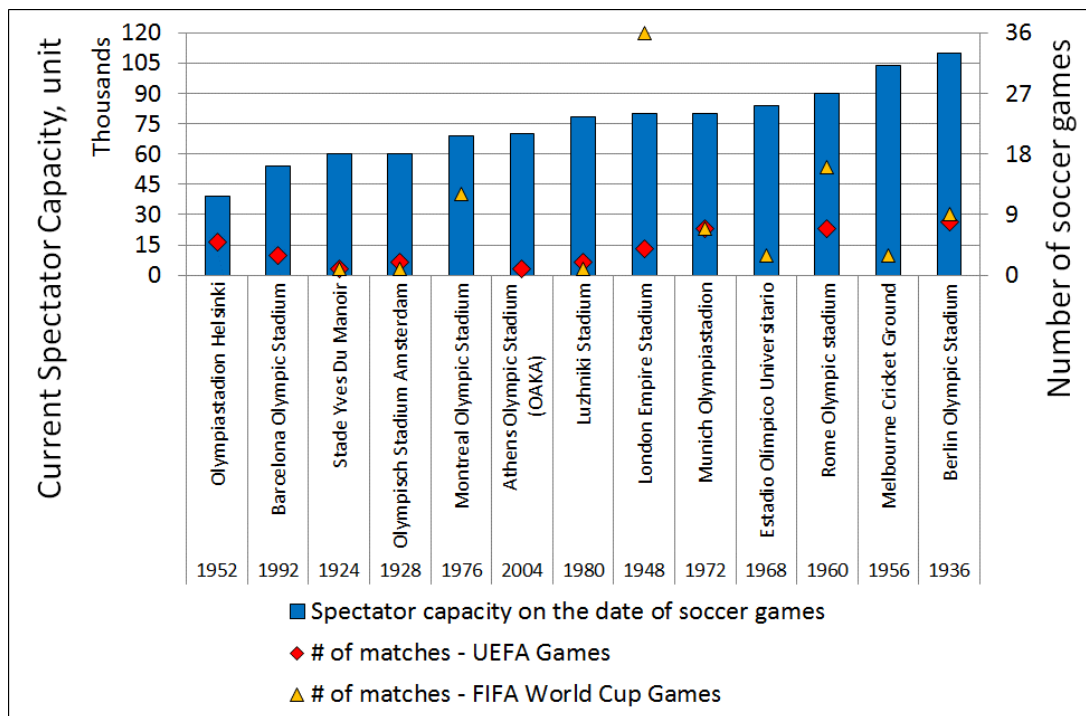


Figure 4.8 Number of FIFA and UEFA major soccer games hosted by Olympic Stadiums.

In short, main Olympic stadiums were observed to have a potential to be used for the national and international soccer competitions. The stadiums which have seating capacity of 50,000 in minimum and fully-sheltered stands area have potential to host international soccer competitions. The stadiums renovated to fulfil those requirements seemed to sustain their functioning in time particularly by hosting international soccer games, specifically FIFA and UEFA Soccer Competitions.

4.3.3 Impact of Regional Preferences for Future Use of Olympic Stadiums

Some post-events seemed to be hosted in few numbers by the stadiums. This was observed to be due to the differences and/or preferences in regions and the nature of the stadiums. The distribution of post-event activities hosted by the stadiums

constructed in different continents, such as Europe, Americas, Asia and Oceania, were examined in the graphs shown in Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12. The data obtained are discussed below:

- *Basketball Games* are hosted by the stadiums only in Americas and Europe, namely the “1932/1984 Los Angeles Memorial Colosseum” among 6 stadiums constructed in Americas and “Panathenaic Stadium” among 15 stadiums constructed in Europe.
- *Baseball Games* are hosted only by the stadiums in Americas and Europe, namely the “1932/1984 Los Angeles Memorial Colosseum”, “1976 Montreal Olympic stadium”, “1996 Atlanta Olympic Stadium” among 6 stadiums constructed in Americas’ and the “2012 London Olympic stadium” among 15 stadiums constructed in Europe. The preference of Baseball as a Post-Olympic event in most of the stadiums in Americas can be attributed to the development of baseball in this continent, therefore its being a favourite sport game here (Bloyce & Murphy, 2004), although Baseball was initially invented and played in Great Britain in 1744’s (Bloyce & Murphy, 2004).
- *Cricket Games* are hosted by the stadiums only in Oceania, namely the “1956 Melbourne Cricket Ground” and “2000 Sydney ANZ Stadium”, which are the only stadiums in Oceania. Oceania is the place where Cricket game was become favourite and .developed since 1853 (MCG, 2015). In addition to this, “1956 Melbourne Cricket ground” is the stadium in which the Cricket game was played for the first time in Australia. (OCA, 1956). Therefore, the Olympic Stadiums can sustain their functions in time by hosting the regional sport games.
- *Australian Rules Football Games*, similar to the cricket games, are hosted by the stadiums only in Oceania as well. That game originally-invented in Australia which has been first played in Melbourne (MCG, 2015).
- *Archery Games* are hosted by the stadiums only in Europe, namely the “1896 Panathenaic Stadium”, and “1928 Olympisch Stadium Amsterdam” among 15 stadiums constructed in Europe. The horse-shoe (U-shaped) geometry of Panathenaic stadium was appropriate for Archery games which was the part of Olympic Games in 2004 (Mallon & Ture, 1997). It seemed that the inherent

geometry/layout of stadiums can be suitable for some sport events that make those structures preferable for specific post events.

- *Bandy Games* are hosted by the stadiums only in Europe, namely the “1912 Stockholm Olympic Stadium” and “1952 Helsinki Olympic stadium”, among 16 stadiums constructed in Europe. Considering Bandy as a team game on ice, “1912 Stockholm Olympic stadium” has hosted 50 Bandy matches in time and that was attributed to the availability of the structure to adapt its field/layout for Bandy games (Stockholms Stad, 2015). Therefore, the adaptability of main stadium structures for specific sport events is one of the other criteria to sustainable use/functioning.

Some post-events seemed to be not hosted yet in some continents (Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12). For instances:

- *Gridiron Game* has never been hosted yet by the stadiums in Oceania. This can be attributed to the popularity of other football games in Australia such as, cricket, Australian Rules football and soccer (Szymanski, 2014). Therefore, any sport game which is not popular in a continent seemed not to be hosted by the Olympic stadiums of the continent in future.
- *Rugby Games*, similar to the gridiron games, have not been hosted by the stadiums in Americas yet. Since the other types of football games, such as gridiron and soccer, are much more favourite/popular in Americas (Casey & Hale, 2009; Szymanski, 2014). Rugby games are not hosted by the Olympic stadiums in time. Rugby Games, in fact, initially played in Great Britain, then spread to the other countries in Europe, and then was also held as a post-event for stadiums in Asia and Oceania (Casey & Hale, 2009).

It is interesting that no regional/traditional sports/activities were performed in stadiums built in Asia (1964 Tokyo National Stadium - Japan, 1988 Jamsil stadium - Korea, and 2008 Beijing National Stadium - China) during their service lives (Figure 4.11). Those very large open air sports spaces, where a crowded people/population of the region can be brought together, have potential to organize post-events/activities

according to the regional preferences if the physical and architectural features of stadiums are suitable/adaptable for their traditional/regional post-events. The ones built in Europe, Americas and Oceania seemed to host many regional/traditional sports games of their own, such as baseball, rugby, Australian Rules football and cricket. The reasons why the stadiums in Asia have never been used for sports activities of their own, such as wrestling sports, martial sports, horse racing, kite flying, *etc.* need to be investigated (Boucher, 2008; TIC, 2012).

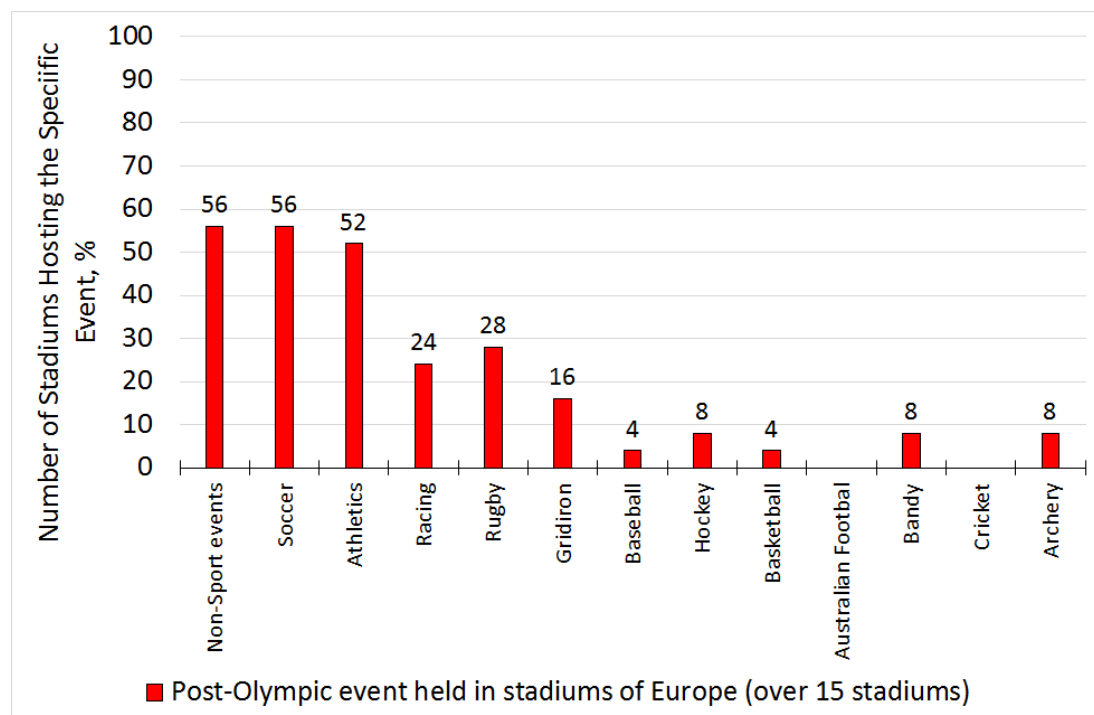


Figure 4.9 The ratio of “the number of stadiums hosting a specific event in Europe” to “the total number of stadiums” in percentage, showing the distribution of many sports types including non-sports activities hosted by stadiums in Europe.

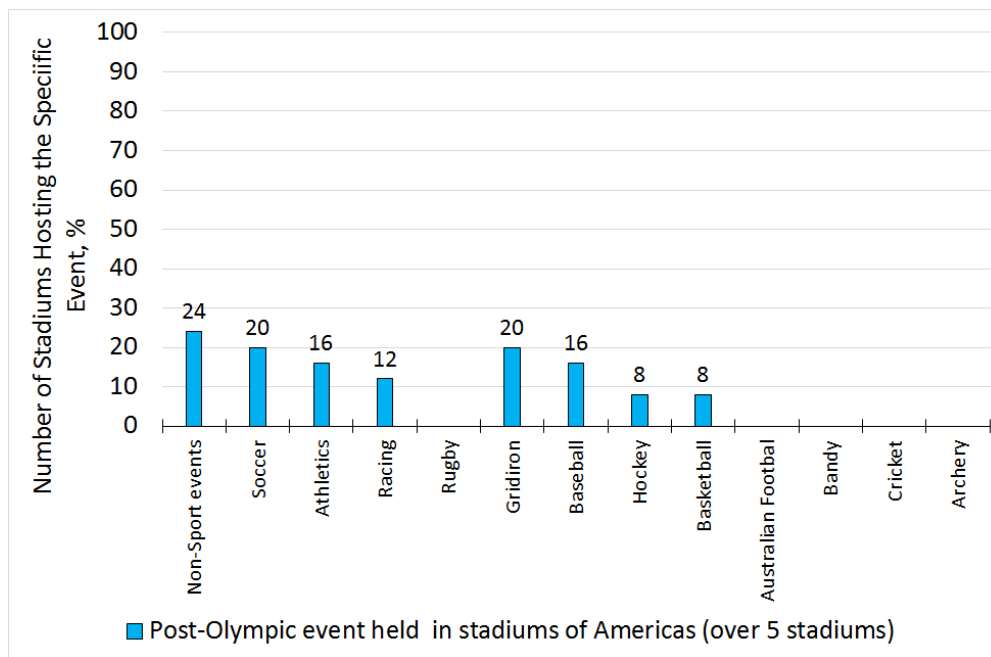


Figure 4.10 The ratio that shows “the number of stadiums hosting a specific event in Americas” to “the total number of stadiums” in percentage, showing the distribution of many sports types including non-sports activities hosted by stadiums in Americas.

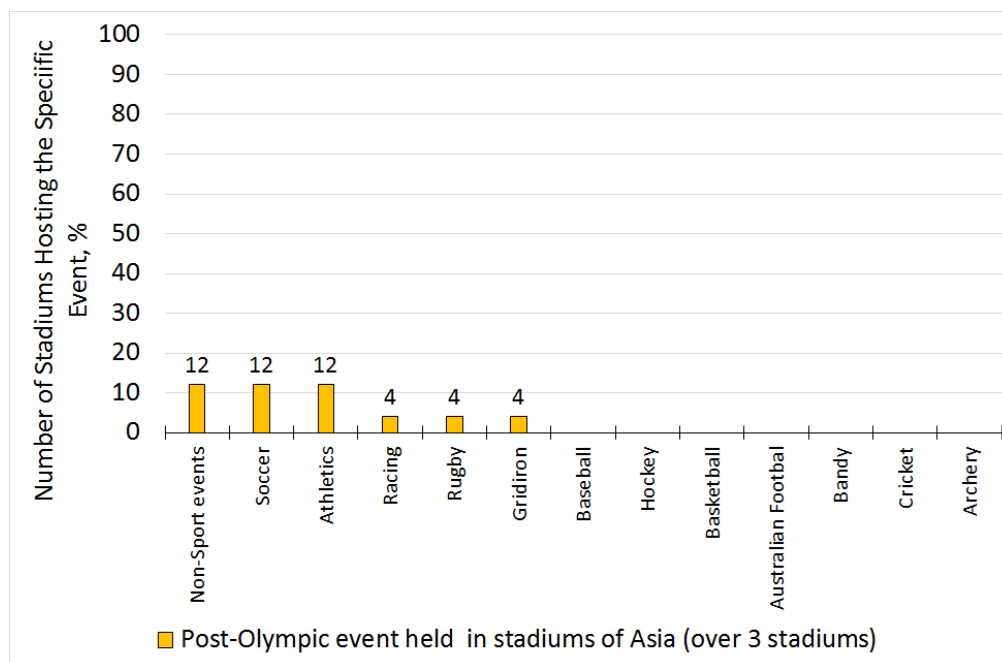


Figure 4.11 The ratio of “the number of stadiums hosting a specific event in Asia” to “the total number of stadiums” in percentage, showing the distribution of many sports types including non-sports activities hosted by stadiums in Asia.

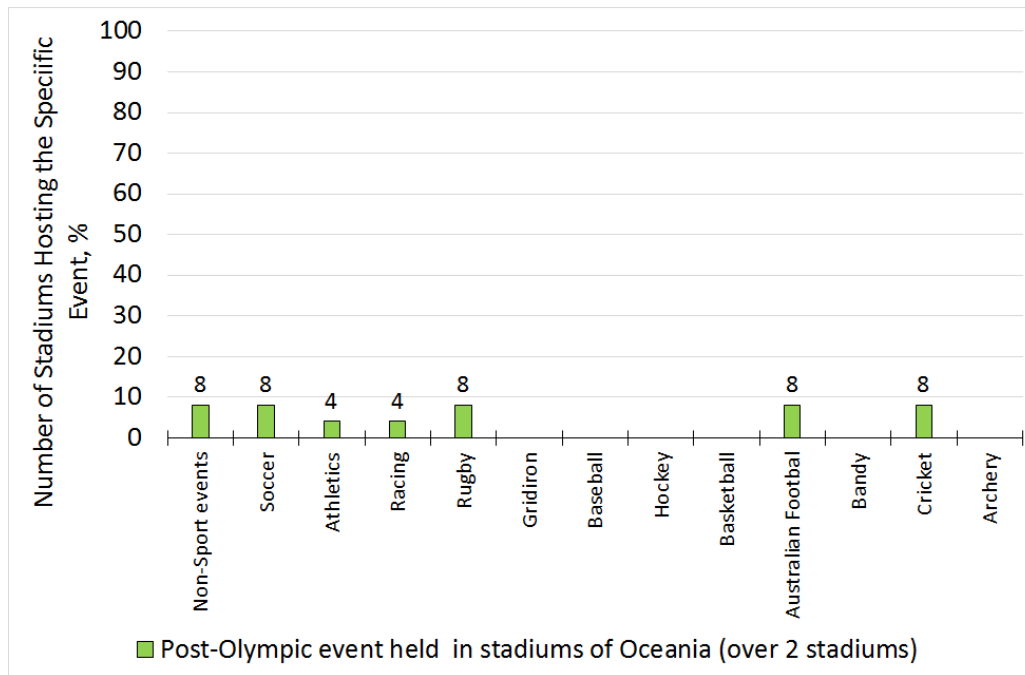


Figure 4.12 The ratio of “the number of stadiums hosting a specific event in Oceania” to “the total number of stadiums” in percentage, showing the distribution of many sports types including non-sports activities hosted by stadiums in Oceania.

4.4 RELATIONSHIP BETWEEN THE SPECTATOR CAPACITY AND HOST CITY POPULATION

The relationship between the spectator capacity of main stadiums and population of the host cities in Olympic date were examined in the graph given in Figure 4.13. In addition, the correlation between the “Overall Spectator Capacity” and “Host city population” was examined by the plot of data (Figure 4.14). No relationship, in fact, was observed between the overall spectator capacity and host city populations (Figure 4.13.). However, the scatter diagram given in Figure 4.14 allowed better-interpretation of data by grouping them mainly in four ranges.

The results are given below (Figure 4.14):

- The small cities having the population below one million (in the range of 113000 – 789000) on Olympic date seemed to have stadiums with a spectator capacity in a very wide range within 10000 – 85000. That clearly showed that there is no correlation between the host city population and overall spectator capacity of Olympic stadiums (See Group 1 in figure 4.14). Those stadiums are namely “1896 Panathenaic Stadium”, “1904 Francis Field”, “1912 Stockholm Stadium”, “1920 Olympisch Stadium Antwerp”, “1928 Olympisch Stadium Amsterdam”, “1952 Olympiastadion Helsinki”, “1996 Centennial Olympic Stadium”, and “2004 Athens Olympic Stadium”.
- The cities having the population between 1.5 to 3.5 million (in the range of 1338924 – 3347982) on Olympic date seemed to have stadiums with a spectator capacity in larger numbers (in the range of 60000 – 93000) (See Group 2 in figure 4.14). That showed the larger stadium capacities were hosted by higher city populations in certain ranges. This range covers seven stadiums namely; “1924 Stade Yves-du-Manoir Paris”, “1948 Wembley Stadium”, “1960 Stadio Olimpico”, “1972 Munich Olympic Stadium”, “1976 Montreal Olympic Stadium”, “1984 Los Angeles Memorial Coliseum”, and “1992 Barcelona Olympic Stadium”.
- The big cities having a wide range of population between 4.5 to 15 million (in the range of 4536514 – 14813000) seemed to have stadiums with narrower spectator capacity range (75000 – 100000) (See Group 3 in figure 4.14). It was observed that the big cities, such as London in Britain, Mexico City in Mexico, Tokyo in Japan, having population more than 8 million, even the biggest one (Beijing in China) with the population of 15 million hosted Olympic stadiums with the spectator capacity in the range of 80000-91000. That also clearly presented “no correlation between the host city population and overall spectator capacity of Olympic stadiums”.
- On the other hand, the extreme cases were determined that the stadiums having the largest spectator capacities above a hundred thousand hosted by the cities having a population between 1.5 to 4 million (See Group 4 in figure 4.14). For

instance, Melbourne in Australia having 1.5 million people on Olympic date had one of the largest Olympic stadium in the world, namely “1956 Melbourne Cricket Ground” with a capacity of 104000.

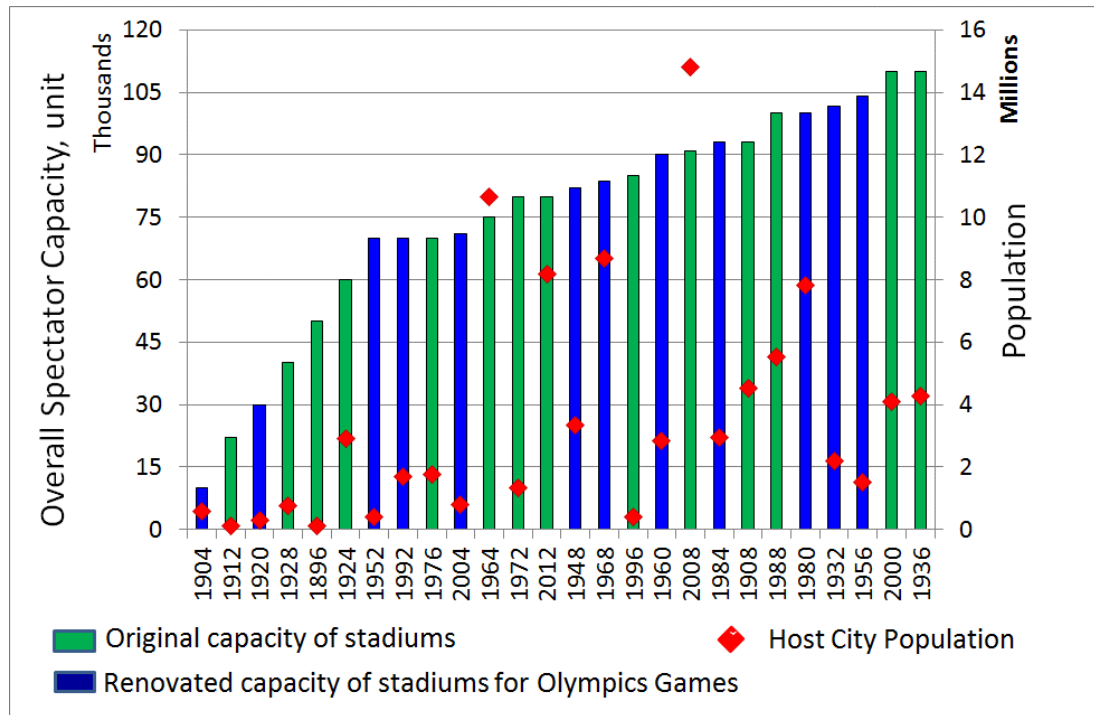


Figure 4.13 The plot of host city population and overall spectator capacities of summer Olympic stadiums from 1896 to 2012 in chronological order.

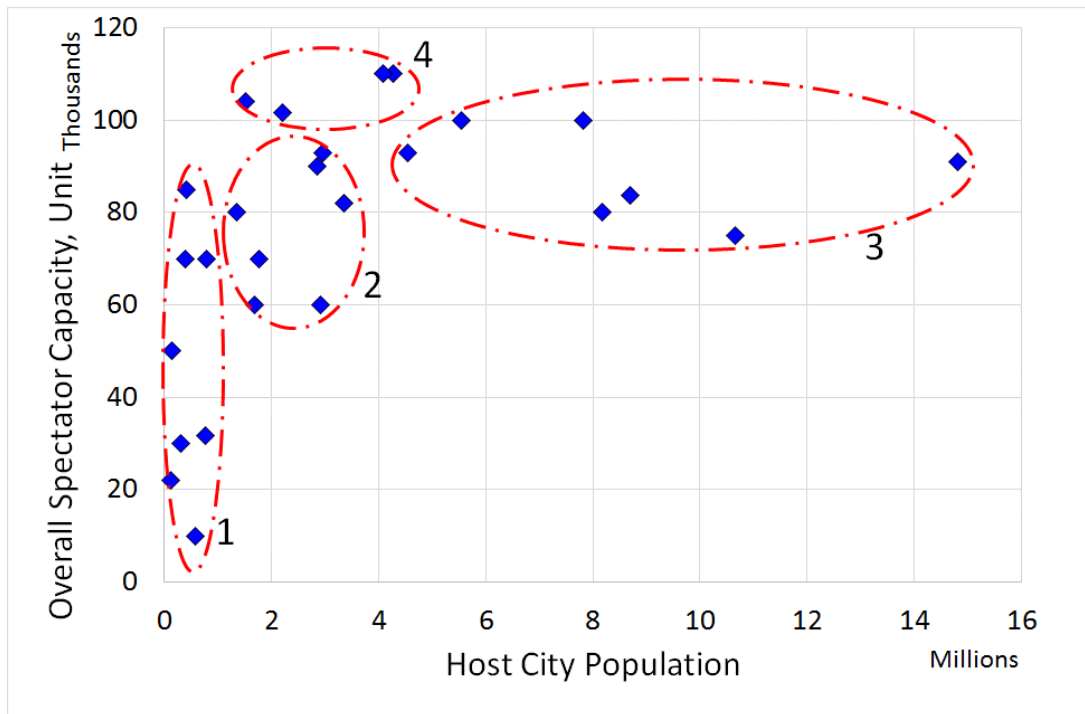


Figure 4.14 The graph showing overall spectator capacities of the Olympic stadiums versus population of their host cities.

Although some relationships have been observed in certain ranges, a significant correlation between spectator capacity and population of host cities has not been observed. This meant that population of the host cities has not been considered as a design factor for main stadiums of summer Olympic Stadiums.

4.5 APPROPRIATENESS OF PLAYING FIELD ORIENTATION OF OLYMPIC STADIUMS

The data on orientations of each stadium in relation to sun exposure are given in Table 4.3 in terms of the slope of longitudinal central axis of their playing field that shows the deviation of that axis in reference to the N/S axis. The schematic scaled plan drawings specifically prepared for the analyses are given in Appendix D. The orientation of each stadium was evaluated in comparison to the proper slope ranges

summarized in Table 2.2 which gives the relevant guidelines defined in regulations and/or recommendations. The plot of data on Cartesian coordination plane which allowed their better-interpretation is given in Figures 4.15.

Table 4.3 Orientation of playing field longitudinal axis for main structures of summer Olympic Games from 1986 to 2012.

Name	City/ Country	Continent	Zone	Slope of playing field axis	Relevant figure
1896 Panathenaic Stadium	Athens/ Greece	Europe	NH	31° N-to-W	Figure D.1
1904 Francis Field	St. Louis/ USA	Americas	NH	83° N-to-W	Figure D.1
1908 White City Stadium	London/England	Europe	NH	38° N-to-W	Figure D.1
1912 Stockholm Stadium	Stockholm/Sweden	Europe	NH	38° N-to-E	Figure D.1
1920 Olympisch Stadium	Antwerp/Belgium	Europe	NH	53° N-to-E	Figure D.2
1924 Stade Yves-du-Manoir	Paris/France	Europe	NH	6° N-to-W	Figure D.2
1928 Olympisch Stadium Amsterdam	Amsterdam/Netherlands	Europe	NH	12° N-to-W	Figure D.2
1932 Los Angeles Memorial Coliseum	Los Angeles/USA	Americas	NH	90° N-to-W	Figure D.2
1936 Olympiastadion Berlin	Berlin/ Germany	Europe	NH	82° N-to-E	Figure D.3
1948 Empire Stadium	London/ England	Europe	NH	89° N-to-E	Figure D.3
1952 Olympiastadion Helsinki	Helsinki/ Finland	Europe	NH	11° N-to-W	Figure D.3
1956 Melbourne Cricket Ground	Melbourne/ Australia	Oceania	SH	85° N-to-E	Figure D.3
1960 Stadio Olimpico	Rome/Italy	Europe	NH	16° N-to-W	Figure D.4
1964 National Olympic Stadium	Tokyo/ Japan	Asia	NH	24° N-to-E	Figure D.4
1968 Estadio Olímpico Universitario	Mexico City/ Mexico	Americas	NH	6° N-to-E	Figure D.4

Table 4.3 (Continued).

1972 Munich Olympic Stadium	Munich/Germany	Europe	NH	20° N-to-W	Figure D.4
1976 Montreal Olympic Stadium	Montreal/Canada	Americas	NH	15° N-to-W	Figure D.5
1980 Luzhniki Stadium	Moscow/Russia	Europe	NH	44° N-to-W	Figure D.5
1984 Los Angeles Memorial Coliseum	Los Angeles/USA	Americas	NH	90° N-to-W	Figure D.5
1988 Jamsil olympic stadium	Seoul/South Korea	Asia	NH	7° N-to-W	Figure D.5
1992 Barcelona Olympic Stadium	Barcelona/Spain	Europe	NH	1° N-to-E	Figure D.6
1996 Centennial Olympic Stadium	Atlanta/USA	Americas	NH	1° N-to-E	Figure D.6
2000 ANZ Stadium	Sydney/Australia	Oceania	SH	11° N-to-E	Figure D.6
2004 Athens Olympic Stadium	Athens/Greece	Europe	NH	20° N-to-W	Figure D.6
2008 Beijing National Stadium	Beijing/China	Asia	NH	2° N-to-W	Figure D.7
2012 London Olympic Stadium	London/England	Europe	NH	2° N-to-E	Figure D.7
NH – Northern hemisphere; SH – Southern Hemisphere					

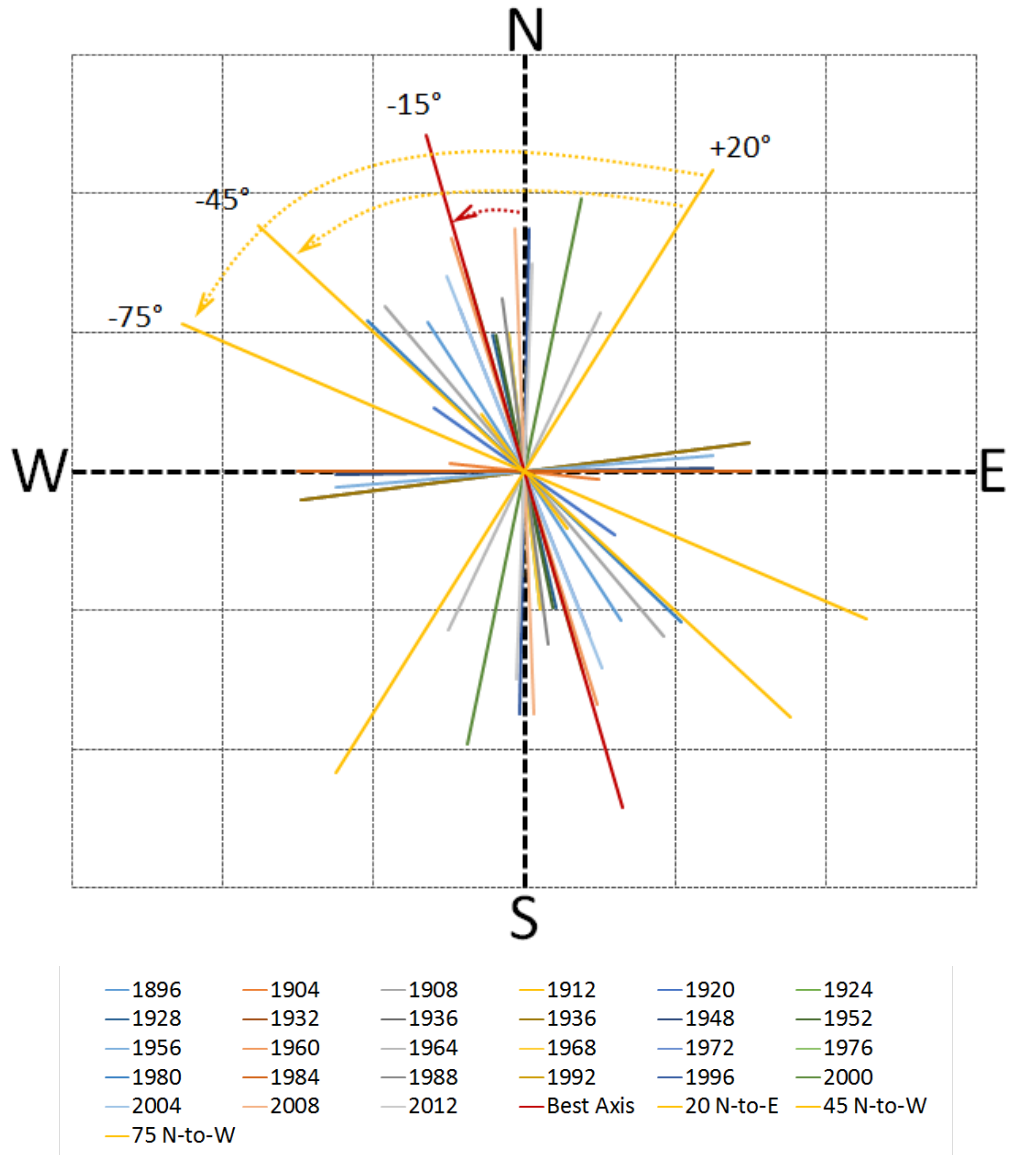


Figure 4.15 The distribution of slopes showing the deviation of longitudinal central axes of each stadium from North that presents their positioning in relation to the acceptable/recommended slope ranges.

Table 4.4 List of stadiums classified according to the appropriateness of their orientation.

Stadiums	Appropriateness of orientation		
1924 Stade Yves-du-Manoir	Best orientated stadiums for many sports	Properly oriented stadiums for athletics games, especially for track and fields	Properly oriented stadiums for football and rugby games
1928 Olympisch Stadium Amsterdam			
1952 Olympiastadion Helsinki			
1960 Stadio Olimpico			
1968 Estadio Olímpico Universitario			
1976 Montreal Olympic Stadium			
1988 Jamsil Olympic stadium			
1992 Barcelona Olympic Stadium			
1996 Centennial Olympic Stadium			
2008 Beijing National Stadium			
2012 London Olympic Stadium			
1896 Panathenaic Stadium			
1908 White City Stadium			
1972 Munich Olympic Stadium			
1980 Luzhniki Stadium			
2000 ANZ Stadium			
2004 Athens Olympic Stadium			
1920 Olympisch Stadium			
1904 Francis Field	Poorly-oriented stadiums considering optimum orientation in relation to sun exposure		
1912 Stockholm Stadium			
1932/1984 Los Angeles Memorial Coliseum			
1936 Olympiastadion Berlin			
1948 Empire Stadium			
1956 Melbourne Cricket Ground			
1964 National Olympic Stadium			

Among 25 stadiums, 18 stadiums were found to be properly-oriented for most sports games while only seven stadiums were found to be poorly-oriented according to the optimum orientations considering sun exposure (Figure 4.15 and Table 4.4). The recommendations on sustainability issues which guide building design for proper orientation were mentioned firstly in 1996 (USGBC, 1996). The integration of sustainability issues for stadiums design was observed in technical manuals declared in 2003 (DIN, 2003). All poorly-oriented stadiums, in fact, have been constructed before 1964. One of the reasons causing improper positioning of those stadiums might

be attributed to the lack of relevant recommendations/guidelines on sustainability issues and their integration with stadium design criteria.

On the other hand, properly-oriented all (18) stadiums were determined to provide appropriate directions for football and rugby games (Figure 4.15 and Table 4.4) that fell into the range between 20° deviation from North to East and 75° deviation from North to West (20°N/E–75°N/W). Among all, 17 stadiums were properly-oriented for athletics games, particularly for track and field games (Figure 4.15 and Table 4.4) since directions of their playing fields fell into the range between 20° deviation from North to East and 45° deviation from North to West (20°N/E–45°N/W). Among all, eleven stadiums had the best directions falling into 0°-15° deviation from North to West which were recommended for many sports types (Figure 4.15 and Table 4.4).

The remarks obtained from the evaluations were summarized below:

- Although the preliminary recommendations on sustainability issues and guidelines considering protection against sun firstly mentioned in 1996, some stadiums constructed before 1996 were observed to well-designed or well-planned. That signalled the awareness of designers on environmental control issues in the early design stage of stadiums and comfort conditions for athletes although relevant guidelines have not been declared before 1996.
- The presence of a properly-oriented ancient stadium constructed in 329 BC, (the original positioning of Panathenaic Stadium) exhibited the consciousness of ancient builders who considered saving athletes from blinding effect of sun in relation to the rotation of earth around sun.
- The 2000 ANZ Stadium located in southern hemisphere (in Australia) where the general direction to receive sun throughout the day is the North, contrary to the case in northern hemisphere, has also been properly-oriented.
- The orientation of the 1920 Olympisch Stadium's playing field was found to best-fit for soccer and rugby games. That was due to the fact that this stadium, in origin, was constructed for soccer games in 1914, and then renovated for Summer Olympic Games performed in 1920 with a spectator capacity of 30,000 seats. It

was latest renovated in 2000 specifically to be used for national soccer games. Its capacity has been reduced to 12,771 seats and all seat area has been sheltered with a roof structure.

4.6 EFFICIENCY OF STANDS PLAN LAYOUTS IN RELATION TO THE RECOMMENDED VIEWING DISTANCES

The appropriate viewing performance of stands area for soccer/rugby and athletics games was evaluated on ground-plan layout of stadiums according to the recommended/accepted optimum and maximum viewing circles. The scaled sketch drawings produced and processed for the evaluation of each stadium were presented in Appendix E. The data obtained for assessing the efficiency of stand areas in reference to:

- i) the principles on recommended viewing distances,
- ii) precautions to save spectators from blinding effect of sun, such as presence of roof and asymmetrical patterns allowing more seats positioned to the south and west,
- iii) geometric layout of stands area, were summarized in Table 4.5.

Table 4.5 The data on geometric layout of stands area for each stadium, state of their viewing conditions for soccer/rugby and athletics games, and any precaution(s) to save spectators from blinding effect of sun.

Stadium	Layout geometry of stands area	Efficiency for		Saving spectators from blinding effect of sun	
		Soccer/Rugby games	Athletics Games	on Olympic date	Current state
1896 Panathenaic Stadium	Elongated U-shaped Geometry	Many seats at SE positioned beyond OVC and MVC where their viewing locations are not preferable.	Some seats at SE positioned beyond OVC while majority of spectators have preferable viewing locations	No special care for seating geometry in accordance with W & E directions; No roof	
1904 Francis Field	Open rectangular Geometry	All seats positioned within the OVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC, therefore had preferable viewing locations.	No special care for seating geometry in accordance with W and E directions; No roof	
1908 White City Stadium	Semicircular Geometry	Many seats at SE and NW positioned beyond OVC and MVC where viewing locations are not preferable.	Some seats at NW and SE positioned beyond the OVC while majority of spectators have preferable viewing locations	Partially-sheltered stand area by roofs positioned at SW and NE	Fully-sheltered stand area
1912 Stockholm Stadium	U-Shaped Geometry(close to Basket arch geometry)	A few seats at NE and SW positioned beyond OVC while all seats positioned within the MVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC, therefore had preferable viewing locations	A special care was given for sheltering stands which were partially covered by roofs positioned at NW, SW and SE.	
1920 Olympisch Stadium	Semicircular Geometry	A few seats at SE and NW positioned beyond the OVC while all seats positioned within the MVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC, therefore had preferable viewing locations.	Partially-sheltered stand area by roofs positioned at SW and NE	Fully-sheltered stand area

Table 4.5 (Continued).

1924 Stade Yves-du-Manoir	Semicircular Geometry	Some seats at NW and SE positioned beyond the OVC while almost all seats positioned within MVC. Viewing locations for spectators are preferable.	Almost all seats positioned within the OVC, therefore had preferable viewing locations.	A special care was given for sheltering stands which were partially covered by roofs positioned at E & W.
1928 Olympisch Stadium Amsterdam	Oval Geometry	A few seats at NW and SE positioned beyond OVC while all seats positioned within the MVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC, therefore had preferable viewing locations.	A special care was given for sheltering stands which were partially covered by roofs positioned at E and W. Asymmetric geometry providing more spectators have their backs to the sun during afternoons.
1932 Los Angeles Memorial Coliseum	Semicircular Geometry	Many seats at E & W positioned beyond OVC and MVC where their viewing locations are not preferable.	Many seats at E & W positioned beyond the OVC while majority of spectators have preferable viewing locations.	Asymmetric geometry to accommodate more spectators to the W, and having their backs to the sun during afternoons.
1936 Olympiastadion Berlin	Oval Geometry	Many seats at E & W positioned beyond OVC and MVC where their viewing locations are not preferable.	Some seats at E & W positioned beyond the OVC while majority of spectators have preferable viewing locations.	No special care for seating geometry in accordance with W and E directions; No roof Fully-sheltered stand area in xxx
1948 Empire Stadium	Semicircular Geometry	Many seats at E & W positioned beyond the OVC and a few seats at E and W positioned beyond the MVC. Majority of spectators have preferable viewing locations	Only a few seats at E & W positioned beyond the OVC, while all seats had preferable viewing locations.	Partially-sheltered stand area by roofs positioned at N & S. Fully sheltered stand area

Table 4.5 (Continued).

1952 Olympiastadion Helsinki	Semicircular Geometry	Some seats at NW and SE positioned beyond the OVC while all seats positioned within the MVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC, therefore had preferable viewing locations	Partially-sheltered stand area by roofs positioned at W.	Fully sheltered stand area
1956 Melbourne Cricket Ground	Circular Geometry	Many seats at all directions positioned beyond the OVC while a few seats at E and W positioned beyond the MVC. Majority of spectators have preferable viewing locations.	Some seats at E & W positioned beyond the OVC while all seats had preferable viewing locations.	Partially-sheltered stand area by roofs positioned at N, E, and SE.	Fully sheltered stand area
1960 Stadio Olimpico	Oval Geometry	Many seats at NW and SE positioned beyond the OVC and MVC where their viewing locations are not preferable.	Some seats at NW and SE positioned beyond the OVC while majority of spectators have preferable viewing locations.	No special care for seating geometry in accordance with W & E directions; No roof	Fully sheltered stand area
1964 National Olympic Stadium	Oval Geometry	Many seats at NE, E, and SW positioned beyond the OVC while a few seats at NE and S positioned beyond the MVC. Majority of spectators have preferable viewing locations.	A few seats at NE and S positioned beyond the OVC while all seats had preferable viewing locations.	A special care for sheltering stands: Partially-sheltered stand area by roofs positioned at NW and W	Asymmetric geometry to accommodate more spectators to the W, and having their backs to the sun during afternoons.
1968 Estadio Olimpico Universitario	Circular Geometry	Some seats at all directions positioned beyond the OVC while all seats positioned within the MVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC, therefore had preferable viewing locations.		

Table 4.5 (Continued).

1972 Munich Olympic Stadium	Circular Geometry	Many seats at all directions positioned beyond the OVC while a few seats at NE, NW, SE, and SW positioned beyond the MVC. Majority of spectators have preferable viewing locations	A few seats at NE, NW, SE, and SW positioned beyond the OVC, therefore had preferable viewing locations.	A special care was given for sheltering stands by roofs which were positioned at NW and W, SW, and S. Asymmetric geometry to accommodate more spectators to the W and having their backs to the sun during afternoons
1976 Montreal Olympic Stadium	Oval Geometry	Many seats at N, NW, S, & SE positioned beyond the OVC and MVC where their viewing locations are not preferable.	Some seats at N, NW, S, and SE positioned beyond the OVC while majority of spectators have preferable viewing locations.	Fully sheltered stand area
1980 Luzhniki Stadium	Semicircular Geometry	Many seats at all directions positioned beyond the OVC and MVC where their viewing locations are not preferable.	Some seats at NW and SE positioned beyond the OVC while majority of spectators have preferable viewing locations.	partially covered by roofs positioned at all directions
1988 Jamsil Olympic stadium	Circular Geometry	Many seats at N, NW, S, and SE positioned beyond the OVC while a few seats at N, NW, S, and SE positioned beyond the MVC. Majority of spectators have preferable viewing locations	A few seats at N, NW, S, and SE positioned beyond the OVC while majority of spectators have preferable viewing locations	Stands area mostly-sheltered by roofs positioned at all directions
1992 Barcelona Olympic Stadium	Basket Arch Geometry	A few seats at N and S positioned beyond the OVC while all seats positioned within the MVC. Viewing locations for spectators are preferable.	All seats positioned within the OVC therefore had preferable viewing locations.	A special care was given for sheltering stands which were partially covered by roofs positioned at W.

Table 4.5 (Continued).

1996 Centennial Olympic Stadium	Semicircular Geometry	Many seats at N and S positioned beyond the OVC and MVC where their viewing locations are not preferable.	Many seats at N & S positioned beyond the OVC while majority of spectators have preferable viewing locations.	A special care was given for sheltering stands which were partially covered by roofs positioned at S.
2000 ANZ Stadium	Circular Geometry	Many seats at N, NE, S, and SW positioned beyond the OVC and MVC where their viewing locations are not preferable	Some seats at N, NE, S, and SW positioned beyond the OVC while majority of spectators have preferable viewing locations.	A special care was given for sheltering stands which were partially covered by roofs positioned at E & W. Fully sheltered stand area
2004 Athens Olympic Stadium	Oval Geometry	Many seats at NW and SE positioned beyond the OVC while some seats at NW and SE positioned beyond the MVC. Majority of spectators have preferable viewing locations	A few seats at NW and SE positioned beyond the OVC while majority of spectators have preferable viewing locations	A special care was given for sheltering stands which were partially covered by roofs positioned at all directions.
2008 Beijing National Stadium	Oval Geometry	Many seats at N and S positioned beyond the OVC and MVC where their viewing locations are not preferable.	Some seats at N and S positioned beyond the OVC while majority of spectators have preferable viewing locations.	Fully sheltered by roof

Table 4.5 (Continued).

2012 London Olympic Stadium	Oval Geometry	Many seats at N and S positioned beyond the OVC while some seats at N and S positioned beyond the MVC. Majority of spectators have preferable viewing locations	Some seats at N and S positioned beyond the OVC while majority of spectators have preferable viewing locations	A special care was given for sheltering stands which were partially covered by roofs positioned at all directions.
LEGAND		NOT SATISFACTORY		
		PARTIALLY SATISFACTORY		
		ACCEPTABLE		
		SATISFACTORY		

It should be noted that the main stadiums are designed as the combination of tracks surrounding a central playing field. That makes a stadium structure not only an ‘athletics stadium’ but also a ‘multipurpose stadium’. Since there is a necessity to sustain the long-term functioning of stadium structures, a special care was given to the viewing comfort conditions in stands area for outdoor many sports games. Here, the efficiency of stands area for outdoor sports was assessed based on the ideal viewing requirements of soccer games and athletics games since both sports types are most favourable/prevailing outdoor activities to be hosted by stadiums.

According to the post-event analyses, almost all (23 stadiums) stadiums among 25 in total sustain their functioning by hosting national and international soccer games (Table B.1). However only 13 of those stadiums provide satisfactory viewing conditions in their stands areas for outdoor sports. That showed the inadequacy in stands design for the half of summer Olympic stadiums and importance of prospective post-event selection from early-design stages of Olympic Games stadiums.

The data given in Table 4.5 were interpreted as below:

- The viewing locations of all stadiums’ stands were found to be satisfactory or partially-satisfactory for watching athletics sports while stands layout of only 13 stadiums were acceptable/satisfactory for watching other outdoor sports events, particularly the soccer games.
- Those 13 stadiums can host national and international soccer tournaments. However, 7 of those stadiums are not available to be used for FIFA and UEFA World Cup Competitions due to the lack of roof structure which totally-/partially-covers the stands area and/or required seat capacity of 50000 in minimum for World Cup Competitions.
- Among 13 stadiums providing satisfactory viewing locations, only 3 stadiums can be used for hosting UEFA World Cup Competitions since they provided fully-sheltered spectator area and seat capacity above 50000. However, only “1948 Empire Stadium” has been used for UEFA soccer competitions which was demolished in 2002. The reasons of why “1956 Melbourne Cricket Ground “ and

“1988 Jamsil Olympic stadium” have not been preferred for UEFA World Competitions in time needs to be investigated.

- Among those 13 stadiums, only 6 stadiums can be used for hosting FIFA World Cup Competitions. However, only 3 of them have been used for FIFA soccer competitions in the past. “The 1948 Empire Stadium” used for FIFA competitions has been demolished in 2002. On the other hand, “1964 National Olympic Stadium”, “1988 Jamsil Olympic Stadium” and “1992 Barcelona Olympic Stadium” have not been used till 2015. The reason why those stadiums have not been preferred for FIFA Competitions in time needs to be investigated.

The layout geometries of stadiums’ stands area were classified and the relationship between their layout geometry and viewing performance was discussed below:

- The relationship between the dimensions of spectators stand area and its geometry seemed to be determinative for efficiency assessment of viewing locations.
- Among the layout types for spectators’ stands, semicircular geometry was observed to be the most preferred layout while the next preferred layout was oval geometry followed by the circular geometry.
- Considering the preferable viewing zones and highest spectator capacity, ‘the circular geometry’ for the stands layout in plan seemed to be advantageous in comparison to the other geometrical layouts. For instances, the plan layouts of stands area for:
 - “1956 Melbourne Cricket Ground”,
 - “1968 Estadio Olímpico Universitario”,
 - “1972 Munich Olympic Stadium”, and
 - “1988 Jamsil Olympic stadium”

have circular geometry and their spectator capacities vary in the range of 80000 and 104000 on Olympic date.

Among them, “1968 Estadio Olímpico Universitario” and “1972 Munich Olympic Stadium” are more noticeable than the others due to their inherent ‘asymmetrical seating geometry’ that allowed to accommodate more spectators to the west while

keeping them within the recommended viewing zones/circles in plan layout. Such a layout allows keeping backs of spectators to the sun during afternoon games.

- However, semicircular and oval geometries having longitudinal dimensions around 230m were observed to perform good spectator/player relationship and to provide high spectator capacities as well. For instances plan layouts of the stands area for:

- “1924 Stade Yves-du-Manoir”,
- “1948 Empire Stadium”,
- “1952 Olympiastadion Helsinki”, and
- “1964 Tokyo National Stadium”

have semicircular geometry and their spectator capacities vary in the range of 60000 and 75000 on Olympic date.

In short, for multipurpose uses of stadium structures in future, there is necessity of providing excellent spectator/player interaction by:

- planning the geometrical layout of spectator stands compatible with the recommended viewing comfort/facilities, preferably with ideal viewing circles recommended for international soccer games,
- providing roofs to fully-shelter the spectator stands,
- conscious selection of geometry with a special care to locate most seats at south and west.

4.7 COMMON SUSTAINABILITY FEATURES OBSERVED IN OLYMPIC STADIUMS IN RELATION TO ENVIRONMENTALLY SENSITIVE STADIUM DESIGN

Due to the availability of written/published documents, the main structures of summer Olympic Games built after 1995 were examined in terms of some sustainability issues, specifically site preservation, water and energy efficiencies and long-term functioning. The period since 1996 corresponds with the attempts for environmentally sensitive design of Olympic venue (IOC, 1999, 2014; FIFA, 2007; UEFA, 2011). Specific items/actions included in design and construction of Olympic stadiums and Venues related with those sustainability issues are listed in Table 4.6.

Long-term functioning is one of the main criteria for sustainable use of stadium structures, therefore the planning of an Olympic stadium for targeted post-events has vital importance in this regards. The stadiums built after 1995 were all observed to consider mainly the items/approaches listed below which made them advantageous for hosting non-sports activities and international many sports competitions (Table 4.6). Those approaches are:

- Deciding/determination of targeted post events: Consideration of regional preferences, needs of host city/country in early-stages of stadium design, and then designing the stadiums, their seating capacities and facilities in accordance with relevant requirements/guidelines (IOC, 2005);
- Flexible design of playing field: Involvement of technological features supporting/providing adaptability of playing field for targeted post events (Table 4.6 and Table 5.1).
- Fully-sheltered seating capacity in acceptable ranges for targeted post-events: Providing a fully-sheltered seating capacity in certain ranges required for Olympic Games, on the other hand allowing dismantling/removing temporary seats while keeping fully-sheltered permanent seating capacity in acceptable ranges for targeted post-events (Table 4.6 and Table 5.1).

In terms of site preservation, the inherent natural, ecological and resourcing features of the site seemed to be considered (Table 4.6). For instances, a special care seemed to be given:

- to construct stadium on a disturbed site: either an existing stadium has been adapted/renovated to be used for Olympic Games or a new stadium being part of a green recreational venue has been constructed in an industrial zone.
- to protect the ecological/native lives/habitats of the region as much as possible and to preserve the watersheds of the region.

Efficient uses of water and energy and renewable energy sources seemed to be considered in Olympic stadiums by integration of some technological and/or automated systems. Involvement of relevant systems were observed to provide such technological features listed below:

- Reuse of rainwater directly collected from rainwater drainage systems and treated greywater generated from indoor uses, for non-potable purposes;
- Controlled consumption of water by automated systems mostly for irrigation purposes;
- Integration of passive design strategies for natural ventilation, passive cooling and heating of stadiums' indoors;
- Use of renewable energy sources, such as solar photovoltaic panels placed on stadium's roof and ground-source heat pump systems to produce energy for mechanical lighting, heating and cooling purposes.

The performance assessment of energy-/water-efficient systems and/or evaluation of the stadium structures in terms of environmentally sensitive design criteria were not the concern of this study. On the other hand, sustainability issues mentioned in stadiums technical manuals seemed to be considered in stadiums design by the involvement of some common features such as saving/reproducing energy and protection of nature life and not-disturbed earth as much as possible.

Table 4.6 Some sustainability features of Olympic Stadiums from 1996 to 2012 related with site preservation, water and energy efficiencies and long-term use.

Name	Site preservation / Issues	Water Efficiency	Energy Efficiency	Long-term use	Reference(s)
1996 Centennial Olympic Stadium	<i>Building of the stadium on a disturbed site:</i> – Construction of the stadium in a parking lot.	-	-	<i>Adaptable design of stadium for targeted post event (Baseball):</i> – Conversion of multi-purpose stadium to Baseball stadium after Olympic Games – Reduction in Olympic seats capacity (from 60,000 to 54,000) by removing temporary stands area at N which was made of precast concrete structure positioned on slab-on-grade, and then reconstructing new precast concrete stands.	OCO, 1896; French & Mike, 1997

Table 4.6 (Continued).

Name	Site preservation / Issues	Water Efficiency	Energy Efficiency	Long-term use	Reference(s)
2000 ANZ Stadium	<i>Building of the stadium on a disturbed site:</i> - Construction of the stadium in an industrial dump region. <i>Design of stadium venue as a green recreational field.</i> <i>Acting for protection of ecological/native lives/habitats of the region.</i> - Allowing survival of native Green and Golden Bell Frogs by providing a new appropriate site for them.	<i>Reuse of rainwater:</i> - Irrigation of playing field with the rainwater collected by the stadium's roof drainage system. <i>Reuse of greywater generated from indoor uses:</i> - Integration of greywater recycling and purification systems for toilet flushing and landscape watering	<i>Integration of passive design strategies:</i> natural ventilation, passive cooling and heating systems used for indoor comfort of stadium	<i>Adaptable design of stadium for targeted post events(soccer, rugby, cricket and Australian Football):</i> - Configuration of existing (athletics) playing field layout as a rectangular field surrounded by moving seats, when needed; - Major reduction in Olympic seats capacity (from 110,000 to 83,500) by dismantling two stands area made of steel structure and projecting at N & S.	OCA, 2000; Traganou, 2008; Darcovich & Jenny, 2008; Georgoulas & Patramanis, 2009
2004 Athens Olympic Stadium	<i>Adapting an existing stadium to be used for Olympic Games</i>	<i>Controlled consumption of water:</i> Integration of automatically-functioning irrigation system for efficient watering of playing field.	-	<i>Adaptable design of stadium for multi-purpose uses:</i> Configuration of playing field with and without lawn surfaces by using mountable/ demountable lawn modules/capsules.	AOC, 2004; OAKA, 2005; Georgoulas & Traganou, 2008; Patramanis, 2009;

Table 4.6 (Continued).

Name	Site preservation / Issues	Water Efficiency	Energy Efficiency	Long-term use	Reference(s)
2008 Beijing National Stadium	<i>Preservation of watersheds in region:</i> – Construction of permeable outdoor pavements on grounds to feed and keep inherent water sources in Olympic venue.	<i>Reuse of rainwater:</i> – Supply of non-potable water with the rainwater collected by the roof, surface water and subsoil water drainage system	<i>Use of renewable energy sources:</i> – Producing energy for lighting with solar photovoltaic panels placed on stadium's roof. – Producing heat for warming up stadium in winter and energy for functioning air conditioning system in summer with ground-source heat pump systems.	<i>Adaptable design of stadium for multi-purpose uses:</i> – Reduction in Olympic seats capacity (from 91,000 to 80,000) by dismantling the higher parts of stands.	BOCOG, 2008; Choi & Michael, 2009; Parrish, 2009
2012 London Olympic Stadium	<i>Building of the stadium on a disturbed site:</i> – Construction of the stadium in an industrial region. <i>Design of stadium venue as a green recreational field.</i>	<i>Reuse of rainwater:</i> – toilet flushing and landscape watering with the rainwater collected by the surface water and subsoil water drainage system <i>Controlled consumption of water:</i> – Integration of automatically-functioning (pop-up) irrigation system for efficient watering of playing field.		<i>Adaptable design of stadium for foreseen multi-purposes use:</i> – Major reduction in Olympic seats capacity (from 80,000 to 54,000) by dismantling the top roof and seating tier while reconstructing a permanent roof covering the permanent/remaining seats.	Poynter & Lain, 2009; Cole. & Hulme, 2011; Dyckhoof & Claire, 2012; Knight & Sybil; (2012) The Stadium, 2015;

CHAPTER 5

DISCUSSION

The joint interpretation of the results were done in relation to the acceptances/recommendations to sum up the overall findings to assess the efficiency of stadiums in terms of some major criteria on physical performances/capacities of stadiums as well as to clarify the requirements and/or necessities expected from stadiums to ensure their use in time for some specific or multi-sports activities. Discussions were done in reference to the technical recommendations and/or guidelines accepted/declared by international sports committees / federations / associations and standards listed in Table 2.2.

In total 26 stadium structures have been built in 22 different cities of 18 countries distributed in 4 continents (Europe, Americas, Asia and Oceania) (Table 3.1). Among 18 countries, USA and England hosted summer Olympic Games for 4 and 3, respectively while Greece, Germany and Australia hosting for 2 times. Among 22 cities, Los Angeles and London hosted summer Olympic Games for 2 and 3 times, respectively. Among all stadiums, 15 stadiums are located in Europe, 5 stadiums in Americas, 3 stadiums in Asia and 2 stadiums in Oceania (Figure 3.2).

Each host city of stadiums from 4 different continents were determined to locate in seven different climate types of mainly “warm temperate” or “snow” climate zones according to the Köppen-Geiger World Climate Classification (Table 4.1). Due to the precipitation and warmest temperature characteristics of those climates, all stadiums were expected to have a roof structure fully-covering their stands area to protect the spectators from exposed outdoor conditions of those climates. However, except 4

stadiums fully- or mostly-sheltered in their origin among 26 stadiums, 22 stadiums were have been originally-built without roof or with partial covers only sheltering VIP and private seats (Table 4.2). Due to the necessity of fully-sheltered stands, “the requirement of fully-sheltered stands area” was involved in technical recommendations/guidelines for stadium design, and that requirement became an obligatory requirement especially declared for international soccer and athletics competitions (FIFA, 1995; UEFA 2001; IAAF 2014). According to the UEFA Technical Recommendations and Technical Regulations for IAAF World Athletics Series, the main stadiums to be used for international soccer and athletics competitions all seats had to be fully-covered by a roof structure (UEFA, 2001; Nixdorf, 2007; IAAF, 2014).

The overall capacity of Olympic stadiums was determined to vary in the range of 10,000 - 110,000 spectators considering 26 stadiums used for summer Olympic Games. No significant correlation between spectator capacity and population of host cities was determined. It seemed that population of the host cities has not been considered as an important design factor for main stadiums of summer Olympic Stadiums.

These capacities were observed to differ in ranges belonging to two periods, specifically the first period between 1896-1928 years and the second period between 1932-2012 years. Within the first period the average original capacity was determined to be $42,371 \pm 27,881$ spectators while within the second period the average original capacity was determined to be $87,120 \pm 14,598$ spectators. A sharp increase in the spectator capacities from 42 thousands to 87 thousands starting in 1932 is remarkable. That rise corresponds to the emergence of television and TV broadcasting of sport events in 1930's as well (Honre & Garry, 2012).

On the other hand, original capacities of stadiums were observed to decrease during renovations in both periods. Within the first period of 1896-1932 years, the average original capacity was decreased to a current capacity of $27,732 \pm 26,016$ with a

reduction of 34%. The current capacities were also observed to decrease to 20,000 spectators towards the end of this period. All pointed out a tendency for converting Olympic stadiums to low-capacity stadiums in that period, in other words to be used/function for national/regional post-events in future. Within the second period of 1932-2012 years, the original capacity was decreased to a current capacity of $70,693 \pm 16,189$ with a reduction of 19%. The current capacities were also observed to decrease to 60,000 spectators towards the end of this period. That exhibited the efforts for achieving the recommended seating capacity in those structures in order to prepare them to host many international sports events in future for sustaining their service life.

Self-sustaining capability of stadium structures is a crucial criterion for their survival in time. The main issue of authorities and host countries is to sustain the functioning of those huge structures in time for economical, environmental, efficiency and socio-cultural purposes. Their inherent features, allowing their use for some specific post-events in time, have vital importance for their long-term functioning. Some features especially the ones related with the fundamentals of Olympic stadium design criteria, such as spectator capacity, presence of roof, orientation of playing field should be considered and involved during design stage. The location of stadiums and their design characteristics particularly configured according to the regional preferences and uses are the other features of stadiums that might contribute to their further use in time.

The analyses of post-event use in relation to the inherent features of stadium structures have shown the selection criteria for post-functioning of stadium structures in relation to their own features. The study is restricted with the analyses of specific features of stadium structures due to the availability of data extraction from wide range of written sources. The examinations, therefore were done on the basis of data specifically on spectator capacity of stadiums, post-Olympic activity types, host city population, the location and climatic zone of host country, orientation of stadiums' playing fields, spectators' stands layout as well as on some sustainability issues, whether involved or not, in their design.

The stadiums were observed to be used dominantly for “Non-Sport Events” during their service life after Olympic Games. It seemed that the existing main stadium structures are used in time to bring together a crowded population for musical, cultural and touristic activities, ceremonies and festivals. In that respect, cultural significance of those structures were observed to be the main determinative factor. When UNESCO added the site of Olympia to the World Cultural Heritage (WCH) in 1989, cultural and historical significance and cultural heritage values of Olympic stadiums were recognized (UNESCO, 2012; Kiuri & Teller, 2015). The stadium venues have potential connecting people to places and past events in a special way and raising awareness of people on their unique role in sport history of host country and world (Abercrombie, 2012; Wansborough & Mageean; 2000; Kiuri & Teller, 2015). Therefore, those structures have self-sustaining features due to their particular cultural value (Kluge, 2009). (Long, 2008; Kiuri & Teller, 2015). Among 25 main stadiums, 10 of them, namely:

- The 1896 Panathenaic Stadium,
- The 1912 Stockholm Stadium,
- The 1928 Olympisch Stadium Amsterdam,
- The 1932/1984 Los Angeles Memorial Coliseum,
- The 1936 Olympiastadion Berlin,
- The 1948 Empire Stadium,
- The 1956 Melbourne Cricket Ground,
- The 1968 Estadio Olímpico Universitario,
- The 1980 Luzhniki Stadium, and
- The 2000 ANZ stadium,

have become an environmental, socio-cultural and/or historical landmark in hosting city and still in use with post-Olympic activities and keep their authentic values.

The second activity type hosted by the stadiums is the “Soccer Games”. Main Olympic stadiums were observed to be used for the national and international soccer competitions. That might be due to the establishment of FIFA World Cup Games which made the soccer games favourite in the world after 1930’s together with the

broadcasting of Olympic Games on television. It was determined that the stadiums which have seating capacity of 50,000 in minimum and fully-sheltered spectator stand area have potential to host international soccer competitions. The stadiums which were renovated specifically to fulfil those requirements seemed to sustain their functioning in time by hosting international soccer games, namely FIFA and UEFA Soccer Competitions.

The next favourite post-Olympic event is the “Athletics Games” which is one the main sport events that all Olympic main stadiums were originally shaped and designed according to the requirements of that sport activity. The use of stadiums for their authentic function, Athletics Games, therefore should be expected. On the other hand, the use of stadiums for non-sport activities and soccer games seem to be more dominant when compared with the use of stadiums for Athletics.

It should be noted that there is a potential use of stadiums to host national/international competitions of regional sports in host countries. Favourite sports types of the region/citizens and appropriateness of stadium’s physical features for those sports types have vital importance that can make a stadium preferable to be used for a long period of time. It was observed that some stadiums host a few types of post-events which are regional and/or authentic sports types, such as baseball, cricket and Australian Rules football. In short, adaptability of playing field and/or stands layout(s) for foreseen regional uses/activities is a physical feature encouraging “post-Olympic functioning of stadiums” (Table B.1). For instance:

- *Baseball Game* is preferred in most of the stadiums in Americas as a Post-Olympic event. Since baseball is developed in this continent it is one of the favourite sport game here.
- *Cricket* and *Australian Rules Football* are the regional sport games of Australia. Therefore, the Olympic Stadiums in Oceania are used naturally to host those games in their lifelong.

- *Archery and Bandy Games* are hosted by the stadiums in Europe where inherent geometry/layout of their playing fields and stands area are adaptable for those specific post events.

Although many stadiums built in Europe, Americas and Oceania hosted many regional/traditional sports games, such as baseball, rugby, Australian Rules football and cricket, all 3 stadiums built in Asia (1964 Tokyo National Stadium, 1988 Jamsil Olympic Stadium, and 2008 Beijing National Stadium) have never been used for any regional/traditional sports/activities during their service lives. That indicated that the possibilities of using those stadiums for their regional preferences and adapting the layout of their playing fields and stands areas for their traditional/regional sports activities.

The Olympic stadiums are designed to host international athletics and soccer competitions of Olympic Games, and during their lifelong all of those stadiums hosted some national/international non-sports activities and many sports competitions (Table 5.1). However, their current uses do not indicate that all these stadiums have physical features satisfactory for the required/recommended comfort conditions. According to the technical manuals/guidelines of stadiums, those structures, in fact, should have been provided some basic qualifications, such as minimum seating capacity, fully-/partially-sheltered seat capacity, ideal positioning of stands and playing field areas. Among those features, three criteria based on correct positioning of stadiums and their geometric layouts and presence of a roof, if all well-fulfilled, make the stadiums remarkable. Those criteria are:

- “orientation of playing field” which should be positioned in accordance with the acceptable/recommended slopes ranges, is crucial for the athletes to save them from blinding effect of sun during games, and
- “positioning and geometric layout of stands area” which should be shaped in relation to the recommended viewing distances for many sport types, are critical for the spectators to provide ideal viewing locations and satisfactory visual comfort conditions for them while watching games.

- “fully-sheltered stands area” which provides sun-shaded and rain-shield seats for spectators.

The examinations have shown that only 2 stadiums among all, namely “1952 Olympiastadion Helsinki”, and “1988 Jamsil Olympic Stadium”, provide preferable/satisfactory features for spectators and athletes in current state since those two stadiums provide appropriate orientation of playing field and ideal viewing comfort to host many sports games as well as fully-sheltered conditions for spectators (Table 5.1). It meant that they are preferable for many sports competitions in comparison to the other stadiums. Those stadiums also have potential to host international many sports competitions due to their seating capacities more than 30,000 and 60,000 spectators, respectively.

Except those well-thought 2 stadiums, there are 6 stadiums listed below inherently designed with properly-oriented playing fields and well-shaped stands area for multi-purpose uses, while the others do not satisfy one or both of those criteria (Table 5.1). Those stadiums, except “1928 Olympisch Stadium Amsterdam”, “1968 Estadio Olímpico Universitario” ranked as cultural heritage of their countries and “1972 Munich Olympic Stadium” being an iconic focal point of Munich, may ensure their long-term functioning if a roof structure covering their overall stands area is added. Such a roof completion will definitely increase the preference/potential of the remained 3 stadiums to host many international sports competitions in future.

- 1924 Stade Yves-du-Manoir
- 1928 Olympisch Stadium Amsterdam
- 1968 Estadio Olímpico Universitario
- 1972 Munich Olympic Stadium
- 1992 Barcelona Olympic Stadium
- 2012 London Olympic Stadium

The remained 15 stadiums, in one way or another, seemed not to fulfil the technical requirements for correct positioning of stadiums and their geometric layouts (Table 5.1). Among those 15 stadiums, 7 stadiums have been ranked as cultural heritage of

their cities, therefore, seemed to have ensured their survival by means of cultural and touristic activities. Among the remained 8 stadiums, the 2008 Beijing National Stadium is still in use for Olympic Games. The other 7 stadiums, they are the home grounds for national soccer/baseball/gridiron teams in current state. That proves the major roles of cultural values and regional preferences/activities on long-term functioning of stadiums although their actual physical performances are not preferable for hosting sports games/competitions (Table 5.1).

Table 5.1 Basic features of Olympic stadiums in origin and in current state, showing their potentials and limitations to be used for some post-Olympic activities.

Stadium	Overall spectator capacity on Olympic date	Current overall spectator capacity	Geometrical layout of stands area	Types of post-Olympic activities hosted by stadiums during their lifelong	Demolished date	Officially-registered cultural heritage status	Appropriateness of playing field orientation for many outdoor sports games	Ideal viewing comfort of stands for many outdoor sports games	Ideal viewing comfort of stands for athletics games	Requirements for hosting FIFA and UEFA World Competitions		Best efficiency to be used for post events – Main failure for hosting any sports games.
										Presence of sheltered seating area	Sufficiency of current seat capacity	
1896 Panathenaic Stadium	50000	50000	Elongated U-shaped	Non-Sports events, Athletics, Basketball, Archery	–	Green	Green	Orange	Yellow	Orange	50000	Cultural, touristic & non-sport activities; national athletics competitions • Inefficient viewing at stands for many sports, • Lack of roof.
1904 Francis Field	10000	4000	U-shaped	Non-Sports events, Soccer, Athletics, Gridiron	–	Orange	Orange	Green	Green	Orange	4000	Non-sports activities • Lack of properly-oriented playing field, • Very low seating capacity • Lack of roof.

Table 5.1 (Continued).

1908 White City Stadium	93000	76567	Semicircular	Non-Sports events, Soccer, Athletics, Racing, Rugby,	1984						76567	Non-sports activities; international athletics competitions • Inefficient viewing at stands for many sports
1912 Stockholm Stadium	22000	14500	U-Shaped (close to Basket arch geometry)	Non-sports events, Soccer, Athletics, Racing, Bandy	–						14500	Cultural, touristic & non-sports activities • Lack of properly-oriented playing field
1920 Olympisch Stadium	30000	12771	Semicircular	Soccer	–						12771	Non-sports activities; national most sports competitions
1924 Stade Yves-du-Manoir	60000	14000	Semicircular	Non-sports events, Soccer, Athletics, Rugby	–						14000	Non-sports activities; national most sports competitions
1928 Olympisch Stadium Amsterdam	31600	22288	Oval	Non-sport events, Soccer, Athletics, Gridiron, Racing, Hockey, Archery	–						22288	Cultural, touristic & non-sports activities; national most sports competitions
1932 Los Angeles Memorial Coliseum	101574	93607	Semicircular	Non-sports events, Soccer, Athletics, Racing, Gridiron, Baseball, Hockey, Basketball	–						93607	Cultural, touristic & non-sports activities • Lack of properly-oriented playing field, • Inefficient viewing at stands for many sports, • Lack of roof.

Table 5.1 (Continued).

1936 Olympiastadion Berlin	110000	79200	Oval Geometry	Non-sports events, Soccer, athletics, Gridiron	–						79200	Cultural, touristic & non-sports activities • Lack of properly-oriented playing field, • Inefficient viewing at stands for many sports.
1948 Empire Stadium	82000	76000	Semicircular	Non-sports, Soccer, Racing, Rugby, Gridiron, Hockey	2002						76000	Cultural, touristic & non-sports activities • Lack of properly-oriented playing field.
1952 Olympiastadion Helsinki	70000	39000	Semicircular	Non-sports events, Soccer, Athletics, Bandy	–						39000	Non-sports activities; international most sports competitions
1956 Melbourne Cricket Ground	104000	100024	Circular	Non-sports events, Soccer, Athletics, Rugby, Australian Football, Cricket	–						95000	Cultural, touristic & non-sports activities • Lack of properly-oriented playing field
1960 Stadio Olimpico	90000	70634	Oval	Non-sports events, Soccer, Athletics, Rugby	–						70634	Non-sports activities; international athletics competitions • Inefficient viewing at stands for many sports.

Table 5.1 (Continued).

1964 National Olympic Stadium	75000	57363	Oval	Non-sports events, Soccer, Athletics, Rugby Gridiron	—						57363	Non-sports activities • Lack of properly-oriented playing field
1968 Estadio Olímpico Universitario	83700	68945	Circular	Non-sports events, Soccer, Athletics, Gridiron	—						68945	Cultural, touristic & non-sports activities; national most sport competitions • Lack of roof.
1972 Munich Olympic Stadium	80000	69250	Circular	Non-sports events, Soccer, Athletics, Racing	—						57450	Non-sports activities; international most sports competitions
1976 Montreal Olympic Stadium	70000	56000	Oval	Non-sports events, Soccer, Racing, Gridiron, Baseball	—						56000	Non-sports activities; international athletics competitions • Inefficient viewing at stands for many sports.
1980 Luzhniki Stadium	100000	78360	Semicircular	Non-sports events, Soccer, Athletics, Rugby	—						78360	Cultural, touristic & non-sports activities; international athletics competitions • Inefficient viewing at stands for many sports.

Table 5.1 (Continued).

1984 Los Angeles Memorial Coliseum	93000	93607	Semicircular	Non-sports events, Soccer, Athletics, Racing, Gridiron, Baseball, Hockey, Basketball	–						93607	Cultural, touristic & non-sports activities
												• Lack of properly-oriented playing field, • Inefficient viewing at stands for many sports, • Lack of roof.
1988 Jamsil Olympic stadium	93000	69841	Circular	Non-sports events, Soccer, Athletics	–						69841	Non-sports activities; international most sports competitions
1992 Barcelona Olympic Stadium	60000	54000	Basket Arch	Non-sports events, Soccer, Athletics, Rugby, Gridiron	–						54000	Non-sports activities; international most sports competitions
1996 Centennial Olympic Stadium	85000	49831	Semicircular	Non-sports, Baseball	–						49831	Non-sports activities; specifically renovated for international Baseball competitions
												• Inefficient viewing at stands for many sports
2000 ANZ Stadium	110000	83500	Circular	Non-sports events, Soccer, Racing, Rugby, Australian Football, Cricket	–						83500	Cultural, touristic & non-sports activities; international athletics competitions
												• Inefficient viewing at stands for many sports.
2004 Athens Olympic Stadium	70000	70000	Oval	Non-sports events, Soccer, Athletics	–						70000	Non-sports activities; international most sports competitions

Table 5.1 (Continued).

2008 Beijing National Stadium	91000	80000	Oval	Non-sports events, Soccer, Athletics, Racing	–						80000	Non-sports activities; international athletics competitions • Inefficient viewing at stands for many sports.
2012 London Olympic Stadium	80000	54000	Oval	Non-sports events, Soccer, Athletics, Racing, Rugby, Baseball	–						54000	Non-sports activities; international most sports competitions
LEGAND				NOT-SATISFIED / IMPROPER								
				PARTIALLY-SATISFIED								
				SATISFIED / ACCEPTABLE								
				DEMOLISHED								

ll the physical performances/capacities examined in the study are, in fact the issues contributing to the sustainability features of Olympic stadiums, particularly on their long-term use. On the other hand, those physical performance criteria have not been emphasized as sustainability criteria for long-term use of stadiums in their technical manuals related with sustainable design. According to those manuals related with sustainable stadium design, some environmentally sensitive features seemed to be included in design and construction stages of stadiums. Due to the fact that most stadiums were determined to be inadequate/not-satisfactory to fulfil some physical performance requirements for many sports competitions, there is a necessity to include physical performance requirements for many sports types into the technical manuals related with sustainable stadium design.

CHAPTER 6

CONCLUSION

Main stadium structures of summer Olympic Games are large scale structures which are specifically-designed to accommodate thousands of spectators and many sports competitions of Olympic Games. Their design, therefore, should be based on some major performances criteria considering their original and post-Olympic uses. The inherent physical performances/hosting capacities of those structures demonstrate their appropriateness, specifically potentials and limitations, for international and regional prospective events. Here, a knowledge is achieved by the individual assessment of each stadium structure on their physical performances/capacities based on quantitative data/parameters and by their joint evaluation to better understand the evolution of stadiums in time.

In total, 26 main stadiums of summer Olympic Games from 1896 to 2012 were examined in terms of their seating capacity, sheltered seat capacity, ideal orientation/positioning of stands and playing field areas as well as presence of any feature related with sustainability issues. The data obtained/produced to assess spectator capacity performance, physical performance of geometrical layout with a focus on viewing comfort conditions for athletes and spectators, and long-term functioning of stadiums. The efficiency assessment of their performances were done in reference to the technical recommendations and/or guidelines.

The results have shown the importance of inherent features of stadium structures for their post-functioning. The presence of fully-sheltered stands area is essential due to the climatic conditions of host cities located in seven different climate zones.

Supporting that, technical guidelines also require its presence particularly for international soccer and athletics competitions. The ranges of spectator capacities differ for two periods between 1896-1928 years and 1932-2012 years where 42 thousands and 87 thousands of spectators in average are observed, respectively, with a remarkable sharp increase for the second period. The trend of capacity reduction in current state signals the efforts for achieving recommended/operable seating capacity in Olympic stadiums to be able to host either many international sports events or regional sports competitions for sustaining their service life. The minimum seating capacities above 30,000 spectators have potential to host international sports competitions while the ones below that capacity can be preferable for national/regional sports events. Non-sports activities, soccer and athletics games are the activities mostly hosted in stadiums as post-Olympic events. Cultural significance of Olympic stadiums is one of the main determinative factor for their survival since their particular cultural values attract a crowded population for cultural and tourism activities. Three criteria based on correct positioning of stadiums and their geometric layouts and presence of a roof, if all provided, make the stadiums preferable/remarkable for many international sports competitions, specifically international soccer and athletics games. The adaptability of playing field and/or stands layout(s) for foreseen regional uses/activities is a physical feature that encourages “post-Olympic functioning of stadiums”. No significant correlation between spectator capacity and population of host cities is determined. All stadiums in current state, in one way or another, keep their functioning by hosting some many post-events. However, the individual evaluation of each stadium in reference to some major physical performance criteria has shown their physical competences/efficiencies for specific type(s) of post events as well as possible improvements/suggestions needed for their long-term-functioning.

The efforts on environmentally sensitive design of stadiums is promising for the long-term functioning of stadiums with a care on environment protection. However, there is a necessity of emphasizing “physical performance requirements defined for stadiums” as a sustainability criteria in “the technical manuals related with their

sustainable design” for properly-performing stadiums during their lifelong functioning.

Viewing all, the study has shown the priorities which should be considered during preliminary stages of Olympic stadium design. Here, those priorities are summarized as guiding remarks for professions related/interested in Olympic and non-Olympic stadium designs to improve their insights for designing well-performing stadium structures and to ensure their long-term functioning after Olympic Games. In this respect:

planning of future functions assigned for Olympic stadium structures is determinative and primary criterion that will guide for taking decisions on their permanent seating capacity, sheltered seating capacity, geometric plan layout and positioning.

The permanent seat capacities below or above 30,000 spectators as well as sheltered seat capacities above 30,000 spectators are expected to direct the post-use of stadium structures for national and international sport activities, respectively.

- The arrangement of Olympic seating capacity and permanent seating capacity may require the integration of flexible design such as integration of mountable/demountable seating area, adaptable playing field configurations for predefined targeted post activities.
- If stands area are needed to shape in high amounts and optimum viewing distances, the plan layouts with circular, semicircular and oval geometries as well as asymmetrical seating configurations to minimize the blinding effect of sun for spectators are recommended.
- Post-use of Olympic stadiums can be planned for the needs of host city. The design of stadiums can be shaped to serve for targeted achievements, such as revival or sustain traditional and/or regional sport and non-sport activities.

There are some other parameters related to the physical performances of stadiums, such as “viewing angle of stands area”, “density of stands area” and “maximum escape distance”. Further studies are also needed for comprehensive performance analyses of Olympic stadiums by including those parameters in evaluations. In addition,

investigations on stadiums' transformability or adaptability are needed in order to involve possible technologies contributing to flexible and sustainable design of Olympic stadiums.

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GLOSSARY

Athletics: are sports activities carried out on a field, e.g. discus, high jump and long jump, or on a track, e.g. running.

Archery: is a sport shooting with bow and arrow on a target disk.

Australian Rules Football: is an Australian game resembling rugby, played on an oval pitch with 18 to a team and a large oval ball that can be punched, kicked or carried

Bandy: is a sport played on ice with sticks, similar to ice hockey but with rules close to those of football.

Baseball: is a game played with a bat and ball by two teams of nine players on a field with four bases marking the course the batters must take to score runs.

Basketball: is a game played by two teams of five players who score points by throwing a ball through a basket mounted at the opponent's end of a rectangular court.

Cricket: is an outdoor sport played by two teams of 11 players using a flat bat, a small hard ball, and wickets. A player scores by batting the ball and running, while the defenders can get a player out by bowling and hitting the wicket, catching a hit ball, or running the player out

Hockey: is an outdoor sport played on grass between two teams of eleven, using wooden sticks with curved ends, the aim being to hit a small hard ball into the opposing goal.

Soccer: is a game in which 2 teams of 11 players try to kick or head a round ball into the goal defended by the opposing team. A name soccer given to association football in Britain in the 19th century in order to distinguish it from other forms of football. .

Stand: is a stepped structure around the playing field where spectators may sit or stand.

Racing: is the sport of taking part in races, e.g. as a runner, on a horse, or in a sports car.

Rugby: team ball game with an oval ball pass it laterally from hand to hand, and kick it which combines elements of soccer, American football, and handball. The idea of

the game is to score as many points as possible by laying down the ball in the end zone or by kicking the ball between two high goal posts.

APPENDIX A

SPECTATOR CAPACITIES FOR MAIN STADIUMS OF SUMMER OLYMPIC GAMES

Table A.1 The Olympic date and current overall spectator capacity of all main stadium structures, originally-constructed and renovated for the use of Summer Olympic Games from 1896 to 2012 in chronological order.

Name	Build Status	Construction Date	Olympic Spectator Capacity		Current Spectator Capacity		References
			Seat capacity	Standing capacity	Seat capacity	Standing capacity	
1896 Panathenaic Stadium	Originally As Olympic	329 BC	50000	–	50000	–	Easton, & Weinberg, 2006; OCOA, 1896
1904 Francis Field	Renovated as Olympic	1902	10000	–	4000	–	Lucas, 1905
1908 White city Stadium	Originally as Olympic	1908	63,000	30,000	76567	–	BOC, 1908
1912 Stockholm Stadium	Originally as Olympic	1912	10,500	11,500	14500	–	SOC, 1913
1920 Olympisch Stadium	Renovated as Olympic	1914	10,000	20,000	12771	–	Schmidt, 1988; Renson & Marijke, 1997
1924 Stade Yves-du-Manoir	Originally as Olympic	1883	20,000	40,000	14000	–	COF, 1924

Table A.1 (Continued).

1928 Olympisch Stadium Amsterdam	Originally as Olympic	1928	21,600	10,000	22288	–	TNOC, 1928
1932 Los Angeles Memorial Coliseum	Renovated as Olympic	1923	101574	–	93607	–	OCLA, 1933
1936 Olympiastadion Berlin	Originally as Olympic	1936	85,000	35,000	79200	–	OKOB, 1936
1948 Empire Stadium	Renovated as Olympic	1923	72,000	10,000	76000	–	LOCOG, 1948
1952 Olympiastadion Helsinki	Renovated as Olympic	1938	70000	–	39000	–	OCOH, 1955; Olympiastadion, 2015
1956 Melbourne Cricket Ground	Renovated as Olympic	1853	99,000	5,000	95,000	5,024	OCOM, 1958; MCG, 2015
1960 Stadio Olimpico	Renovated as Olympic	1928	65,000	25,000	70634	–	CONI, 1960
1964 National Olympic Stadium	Originally as Olympic	1958	75000	–	57363	–	TOCOG, 1964
1968 Estadio Olímpico Universitario	Renovated as Olympic	1952	83700	–	68945	–	OCOM, 1969
1972 Munich Olympic Stadium	Originally as Olympic	1972	69,000	11,000	57,250	11,800	OCOM, 1972
1976 Montreal Olympic Stadium	Originally as Olympic	1976	70000	–	56000	–	COJO'76, 1976
1980 Luzhniki Stadium	Renovated as Olympic	1956	100000	–	78360	–	OCOG-80, 1980
1984 Los Angeles Memorial Coliseum	Renovated as Olympic	1923	93000	–	93607	–	LAOOC, 1985
1988 Jamsil Olympic stadium	Originally as Olympic	1984	100000	–	69841	–	SLOOC, 1988
1992 Barcelona Olympic Stadium	Renovated as Olympic	1929	60000	–	54000	–	COOB'92, 1992

Table A.1 (Continued).

1996 Centennial Olympic Stadium	Originally as Olympic	1996	85000	–	49831	–	ACOG, 1996
2000 ANZ Stadium	Originally as Olympic	1999	110000	–	83500	–	OCA, 2000
2004 Athens Olympic Stadium	Renovated as Olympic	1982	70000	–	70000	–	Traganou, 2008
2008 Beijing National Stadium	Originally as Olympic	2008	91000	–	80000	–	BOCOG, 2008
2012 London Olympic Stadium	Originally as Olympic	2011	80000	–	54000	–	Knight & Sybil 2012; The Stadium, 2015;

APPENDIX B

TYPES OF POST-EVENTS HOSTED BY THE MAIN STADIUMS OF SUMMER OLYMPIC GAMES

Table B.1 List of major post-Olympic events in terms of their date, name and type which were hosted by each main stadium of summer Olympic Games from 1896 to 2012.

Date	Name of Post-Olympic Event	Type
1896 Panathenaic Stadium		
1905	Basketball Championship Winner's Cup	Basketball
1905	Opening Ceremony of the World Athletics Championship	Non-Sport
1906	Intercalated Olympic Games	Athletics
1916	Aida by Giuseppe Verdi; Opera	Non-Sport
1985	"Rock in Athens"	Non-Sport
1996	Celebration of 100 Years of Olympics	Non-Sport
1996	Welcome ceremony of the Greek Olympic Medallists in the Atlanta Games	Non-Sport
2004	Archery Event-Athens 2004 Olympic Games	Archery
2004	Finish venue for 2004 Olympic Games Women's Marathon Race,	Athletics
2004	Finish venue for Men's Marathon Race, Athens 2004 Olympic Games	Athletics
2007	Jose Carreras	Non-Sport
2008	R.E.M	Non-Sport
2009	Joaquin Cortes	Non-Sport
2010	Finish Venue for the Anniversary classic Marathon Race of Athens	Non-Sport
Source: Hellenic Olympic Committee, 2011		
1904 Francis Field		
1920s, 1930's, 1940s	Home for Bears College Football	Gridiron
1975 to 1977	Home for the NASL's St. Louis Stars	Soccer
1905	Bear over Westminster	Gridiron
1985	NCAA Division III National Men's' Soccer Championship	Soccer
1986	AAU/USA National Junior Olympic Games	Athletics
1987, 1989	First and Second National Senior Olympic Games	Athletics
1994	U.S Olympic Festival	Athletics
2004	The U.S. Women's Olympic Marathon Trials	Athletics
Every year	American Cancer Society's Relay for Life	Non-sport
Source: Washington University, 2015		

Table B.1 (Continued).

1908 White City Stadium		
1927 to 1984	Home for Greyhound Racing	Racing
1931 to 1933; 1962 to 1936	Home for Queens park Rangers F.C	Soccer
1976, 1979	Home for White City Rebels	Racing
1932 to 1970	Amateur Athletic Association Championships	Athletics
1933	London Highfield	Rugby
1934	British Empire Games	Athletics
1934	Women's World Games	Athletics
1970 to 1983	Speedway World Championships	Racing
1976, 1979, and 1982	Speedway World Team cup	Racing
1973	Performance of Ray Davies	Non-Sport
1974	David Cassidy Show	Non-Sport
Source: Yau, 2015		
1912 Stockholm Stadium		
1912 to 1936	Home for AIK; Swedish Football Club	Soccer
1936 to 2013	Home for Djurgårdens IF	Soccer
1934	Track and Field event	Athletics
1942	Running Match	Athletics
1959	SM-finals in Bandy	Bandy
1972, 1975, 1987	Track and Field event	Athletics
December of every year	Marathon (annual event)	Athletics
December of every year since 1967 to present	DN-Galan (annual event)	Athletics
1987	Pop Concert by Eurythmics	Non-Sport
1995	Rolling Stones	Non-Sport
1988, 1993, 1999, 2009	Bruce Springsteen (4 performances)	Non-Sport
NA	Luciano Pavarotti	Non-Sport
1956	Equestrian Games of 1956 Olympics	Racing
1958	European Athletics Championships	Athletics
NA	Finland-Sweden athletics international	Athletics
NA	Swedish Championship finals	Bandy
1992	Michael Jackson	Non-Sport
2008	Kiss	Non-Sport
2010	AC/DC	Non-Sport
Source: Stockholm Stads, 2015; Official report 1956		
1920 Olympisch Stadium		
1921 to Present	Home for FCO Germinal Beerschot Wilrijk	Soccer
Source: Schmidt, 1988; Renson & Marijke, 1997		
1924 Stade Yves Du Manoir		
Current	Home for support Racing Metro 92's	Rugby
Current	Home for Racing Club de France football Colombes 92	Soccer
1938	Football World Cup	Soccer
1938	European Athletics Championships	Athletics
1969	European Cup quarter-final	Soccer
1924 to 1971	French Cup (42 matches in total)	Soccer

Table B.1 (Continued).

1924 to 1972	Rugby Matches (89 matches in total)	Rugby
1924 to 1975	Football Matches (79 matches in total)	Soccer
NA	5 Nations Tournament matches	Rugby
1924 to 1980	Athletics Competitions	Athletics
Source: Racing 92, 2015		
1928 Olympisch Stadium Amsterdam		
1930's to 1989	Home for Dutch national football team	Soccer
1928 to 1966	Home for Ajaks	Soccer
1928 to 1972	Home for Blauw-Wit Club	Soccer
1995 to 1996	Home for American Football Club Amsterdam Admirals	Gridiron
NA	Speedway	Racing
NA	Field Hockey	Hockey
1954	Tour De France	Racing
During 1970's	FC Club	Soccer
1964	Europe Cup-1 final	Soccer
1987	FIM Speedway World Championship	Racing
1996	UEFA Cup final match	Soccer
1999	Merger Athletic club Phanos	Athletics
Since 1999 every year	Dutch Athletics Championship	Athletics
Since 1999 every year	Amsterdam Marathon	Athletics
Since 2003 every year	Mission Olympic (Sport tournament for highschools all over the Netherlands)	Athletics
Since 2005 every year	Olympic Experience	Athletics
2012	European Championship Archery	Archery
Every year	Memorial Day	Non-sports
Charity Events	Open monument Day	Non-sports
Charity Events	Charity Events	Non-sports
NA	Pink Floyd	Non-sports
2016	European Athletic Championships	Athletics
Source: Olympisch Stadion Amsterdam, 2015		
1932/1984 Los Angeles Memorial Coliseum		
1923 to present	Home for USC Trojans	Gridiron
1933 to 1981	Home for UCLA Football	Gridiron
1946 to 1979	Home for Rams	Gridiron
1958 to 1961	Home for Dodgers	Baseball
1960 to 1976	Home for Lakers	Basketball
1967	United Soccer Association	Soccer
1982 to 1994	Home for Raiders	Gridiron
1984 to 1999	Home for Clippers	Basketball
1959 to 2006	Home for USC Basketball	Basketball
1960 to 1972	Homes for Stars	Basketball
1972 to 1974	Home for Sharks	Hockey
1995 to 1996	Home for Ice Dogs	Hockey
1959	World Series	Baseball
1959	MLB All-Star Games	Baseball
1949, 1952, & 1955	NFL championship games	Gridiron

Table B.1 (Continued).

1951, 1972 and 1979	Pro Bowl	Gridiron
1958	Major League Baseball	Baseball
1960	Chargers	Gridiron
1960	Democratic National Convention	Non-sports
1963	Billy Graham's appearance	Non-sports
1967	Super Bowl I	Gridiron
1967	Kings	Hockey
1972	Super Bowl of Motocross	Racing
1972	Wattstax	Non-sports
1973	Super Bowl	Gridiron
1973	Super Bowl VII	Gridiron
1976	Bicentennial Spectacular	Non-sports
1988	Cobras Arena Football	Gridiron
1977	Los Angeles Aztecs	Soccer
1979	Music Festival	Non-sports
1981	Los Angeles Aztecs	Soccer
1982	Speedway World Final	Racing
1983 to 1985	United States Football League (USFL)	Gridiron
1985	Bruce Springsteen and E Street Band; Born in the U.S.A. Tour	Non-sports
1987	Papal Mass by Pope John Paul II	Non-sports
1988	Monsters of Rock Festival Tour	Non-sports
1988	Amnesty International's Human Rights Now! Benefit Concert	Non-sports
1990	Nelson Mandela's 1990 triumphant return to the United States	Non-sports
1991	CONCACAF Gold Cup	Soccer
1996, 1998, & 2000	Gold Cup	Soccer
2003	Summer Sanitarium Tour headlined by Metallica	Non-sports
2004, 2005, & 2006	Legends Football League	Gridiron
2006	RBD	Non-sports
2008	Baseball Games	Baseball
2009	Los Angeles Lakers 2009 NBA Championship victory parade	Non-sports
2009 to 2011	Los Angeles Temptation games	Athletics
2011	LA Rising	Non-sports
2012	Roger Waters performing "The Wall"	Non-sports
NA	SPEED Energy Formula Off-Road Presented By Traxxas	Racing
NA	Rolling Stones	Non-sports
NA	U2	Non-sports
NA	Metallica	Non-sports
NA	The Who	Non-sports
NA	Pink Floyd	Non-sports
NA	Kid Rock	Non-sports
NA	the Grateful Dead	Non-sports
NA	Van Halen	Non-sports
2014	Centroamericana Cup Championships	Soccer
2015	Special Olympics World Games	Athletics
Source: Lacoliseum, 2015; USC, 2015		

Table B.1 (Continued).

1936 Olympiastadion Berlin		
1963 to present	Home for Hertha BSC	Soccer
2003 to 2007	Home for Berlin Thunder	Gridiron
1937	German National Soccer Cup	Soccer
1946	Eight-Nations-Games	Athletics
1974	FIFA World Cup	Soccer
NA	National Soccer League games of Hertha BSC	Soccer
NA	NFL-Europe team	Gridiron
1990 to 1994	American Bowls (five American bowls)	Gridiron
2005	German national soccer	Soccer
2006	FIFA World Cup	Soccer
NA	Robbie Williams	Non-sports
NA	Rolling Stones	Non-sports
NA	ISTAF, an IAAF Golden League Meeting	Athletics
NA	World premiere	Non-sports
1985 to present	DFB Cup Final	Soccer
NA	U16 international match	Soccer
NA	ISTAF celebrated its 70th year of existence	Non-sports
NA	Comeback-Tour(Herbert Grönemeyer and Genesis)	Non-sports
1995	Guns N' Roses	Non-sports
1997	Michael Jackson	Non-sports
NA	Pyronale fireworks world championship	Non-sports
2000	Tina Turner	Non-sports
2007	Genesis	Non-sports
2007, 2008, & 2011	Herbert Groenemeyer (3 performances)	Non-sports
2008 & 2011	Mario Barth, Comedy-act (2 performances)	Non-sports
2008	Olympiastadion Berlin Buddy-Bear	Non-sports
2008	Madonna	Non-sports
2008	German FA Cup Finals for men and women	Soccer
2008	UEFA-Cup games	Soccer
2009 & 2013	Depeche Mode (3 performances)	Non-sports
2009	12th IAAF World Championships	Athletics
2009, 2011 & 2012	ISTAF (Internationales Stadionfest)	Athletics
2009, 2005 & 2009	US Rock Star (3 performances)	Non-sports
2009	DFB Cup Final	Soccer
2009	Pyronale World Championships	Non-sports
2009, 2011 & 2012	B2Run	Athletics
2010	BIG25 road race	Athletics
2010 & 2012	German Cup Final	Athletics
2010	5th Pyronale	Non-sports
2010	AC/DC	Non-sports
2011	75 Years Olympiastadion (Anniverseries and celebrations)	Non-sports
2011	Bundesliga winners final match	Soccer
2011	BIG 25 Berlin (road running competition)	Athletics
2011	German Cup Final match	Athletics
2011	Opening game of FIFA Women's World Championship	Soccer

Table B.1 (Continued).

2011	World Culture Festival	Non-sports
2011	Hertha BSC - Real Madrid	Soccer
2011	Pyronale - Firework-World-Championship	Non-sports
2011	Mass with pope Benedikt XVI	Non-sports
2011	Breakfast-Run	Athletics
2012	BIG 25 Berlin	Athletics
2012	Bruce Springsteen rocks	Non-sports
2012	Hertha BSC - Juventus Turin	Soccer
2012	Pyronale - Firework-World-Championship	Non-sports
2012	Festival of Lights	Non-sports
2013	Bon Jovi	Non-sports
2015	Helene Fischer	Non-sports
2015	UEFA Champions League Final	Soccer
Source: Olympiastadion Berlin, 2015		
1948 White City Stadium		
1923 to 2000	Home for England national football team	Soccer
1991 to 1992	Home for London Monarchs	Gridiron
1946 to 1957 & 1970 to 1971	Home for Wembley Lions speedway team	Racing
1998 to 2000	Home for Arsenal FC	Soccer
NA	Leyton Orient FC	Soccer
1923	White Horse' FA Cup Final	Soccer
1928 to 1998	St Leger Cup	Racing
1929 to 1998	Trafalgar Cup	Racing
1929	Motorcycle speedway	Racing
1929	Challenge Cup	Rugby
1936 to 1960	Speedway World Championship (all of the first fifteen finals)	Racing
1930 to 1931	non-League Ealing A.F.C (8 matches)	Soccer
1949	International rugby league tournament	Rugby
1951 to 1959	women's field hockey matches (Annual matches)	Hockey
1971 to 1991	women's field hockey matches (Annual matches)	Hockey
1963 & 1968, 1971 & 1978	European Cup Final	Soccer
1953 to 2000 excluding 1970	FA Cup Final	Soccer
1968, 1970 & 1973	Speedway World Team Cup	Racing
1965 & 1983	The Animals	Non-sports
1966	World Cup Final	Soccer
1970 & 1971	British League (motorcycle speedway)	Racing
1956 & 1971	Great Britain national football team	Soccer
1972	The London Rock and Roll Show	Non-sports
1974	BriSCA Formula 1 Stock Cars	Racing
1974	Crosby, Stills, Nash and Young	Non-sports
1974	BriSCA Formula 1 Stock Cars	Racing
1975, 1985, 1992 & 1998	Elton John (7 performances)	Non-sports
1975	Evel Knievel demonstration	Non-sports
1979	The Who	Non-sports
1979	Johnny Cash	Non-sports

Table B.1 (Continued).

1982	John Paul II's Celebration of the Eucharist	Non-sports
1982, 1990, 1992 & 1999	The Rolling Stones (12 performance)	Non-sports
1983 to 1993	National Football League (9 matches)	Gridiron
1984	United States Football League (an exhibition game)	Gridiron
1984 to 1985	Bruce Springsteen and the E Street Band;Born in the U.S.A. Tour (3 performances)	Non-sports
1985	Live Aid Event	Non-sports
1985 to 1997	U2 (8 performances)	Non-sports
1985	Challenge Cup	Rugby
1986 & 1992	Queen (2 performances)	Non-sports
1987	Genesis (4 performances)	Non-sports
1987, 1990, 1993, & 2008	Madonna (7 performances)	Non-sports
1988	Middlesex Charity Cup (final match)	Soccer
1988	Human Rights Now! (charity concert)	Non-sports
1988	Nelson Mandela 70th Birthday Tribute	Non-sports
1988	The Freddie Mercury Tribute Concert	Non-sports
1988	Pink Floyd (2 performances)	Non-sports
1988	Bruce Springsteen and the E Street Band; Tunnel of Love Express Tour (2 performances)	Non-sports
1988, 1992, & 1997	Michael Jackson (15 performances)	Non-sports
1989	Cliff Richard (2 performances)	Non-sports
1989	Simple Minds	Non-sports
1965 & 1993	UEFA Cup Winners' Cup	Soccer
1991	Guns N' Roses	Non-sports
1991	World Bowl 91	Gridiron
1992	Rugby League World Cup Final	Rugby
1992 & 1995	Rugby League World Cup Finals	Rugby
1992, 1997, & 1998	Autumn International Series	Rugby
1995	Bon Jovi	Non-sports
1996	Eagles (2 performances)	Non-sports
1996	World Cup Finals	Soccer
1996	UEFA Euro 1996 Final	Soccer
1996 & 2000	Tina Turner (4 performances)	Non-sports
1998	Bee Gees	Non-sports
1998 & 1999	Five Nations Championship (2 matches)	Rugby
1998 to 2000	Arsenal's home Champions League matches	Soccer1
1999	Celine Dion (2 performances)	Non-sports
1999	Challenge Cup	Rugby
2000	First Division play-off final	Soccer
Source: Clarke, 2012; FIFA, 2015		
1952 Olympia-Stadion Helsinki		
Current	Home for Finland national football team	Soccer
1943	Workers' Summer Olympiad	Athletics
1957	Bandy World Championship	Bandy
1983	World Athletics Championships	Athletics
1997	Michael Jackson; History World Tour (2 performances)	Non-sports

Table B.1 (Continued).

2002	50th anniversary of the Helsinki Olympic Games	Athletics
2003, 2008 & 2013	Bruce Springsteen; The Rising Tour (4 performances)	Non-sports
2005	World Championships in Athletics	Athletics
2006	The amazing Race; TV Series	Non-sports
2009	UEFA Women's Euro 2009	Soccer
2010	U2 360° Tour (2 performances)	Non-sports
1971, 1994 & 2012	European Athletics Championships	Athletics
2012	Madonna; MDNA Tour	Non-sports
2013	Muse; The 2nd Law World Tour	Non-sports
2015	One Direction; On the Road Again Tour	Non-sports
Source: Olympiastadion, 2015		
1956 Melbourne Cricket Ground		
Current	Home for Australia national cricket team	Cricket
1851 to present	Home for Victorian Bushrangers	Cricket
1851 to present	Home for Melbourne Football Club	Australian Rules Football
1965 to present	Home for Richmond Football Club	Australian Rules Football
1992 to present	Home for Essendon Football Club	Cricket
1993 to present	Home for Collingwood Football Club	Australian Rules Football
2000 to present	Home for Hawthorn Football Club	Australian Rules Football
2011 to present	Home for Melbourne Stars	Cricket
2014 to present	Home for Carlton Football Club	Australian Rules Football
1937, 1961, 2006, & 2013	Test cricket (4 matches)	Cricket
1955	Test cricket ; England Tour of Australia	Cricket
1959	Billy Graham evangelistic crusade	Non-sports
1970	VFL Grand Final	Australian Rules Football
1970	Queen Elizabeth II	Non-sports
1971, 1972, & 1984	One Day International (3 matches)	Cricket
1974	David Cassidy	Non-sports
1977	Rugby Union; Australia vs New Zealand	Rugby
1977	celebration 100 years of Test cricket between	Cricket
1978	David Bowie	Non-sports
1984	An exhibition match between Australia and Juventus	Cricket
1984	Benson & Hedges World Championship of Cricket	Cricket
1992	Cricket World Cup Final	Cricket
1993	Paul McCartney	Non-sports

Table B.1 (Continued).

1993	Madonna	Non-sports
1993	U2	Non-sports
1994, 1995, & 1997	State of Origin series	Rugby
1995	Rolling Stones	Non-sports
1996	Michael Jackson	Non-sports
1996	Michael Jackson	Non-sports
1997	Three Tenors	Non-sports
1998	Elton John	Non-sports
1998	Billy Joel	Non-sports
1998	FIFA World Cup; Iran vs Australia	Soccer
1999	An exhibition match between Manchester United and Australia	Soccer
1999	friendly match between Brazil B and Australia	Soccer
2000	Melbourne Storm	Rugby
2000	Soccer Preliminaries of Summer Olympic Games	Soccer
2001	2002 FIFA World Cup qualifier	Soccer
2006	Commonwealth Games	Athletics
2008	Twenty20	Cricket
2008	The Police; Concert	Non-sports
2009	2010 FIFA World Cup qualification	Soccer
2009	Sound Relief	Non-sports
2010	The Amazing Race Australia; Australian reality game show	Non-sports
2010	2010 AFL Grand Final	Australian Rules Football
2015	AFL Season	Australian Rules Football
2015	ICC Cricket World Cup	Cricket
2015	International Champions Cup Australia	Soccer
NA	Annual AFL Grand Final	Australian Rules Football
2015	Cricket World Cup Final	Cricket
2015	State of Origin series	Rugby
Source: MCG, 2015		
1960 Stadio Olimpico		
1953 to present	Home for Lazio; Football Club	Soccer
1954 to present	Home for A.S. Roma; Football Club	Soccer
1955 to present	Home for Italian national football team	Soccer
2012 to present	Home for Italian rugby team	Rugby
1968	European Championship Final	Soccer
1973	Intercontinental Cup final	Soccer
1975	Summer Universiade	Athletics
1977	European Cup Final	Soccer
1980	European Championship Final	Soccer
1981 to present	Golden Gala (annual event)	Athletics
1984	European Cup Final	Soccer
1987	World Championships in Athletics	Athletics
1990	FIFA World Cup	Soccer

Table B.1 (Continued).

1990	UEFA Champions League Final	Soccer
1991	Miles Davis	Non-sports
1991	Pat Metheny	Non-sports
1996	Tina Turner	Non-sports
1996	David Bowie	Non-sports
1997	UEFA Champions League Final	Soccer
1999	Backstreet Boys	Non-sports
2001	Sting	Non-sports
2001	Summer Deaflympics	Athletics
2003	The Cure	Non-sports
2004	Eros Ramazzotti	Non-sports
2005	R.E.M.	Non-sports
2005	U2;Vertigo Tour	Non-sports
2006 & 2012	Madonna; Confessions Tour (2 performances)	Non-sports
2006 & 2013	Roger Waters; The Dark Side of the Moon Live (2 performances)	Non-sports
2006	Depeche Mode; Touring the Angel	Non-sports
2007	Iron Maiden, Motörhead, Machine Head, Mastodon and Lauren Harris (1 performance)	Non-sports
2008	Maddona; Sticky & Sweet Tour	Non-sports
2009	Bruce Springsteen; Working on a Dream Tour	Non-sports
2009	UEFA Champions League Final	Soccer
2009	Depeche Mode Tour of the Universe	Non-sports
2010	U2 360° Tour	Non-sports
2013	Depeche Mode; Delta Machine Tour	Non-sports
2013	Six Nations Championship	Rugby
2013	Eros Ramazzotti	Non-sports
2013	Psy	Non-sports
2013	Muse; The 2nd Law Tour	Non-sports
2020	UEFA Euro	Soccer
Source: Olympic stadium rules and regulations, 2015; FIFA, 2015		
1964 National Olympic Stadium		
1976 to 1993	Coca-Cola Classic (seasonal event)	Gridiron
1991	World Athletics Championships	Athletics
1980 to 2001	Intercontinental Cup	Soccer
1967 to 2013	Emperor's Cup (as final venue)	Soccer
Current	Annual university rugby semi-finals and finals	Rugby
Current	All Japan High School Soccer Tournament (annual event)	Soccer
Current	Japanese Super Cup (annual event)	Soccer
2014	SMAP	Non-sports
2014	Sayonara National Olympic Stadium Final Week Japan Night	Non-sports
2014	Dreams Come True	Non-sports
2014	Arashi	Non-sports
2014	L'Arc-en-Ciel	Non-sports
2014	Momoiro Clover Z	Non-sports
2014	AKB48	Non-sports
Source: Japan Sport Council, 2015		
1968 Estadio Olímpico Universitario		
1952 to present	Home for Club de Fútbol Universidad Nacional A. C.	Soccer
1953 to present	Home for Pumas Dorados de la UNAM	Gridiron

Table B.1 (Continued).

1954	Central American Games	Athletics
1955 & 1975	Los Segundos Juegos Deportivos Pan-Americano	Athletics
1950's & 1960	American College Football	Gridiron
1970 & 1976	World Soccer Championships	Soccer
1977	Caribbean	Athletics
1977	Student Games Central American	Athletics
1979	World Universiade	Athletics
1986	FIFA World Cup (several matches)	Soccer
1990	Central American and Caribbean Games	Athletics
NA	Copa Libertadores de América	Soccer
NA	Copa Sudamericana	Soccer
NA	Interamerican Cup	Soccer
NA	Concacaf Champions League	Soccer
NA	Many Cultural events	Non-sports
Source: UNAM, 2015		
1972 Munich Olympiastadion		
1972 to 2005	Home for FC Bayern Munich	Soccer
1973 to 2005	Home for TSV 1860 Munich	Soccer
1972, 1982, & 1992	German Athletics Championships	Athletics
1973, & 1978 to present	Watchtower World Congress	Non-sports
1973	International Athletics Contest	Athletics
1974	World football champions (5 matches)	Soccer
1975	Super Cup (1 match)	Soccer
1976	European Football Championships	Soccer
1976	World Cup Final	Soccer
1979	Start of the German VITAMALZ Tour for Professional Cyclists	Racing
1979	European Cup	Soccer
1980	Goal of the German "Rundfahrt" Tour	Racing
1982	Start of the German "Rundfahrt" Tour	Racing
1984	88. German Catholic Assembly (Katholikentag)	Non-sports
1985, 2003, 2009, & 2013	Bruce Springsteen (4 performances)	Non-sports
1983, 1984, & 1986	International Athletics Meeting	Athletics
1982, 1990, 1995, 1998, 2003, & 2006	Rolling Stones (6 performances)	Non-sports
1987	European Deaf Athletics Championships	Athletics
1987	Mass held by Pope John Paul II.	Non-sports
1988 & 1994	Pink Floyd (2 performances)	Non-sports
1988, 1992, 1997, & 1999	Michael Jackson (4 performances)	Non-sports
1988	European football champions (2 matches)	Soccer
1989	Speedway World Final	Racing
1990	Tina Turner	Non-sports
1990	Prince	Non-sports
1992	Dire Straits	Non-sports
1993	Protestant Church Assembly	Non-sports

Table B.1 (Continued).

1993	Guns'n'Roses	Non-sports
1993, 2005, & 2010	U2 (3 performances)	Non-sports
1995 & 1996	Rock in the Park	Non-sports
1995	Rock over Germany	Non-sports
1996	3 Tenors	Non-sports
1996	Olympique Marseille (Champions League)	Soccer
1996	UEFA Cup 2nd final	Soccer
1997 & 2007	Athletics Spar European Cup Final	Athletics
1997 & 2007	Genesis	Non-sports
1997	Champions League	Soccer
1998	Elton John	Non-sports
1999	Marius Müller-Westernhagen	Non-sports
1999	Big Solar Eclipse Party	Non-sports
1999	IAAF Grand Prix Athletics Final	Non-sports
1999 & 2008	Celine Dion (2 performances)	Non-sports
2001, 2009, & 2015	AC/DC (3 performances)	Non-sports
2001, 2003, 2006, 2008, 2011, & 2013	Bon Jovi (6 performances)	Non-sports
2002	European Athletics Championships	Athletics
2003, 2007, & 2011	Herbert Grönemeyer (3 performances)	Non-sports
2003, 2006, 2007, 2013	Robbie Williams (4 performances)	Non-sports
2004	Athletics Team Challenge	Athletics
2004	Phil Collins	Non-sports
2004	Metallica	Non-sports
2004	Simon&Garfunkel	Non-sports
2005	Open air cinema	Non-sports
2005	Open air opera "Turandot"	Non-sports
2005	Lights of Joy	Non-sports
2005, 2006, 2007, & 2011	Air&Style	Non-sports
2005 & 2006	Weinwelt München (munich world of wine)	Non-sports
2006	Die drei Orchester classical open air at the beginning of soccer world championship	Non-sports
2007	Stock Car Grand Prix	Racing
2007	Red Hot Chili Peppers	Non-sports
2007	European Cup	Soccer
2008	Public Viewing Soccer European championship	Soccer
2008	Nike Human Race	Racing
2009	Madonna	Non-sports
2009 & 2013	Depeche Mode (2 performances)	Non-sports
2010	Cirque du Soleil	Non-sports
2010, 2011, 2012, 2013, & 2015	Boulder World Cup	Athletics
2010 & 2011	SportScheck Outdoor Festival	Athletics
2011 & 2012	DTM Munich	Non-sports
2011	Easter Festival	Non-sports

Table B.1 (Continued).

2011	Take That	Non-sports
2011 to present	B2 Run-Companies Run (annual event)	Athletics
2012	women's final of the UEFA Champions League	Soccer
2012	Red Bull X-Fighters	Racing
2012	Coldplay	Non-sports
2012	Nickelback	Non-sports
2012	Special Olympics	Athletics
2013	Macklemore	Non-sports
2013	X Games Munich	Racing
2014	Church Assembly south Germany	Non-sports
2014	Public Viewing Soccer World Championship	Soccer
2014	Boulder WM	Non-sports
2015	Rockavaria	Non-sports
2015	Helene Fischer	Non-sports
Source: Olympic Park Munich, 2015		
1976 Montreal Olympic Stadium		
1977 to 2004	Home for Montreal Expos (MLB)	Baseball
1976 to 1986 & 1996 to Present	Montreal Alouettes (CFL)	Gridiron
1981 to 1983	Home for Montreal Manic (NASL)	Soccer
1991 to 1992	Home for Montreal Machine (WLAF)	Gridiron
2012 to present	Home for Montreal Impact (MLS)	Soccer
NA	Grey Cup (6 times_	Gridiron
1977	National League	Baseball
1977	Pink Floyd	Non-sports
1977	Emerson, Lake & Palmer	Non-sports
1977	Aida; Opera (2 performances)	Non-sports
1981 & 1982	Drum Corps International World Championship finals	Non-sports
1982	Major League Baseball All-Star Game	Baseball
1984	Pope John Paul II	Non-sports
1988 & 1990	NFL pre-season games	Gridiron
1991 & 1992	World League of American Football	Gridiron
2007	FIFA Under 20 World Cup (several matches)	Soccer
2009	Trophée des Champions Final	Soccer
2009	CONCACAF Champions League quarter-final	Soccer
2010	Brother André	Non-sports
2012	Major League Soccer (MLS)	Soccer
2014	FIFA U-20 Women's World Cup; Final Match	Soccer
2014 & 2015	Spring Training Games; Major League Baseball (4 matches)	Baseball
2015	CONCACAF Champions League; Final Match	Soccer
2015	FIFA Women's World Cup; Tournament Matches	Soccer
Source: Park Olympique Le Stade, 2015		
1980 Luzhniki Stadium		
1956 to present	Soviet Union national football team	Soccer
1984	World Championship in ice motorcycle	Racing
1984	International completion "Friendship"	Athletics
1985	Opening of XII World Festival of Youth and Students	Non-sports
1986	Goodwill Games of 1986	Athletics
1987	Festival of Soviet – Indian friendship	Non-sports
1989	Music Peace Festival	Non-sports

Table B.1 (Continued).

1990	Viktor Tsoy and Kino band	Non-sports
1992	Concert in the memory of Viktor Tsoy	Non-sports
1993	Michael Jackson; Dangerous World Tour	Non-sports
1997	850th anniversary of Moscow	Non-sports
1997	Match Russia – national team of FIFA in the honor of 100th anniversary of Russian football	Soccer
1998	The Rolling Stones	Non-sports
1998	Opening and competitions of the first World youth games	Athletics
1999	UEFA Cup Final	Soccer
2006	Madonna; The Confession Tour	Non-sports
2007	Metallica; Studio '07 tour	Non-sports
2007	Tokio Hotel rock band	Non-sports
2008	festival “MosComSports – 85 years”	Non-sports
2008	Final of UEFA Champions League of 2007—2008	Soccer
2009	Beyonce; I Am... Tour	Non-sports
2010	U2; 360° Tour	Non-sports
2010	Anniversary of Victory in the Great Patriotic War	Non-sports
2012	Red Hot Chili Peppers	Non-sports
2012	WWE SuperRaw show — World Wrestling Federation	Non-sports
2013	Rugby World Cup Sevens	Rugby
2018	FIFA World Cup Final	Soccer
Source: Olympic complex Luzhniki, 2015		
1988 Jamsil Olympic Stadium		
1988 to 2000 & 2013 to Present	Home for Korea Republic national football team	Soccer
2007 to 2010, & 2012 2015 to present	Home for Seoul United	Soccer
1996 & 1999	Michael Jackson (3 performances)	Non-sports
2000	Ricky Martin	Non-sports
2001	The Three Tenors	Non-sports
2002	Roger Waters	Non-sports
2002 & 2004	ETPFEST	Non-sports
2004	Elton John	Non-sports
2006	Backstreet Boys	Non-sports
2006	TVXQ	Non-sports
2006	SM Town (2 performances)	Non-sports
2006 & 2013	Metallica	Non-sports
2009	Mnet Asian Music Awards	Non-sports
2010 & 2014	JYJ (3 performances)	Non-sports
2010	4th Asia Song Festival	Non-sports
2012	SMTown Live World Tour III	Non-sports
2012	Lady Gaga; Born This Way Ball	Non-sports
2013	Muse	Non-sports
2013	EAFF East Asian Cup	Soccer
2014	YG Entertainment; YG Family World Tour	Non-sports
2014	The Return Of The King Asia Tour Concert	Non-sports
2014	15th Anniversary Reunion Concert	Non-sports
2014	God	Non-sports
2015	Paul McCartney; Out There	Non-sports

Table B.1 (Continued).

NA	Athletics Events	Athletics
Source: Jamsil stadium, 2015		
1992 Barcelona Olympic Stadium		
1991 to 1992 & 1995 to 2005	Home for Barcelona Dragons	Gridiron
1997 to 2009	Home for RCD Espanyol	Soccer
2012 to present	Home for Catalans Dragons	Gridiron
1990 to present	Miting Internacional d'Atletisme Ciutat de Barcelona (annual track & field event)	Athletics
1990	The Rolling Stones; Urban Jungle Tour	Non-sports
1990	Prince; Nume Tour	Non-sports
1990 & 2009	Madonna (2 performances)	Non-sports
1990	David Bowie; Sound + Vision tour	Non-sports
1990	Tina Turner; Foreign Affair Tour	Non-sports
1991	Monsters of Rock festival: AC/DC, Metallica, Tesla	Non-sports
1992	Michael Jackson; Dangerous Tour	Non-sports
1993, 2003, & 2012	Bruce Springsteen; Human Touch World Tour (3 performances)	Non-sports
1993	Guns N' Roses	Non-sports
1993	Jean Michel Jarre	Non-sports
1993	rugby league club championship (1 match)	Rugby
1994	Pink Floyd; The Division Bell Tour	Non-sports
1995	Bon Jovi with The Pretenders and Van Halen	Non-sports
1993 & 1994	American Bowl (2 matches)	Gridiron
1995	World Cup in Athletics	Athletics
1997	U2; PopMart Tour	Non-sports
1998, 2003, & 2007	The Rolling Stones (3 performances)	Non-sports
1997	World Bowl '97 (1 match)	Gridiron
1999	Euro 2000 qualifying match	Soccer
2003	World Police and Fire Games	Athletics
2004	Copa del Rey final	Soccer
2007	RBD; Tour Celestial	Non-sports
2007	Euro 2008 qualifying match	Soccer
2007	The Police; Police Reunion Tour	Non-sports
2001 & 2008	Bon Jovi (2 performances)	Non-sports
2008	Euro 2010 qualifying match	Soccer
2009 & 2015	AC/DC (2 performances)	Non-sports
2009	Coldplay; Viva la Vida Tour	Non-sports
2009	The Prodigy	Non-sports
2009	Marilyn Manson	Non-sports
2009	Super League match	Rugby
2010	20th European Athletics Championships	Athletics
2011	Shakira; The Sun Comes Out World Tour	Non-sports
2011	Heineken Cup quarter-final match	Rugby
2012	World Junior Championships in Athletics	Athletics
2013	Muse; The 2nd Law World Tour	Non-sports
2014	One Direction; Where We Are Tour	Non-sports
Source: Estadi Olimpic, 2015; FIFA, 2015		

Table B.1 (Continued).

1996 Centennial Olympic Stadium		
1997 to present	Home for Atlanta Braves (MLB)	Baseball
1997 to 2005 & 2010 to 2013	National League Division Series (held 11 times)	Baseball
1997 to 2005, 2010 and 2013	National League Championship Series (4 times)	Baseball
1999	World Series	Baseball
2000	Major League Baseball All-Star Game	Baseball
2012	NL Wild Card Game	Baseball
NA	Dave Matthews Band	Non-sports
NA	Eminem	Non-sports
NA	Paul McCartney	Non-sports
NA	The Rolling Stones	Non-sports
Source: Turner Field, 2015		
2000 ANZ Stadium		
1999 to present	Home for New South Wales Blues	Rugby
2000 to present	Home for Canterbury-Bankstown Bulldogs (NRL)	Rugby
2002 to present	Home for Sydney Swans (AFL)	Australian rules football
2006 to present	Home for South Sydney Rabbitohs (NRL)	Rugby
2009 to present	Home for New South Wales Waratahs	Rugby
2008 to 2014	Home for St George Illawarra Dragons (NRL)	Rugby
2012 to present	Home for Sydney Thunder (BBL)	Cricket
Current	Home for New South Wales cricket team	Cricket
Current	Home for GWS Giants (AFL)	Australian rules football
2005 to 2008 & 2014 to present	Home for Wests Tigers (NRL)	Rugby
2002	Speedway Grand Prix World Championship series	Racing
2003	Australian Football League	Australian rules football
2003	Rugby World Cup	Rugby
2005, 2006, 2008, 2012, & 2013	NRL Grand Final	Rugby
2009	NRL season	Rugby
2010	AC/DC (3 performances)	Non-sports
2010	U2 (2 performances)	Non-sports
2013 & 2014	A-League All Stars Game (2 matches)	Soccer
2013	Premiers (1 match)	Rugby
2013	Bon Jovi	Non-sports
2013 & 2014	State of Origin series (2 matches)	Rugby
2013	Tom Richards Cup	Rugby
2014	Eminem	Non-sports
2015	AFC Asian Cup Final (5 matches)	Soccer
Source: The Stadium, 2015		
2004 Athens Olympic stadium		
1985 to 1987 & 2003 to present	Home for AEK F.C.	Soccer

Table B.1 (Continued).

2006	Shakira	Non-sports
2007	George Michael	Non-sports
2007	UEFA Champions League Final	Soccer
2008	Madonna; Sticky & Sweet Tour	Non-sports
2009	AC/DC	Non-sports
2009	Carlos Santana	Non-sports
2010	U2; 360° Tour	Non-sports
2010	Pyx Lax	Non-sports
2011	Bon Jovi	Non-sports
2011	Special Olympics World Summer Games	Athletics
2012	Red Hot Chili Peppers	Non-sports
2013	Rogers Waters	Non-sports
2014	One Country, One Voice	Non-sports
2014	Auto BattleShips Festival O.A.K.A.	Non-sports
2014	Lady Gaga	Non-sports
2014	Cirque du Soleil	Non-sports
2014	Amita Motion : Day of Positive Energy	Non-sports
Source: OAKA, 2015		
2008 Beijing National Stadium		
2008	Summer Paralympics	Athletics
2009	Race of Champions	Racing
2010	Birmingham City and Beijing Guoan	Soccer
2009, 2011, & 2012	Supercoppa Italiana	Soccer
2012	Leehom Wang	Non-sport
2012	China Cup	Soccer
2013	SMTown Live World Tour III	Non-sport
2015	World Championships in Athletics	Athletics
2020	Winter Olympics	Athletics
Source: National Stadium, 2015		
2012 London Olympic Stadium		
2016 to future	Home for West Ham United F.C.	Soccer
2013	Concert	Non-sport
2015	Rugby World Cup	Rugby
2015	International Rugby League	Rugby
2013 & 2015	London Athletics Grand Prix	Athletics
2013	Live Nation	Baseball
2015 & 2016	Race of champion	Racing
2017	IPC Athletics World Championships	Athletics
2017	IAAF World Championships in Athletics	Athletics
Source: The stadium, 2015		

Table B.2 List of post-Olympic events hosted by each Olympic stadium

Olympic Date	Stadium	City/Country	Capacity	Soccer	Gridiron	Rugby	Basketball	Baseball	Athletics	Cricket	Australian Football	Hockey	Racing	Archery	Bandy	Non-Sport Events	Number of activity types for each stadium
1896	Panathenaic Stadium	Athens/Greece	50000	☐	☐	☐	☒	☐	☒	☐	☐	☐	☐	☒	☐	☒	4
1904	Francis Field	St-Louis/USA	10000	☒	☒	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	4
1908	White City Stadium	London/United Kingdom	93000	☐	☐	☒	☐	☐	☒	☐	☐	☐	☒	☐	☐	☒	5
1912	Stockholm Stadium	Stockholm/Sweden	22000	☒	☐	☐	☐	☐	☒	☐	☐	☐	☒	☐	☒	☒	5
1920	Olympisch Stadium	Antwerp/Belgium	30000	☐	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	4
1924	Yves-du-Manoir	Paris/France	60000	☒	☐	☒	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	4
1928	Olympisch Stadium Amsterdam	Amsterdam/The Netherlands	31600	☒	☒	☐	☐	☐	☒	☐	☐	☒	☒	☐	☐	☒	7
1932	Los Angeles Memorial Coliseum	Los Angeles/USA	101574	☒	☐	☐	☒	☐	☒	☐	☐	☒	☒	☐	☐	☒	8
1936	Olympiastadion Berlin	Berlin/Germany	110000	☒	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	4
1948	Empire Stadium	London/United Kingdom	82000	☒	☒	☒	☐	☐	☒	☐	☐	☒	☒	☐	☐	☒	6
1952	Olympiastadion Helsinki	Helsinki/Finland	70000	☐	☐	☐	☐	☐	☒	☐	☐	☐	☒	☐	☒	☒	4
1956	Melbourne Cricket Ground	Melbourne/Australia	104000	☒	☐	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	☒	6
1960	Rome Olympic stadium	Rome/Italy	90000	☒	☐	☒	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	4
1964	National Olympic Stadium	Tokyo/Japan	75000	☒	☒	☒	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	5
1968	Estadio Olimpico Universitario	Mexico City/Mexico	83700	☒	☐	☐	☒	☐	☒	☐	☐	☐	☐	☐	☐	☒	4
1972	Munich Olympic Stadium	Munich/Germany	80000	☒	☐	☐	☐	☐	☒	☐	☐	☐	☒	☐	☐	☒	4
1976	Montreal Olympic Stadium	Montreal/Canada	70000	☒	☒	☐	☐	☒	☒	☐	☐	☐	☒	☐	☐	☒	5
1980	Luzhniki Stadium	Moscow/Russia	100000	☒	☐	☒	☐	☐	☒	☐	☐	☐	☒	☐	☐	☒	3
1988	Jamsil olympic stadium	Seoul/Korea	10000	☒	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	3
1992	Barcelona Olympic Stadium	Barcelona/Spain	60000	☒	☒	☒	☐	☐	☒	☐	☐	☐	☐	☐	☐	☒	3
1996	Centennial Olympic Stadium	Atlanta/USA	85000	☒	☐	☐	☐	☒	☒	☐	☐	☐	☐	☐	☐	☒	2
2000	ANZ Stadium	Sydney/Australia	110000	☒	☒	☒	☐	☐	☒	☐	☒	☐	☒	☐	☐	☒	6
2004	Athens Olympic Stadium	Athens/Greece	70000	☒	☐	☒	☐	☐	☒	☐	☒	☐	☐	☐	☐	☒	3
2008	Beijing National Stadium	Beijing/China	91000	☒	☐	☐	☐	☐	☒	☐	☐	☐	☒	☐	☐	☒	4
2012	London Olympic Stadium	London/England	80000	☒	☐	☐	☐	☒	☒	☐	☐	☐	☒	☐	☐	☒	6
number of stadiums hosted each type of post-event																	
				23	9	10	2	4	20	2	3	10	2	2	24		
Olympic Games																	
Europe Asia Oceania																	
Stadiums registered as cultural heritage in bold																	

Table B.3 List of major soccer events hosted by Olympic stadiums.

Name	Event	# of matches	Spectator Capacity during event	Current spectator capacity`	References
1924 Stade Yves Du Manoir	FIFA World Cup	1	60,000	14,000	Racing 92, 2015; FIFA, 2015
	European Cup quarter-final	1	60,000		
1928 Olympisch Stadium Amsterdam	FIFA World Cup	2	60,000	22,288	Olympisch Stadion Amsterdam, 2015; FIFA, 2015
	Europe Cup-1 final	1	60,000		
1923/1984 Los Angeles Memorial Coliseum	Los Angeles Aztecs	1	93,000	93,607	USC, 2015
	CONCACAF Gold Cup	Several matches	93,000		
	Gold Cup	Several matches	93,607		
	Centroamericana Cup Championships	3	93,607		
1936 Olympiastadion Berlin	German National Soccer Cup	Several matches	110,000; 79,200	79,200	Olympiastadion Berlin, 2015; Pretty & Alison, 2012; FIFA 2015
	European Cup Final	4	110,000		
	UEFA Cup Winners' Cup	Several matches	110,000		
	Middlesex Charity Cup	1	110,000		
	FA Cup Final	Several matches	110,000		
	DFB Cup Final	Several matches	79200		
	First Division play-off final	1	79200		
	German FA Cup Finals for men and women	Several matches	79200		
	UEFA-Cup games	Several matches	79200		
	Bundesliga winners	1	79200		
	FIFA Women's World Championship	1	79200		
	UEFA Champions League Final	1	79200		
1948 London Empire Stadium	FIFA World Cup	36	80,000; 76,000	76,000	FIFA, 2015
	UEFA Championships	4	80,000; 76,000		
1952 Olympiastadion Helsinki	UEFA Women's Euro	5	39,000	39,000	Olympiastadion, 2015

Table B.3 (Continued).

1956 Melbourne Cricket Ground	FIFA World Cup qualification	3	104,000	100,024	FIFA, 2015; MGC, 2015
	International Champions Cup Australia	3	100,024		
1960 Stadio Olimpico	European Championship Final	2	90,000	70,634	FIFA, 2015;
	Intercontinental Cup final	1	90,000		
	European Cup Final	1	90,000		
	FIFA World Cup qualification	16	90,000		
	UEFA Champions League Final	3	90,000; 70,634		
1964 Tokyo National Stadium	Intercontinental Cup	Several matches	57,362	57,362	Japan Sport Council, 2015
	Emperor's Cup	Several matches	57,362		
	Japanese Super Cup	Several matches	57,362		
1968 Estadio Olimpico Universitario	World Soccer Championships	Several matches	83,700	68,945	FIFA, 2015; UNAM, 2015
	FIFA World Cup qualification	3	83,700		
1972 Munich Olympiastadion	World football champions	5	80,000	69,250	FIFA, 2015 Olympic Park Munich, 2015
	Super Cup	1	80,000		
	European Football Championships	Several matches	80,000		
	FIFA World Cup	7	80,000		
	UEFA Cup 2nd final	1	80,000		
	Athletics Spar European Cup Final	1	80,000; 69,250		
	European Cup	1	69,250		
	Public Viewing Soccer European championship	1	69,250		
	women's final of the UEFA Champions League	1	69,250		
1976 Montreal Olympic Stadium	FIFA Under 20 World Cup	Several matches	56,000	56,000	FIFA, 2015; Park Olympique Le Stade, 2015
	CONCACAF Champions League quarter-final	2	56,000		
	FIFA Women's World Cup	9	56,000		
1980 Luzhniki Stadium	UEFA Cup Final	1	78,360	78,360	FIFA, 2015; Olympic complex Luzhniki, 2015
	UEFA Champions League Final	1	78,360		
	FIFA World Cup Final	1	78,360		

Table B.3 (Continued).

1992 Barcelona Olympic Stadium	Euro qualifying match	3	54,000	54,000	FIFA, 2015; Estadi Olímpic, 2015
2000 ANZ Stadium	AFC Asian Cup Final	1	83,500	83,500	The stadium, 2015
2004 Athens Olympic Stadium	UEFA Champions League Final	1	70,000	70,000	OAKA, 2015
2008 Beijing National Stadium	Supercoppa Italiana	Several matches	80,000	80,000	National Stadium, 2015
	China Cup	Several matches	80,000		

Table B.4 Number of major international, FIFA and UEFA games hosted by Olympic stadiums.

Name	Spectator Capacity during Soccer matches	Current Spectator Capacity	# of all soccer matches	# of matches - UEFA Games	# of matches - FIFA World Cup Games	Reference(s)
1924 Stade Yves Du Manoir	60,000	14,000	2	1	1	Racing 92, 2015; FIFA, 2015
1928 Olympisch Stadion Amsterdam	60,000	22,288	3	1	2	Olympisch Stadion Amsterdam, 2015; FIFA, 2015
1936 Olympiastadion Berlin	110,000; 79,2000	79,200	25	8	9	Olympiastadion Berlin, 2015; Pretty & Alison, 2012; FIFA 2015
1948 London Empire Stadium	80,000; 76,000	76,000	40	4	36	FIFA, 2015
1952 Olympiastadion Helsinki	39,000	39,000	5	5	-	Olympiastadion, 2015
1956 Melbourne Cricket Ground	104,000	100,024	6	-	3	FIFA, 2015; MGC, 2015

Table B.4 (Continued).

1960 Stadio Olimpico	90,000; 70,634	70,634	24	6	16	FIFA, 2015;
1968 Estadio Olímpico Universitario	83,700	68,945	9	-	3	FIFA, 2015; UNAM, 2015
1972 Munich Olympiastadion	80,000; 69,250	69,250	21	7	7	FIFA, 2015; Olympic Park Munich, 2015
1976 Montreal Olympic Stadium	56,000	56,000	14	-	12	FIFA, 2015; Park Olympique Le Stade, 2015
1980 Luzhniki Stadium	78,360	78,360	3	2	1	FIFA, 2015; Olympic complex Luzhniki, 2015
1992 Barcelona Olympic Stadium	54,000	54,000	3	3	-	FIFA, 2015; Estadi Olímpic, 2015
2004 Athens Olympic Stadium	70,000	70,000	1	1	-	OAKA, 2015

APPENDIX C

MAIN STADIUMS OFFICIALLY-REGISTERED AS CULTURAL HERITAGE

Table C.1 List of Summer Olympic stadiums registered as Cultural Heritage

Stadium	Listing year	Heritage Type	Reference
1896 Panathenaic Stadium	1987	National Architectural Monument	Kiuri & Teller, 2015; Hellenic Olympic Committee, 2011
1912 Stockholm Stadium	1990	Local Historical Building	Stockholms stad, 2008; Kiuri & Teller, 2015;
1928 Olympisch Stadium Amsterdam	1992	National Architectural Monument	Kiuri & Teller, 2015; Olympisch Stadion Amsterdam, 2015
1932 Los Angeles Memorial Coliseum	1984	National Historic Landmark	Marathon Communication, 2005; USC, 2014; Kiuri & Teller, 2015
1936 Olympiastadion Berlin	1996	Local City Landscape	Kiuri & Teller, 2015; Olympiastadion Berlin, 2015
1948 Empire Stadium	1967	National Monument	Kiuri 2015 & Teller
1956 Melbourne Cricket Ground	2005	National Place	Kiuri & Teller, 2015; MCG, 2015
1968 Estadio Olímpico Universitario	2007	UNESCO World Heritage	Kiuri & Teller, 2015; Estadio Olímpico Universitario, 2015
1980 Luzhniki Stadium	1974	National Art Monument	Kiuri & Teller, 2015; Olympic Complex Luzhniki, 2015
2000 ANZ Stadium	2000	Local Object	Kiuri & Teller, 2015; ANZ Stadium, 2015

APPENDIX.C

SCALED SCHEMATIC PLAN LAYOUTS OF STADIUMS: ORIENTATION OF PLAYING FIELDS AND ROOF POSITIONS ON STANDS AREA

The scaled schematic plan drawings of stadiums' playing field orientation together with presence of roof on Olympic date for summer Olympic stadiums from 1896 to 2012 are represented on the following pages.

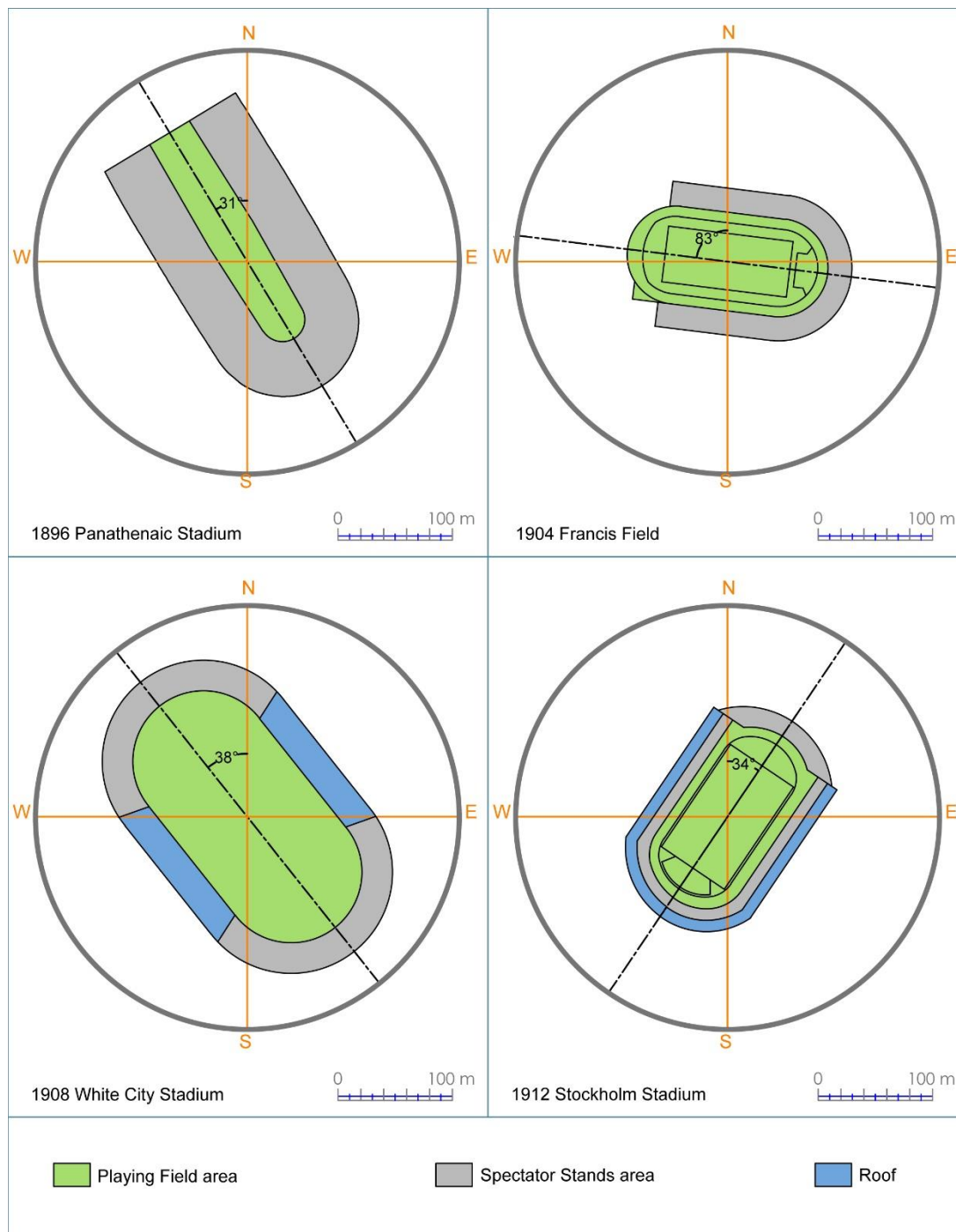


Figure D.1 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 1896 Panathenaic Stadium, 1904 Francis Field, 1908 White City Stadium and 1912 Stockholm Stadium which were processed on their plan layouts.

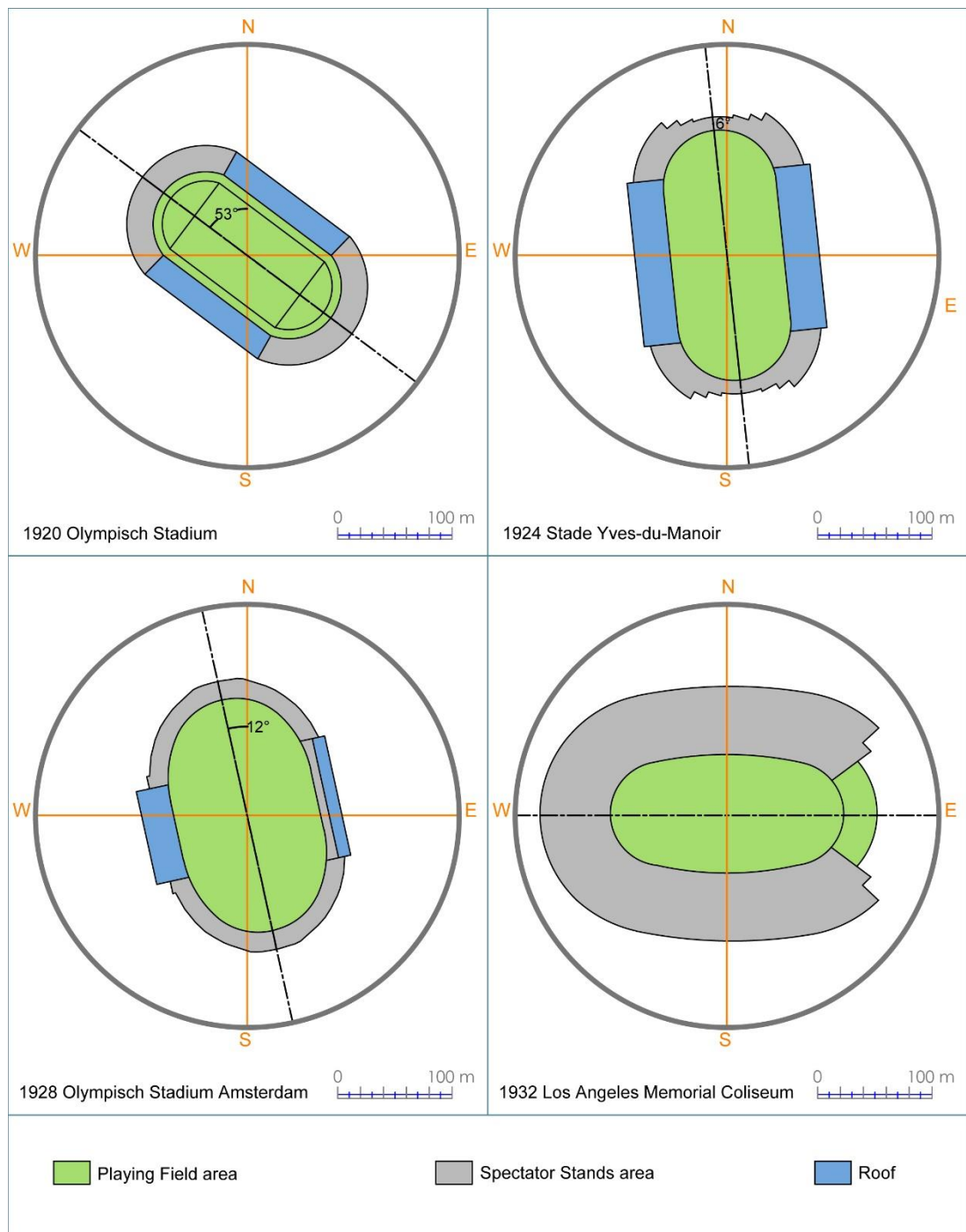


Figure D.2 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 1920 Olympisch Stadium, 1924 Stade Yves-du-Manoir, 1928 Olympisch Stadium Amsterdam and 1932 Los Angeles Memorial Coliseum which were processed on their plan layouts.

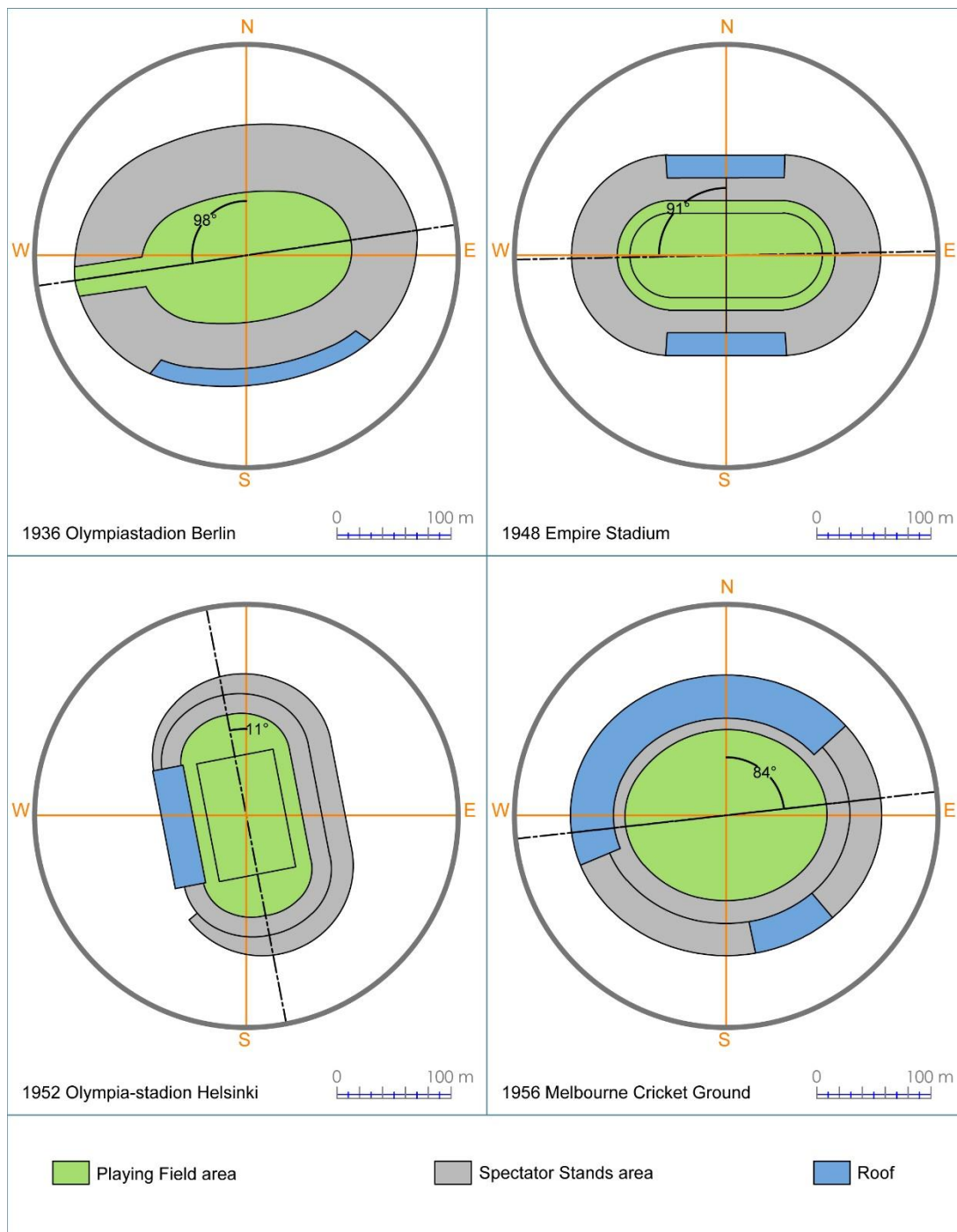


Figure D.3 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 1936 Olympiastadion Berlin, 1948 Empire Stadium, 1952 Olympia-Stadion Helsinki and 1956 Melbourne Cricket Ground which were processed on their plan layouts.

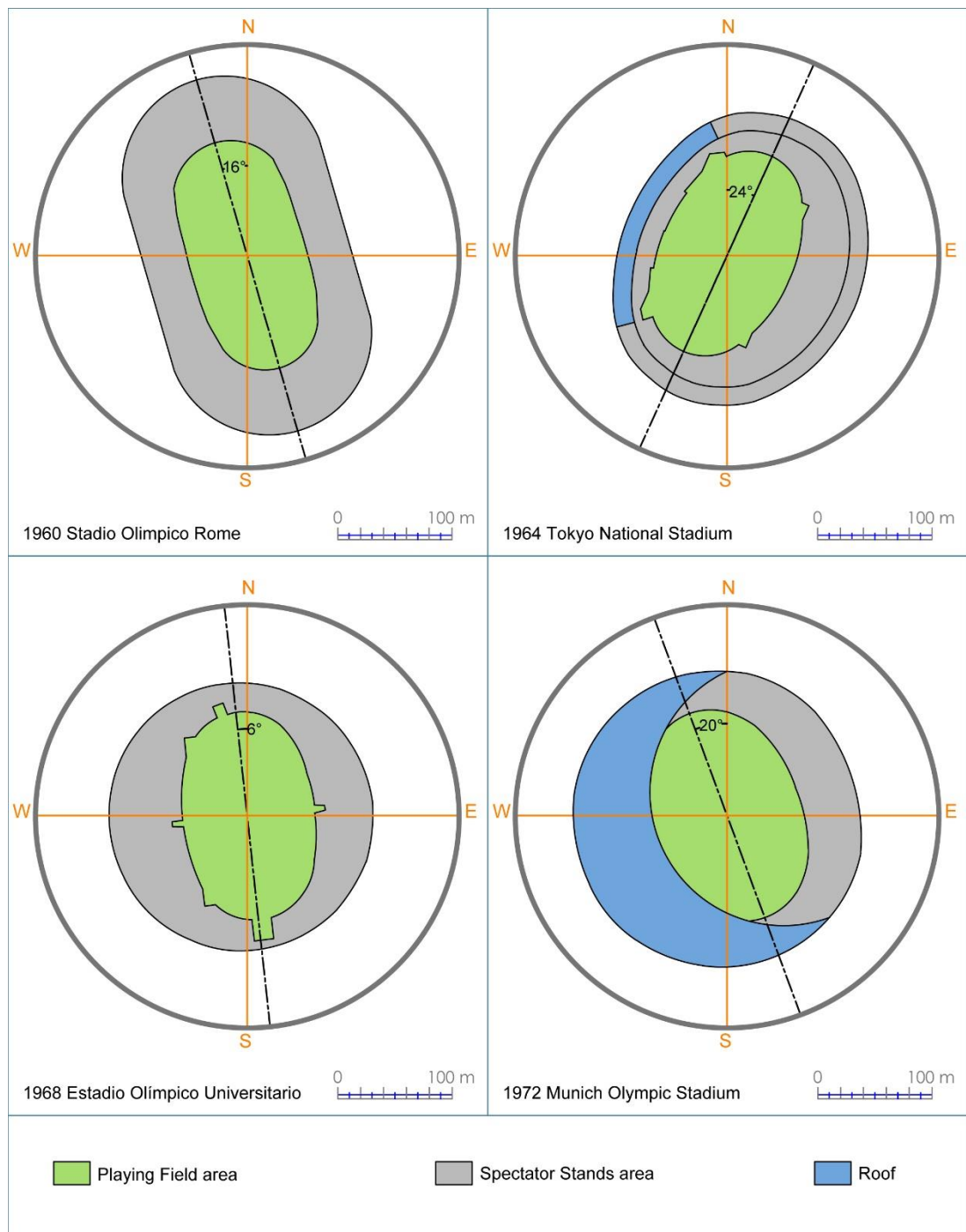


Figure D.4 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 1960 Stadio Olimpico, 1964 National Olympic Stadium, 1968 Estadio Olímpico Universitario and 1972 Munich Olympic Stadium which were processed on their plan layouts.

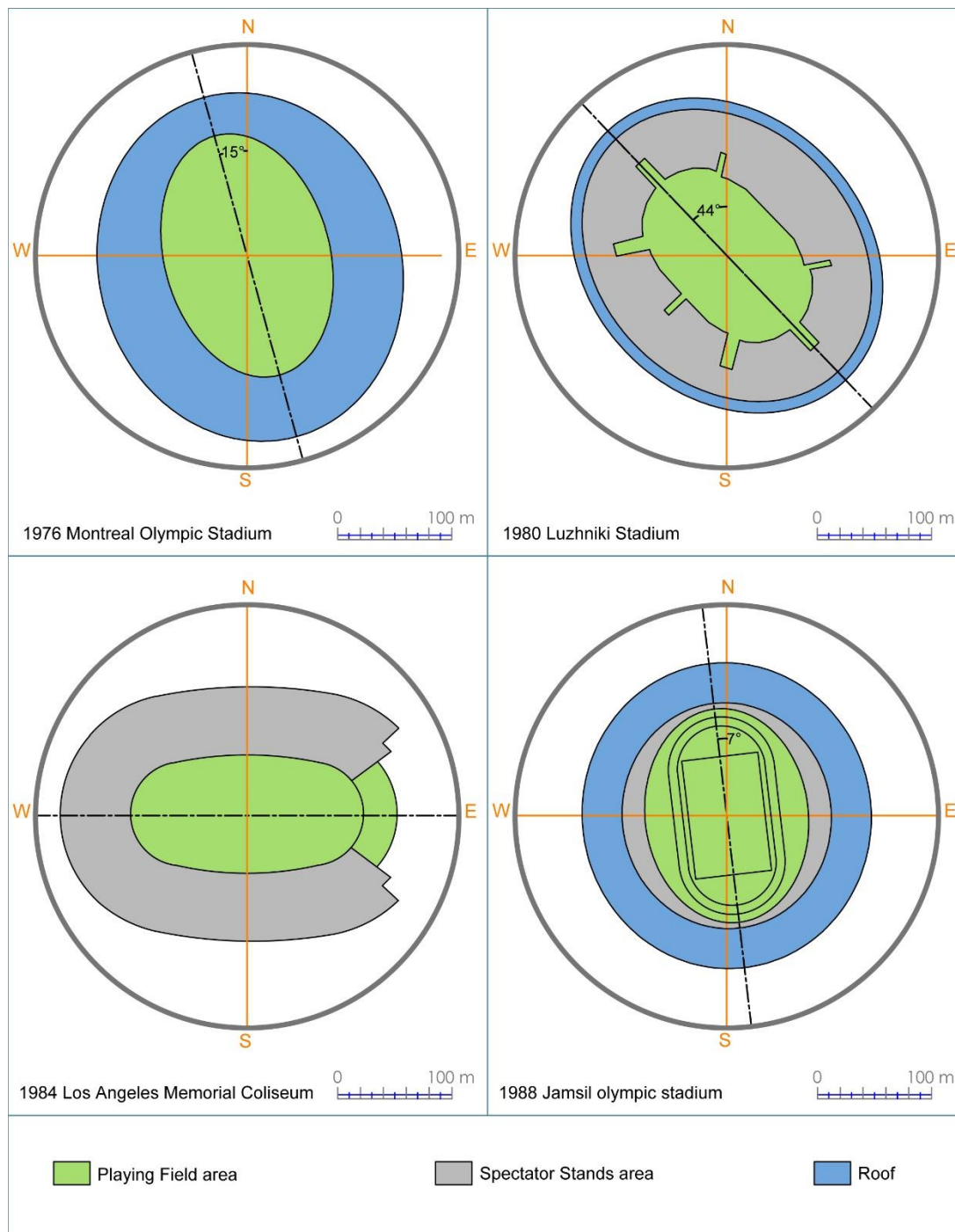


Figure D.5 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 1976 Montreal Olympic Stadium, 1980 Luzhniki Stadium, 1984 Los Angeles Memorial Coliseum, 1988 Jamsil Olympic Stadium which were processed on their plan layouts.

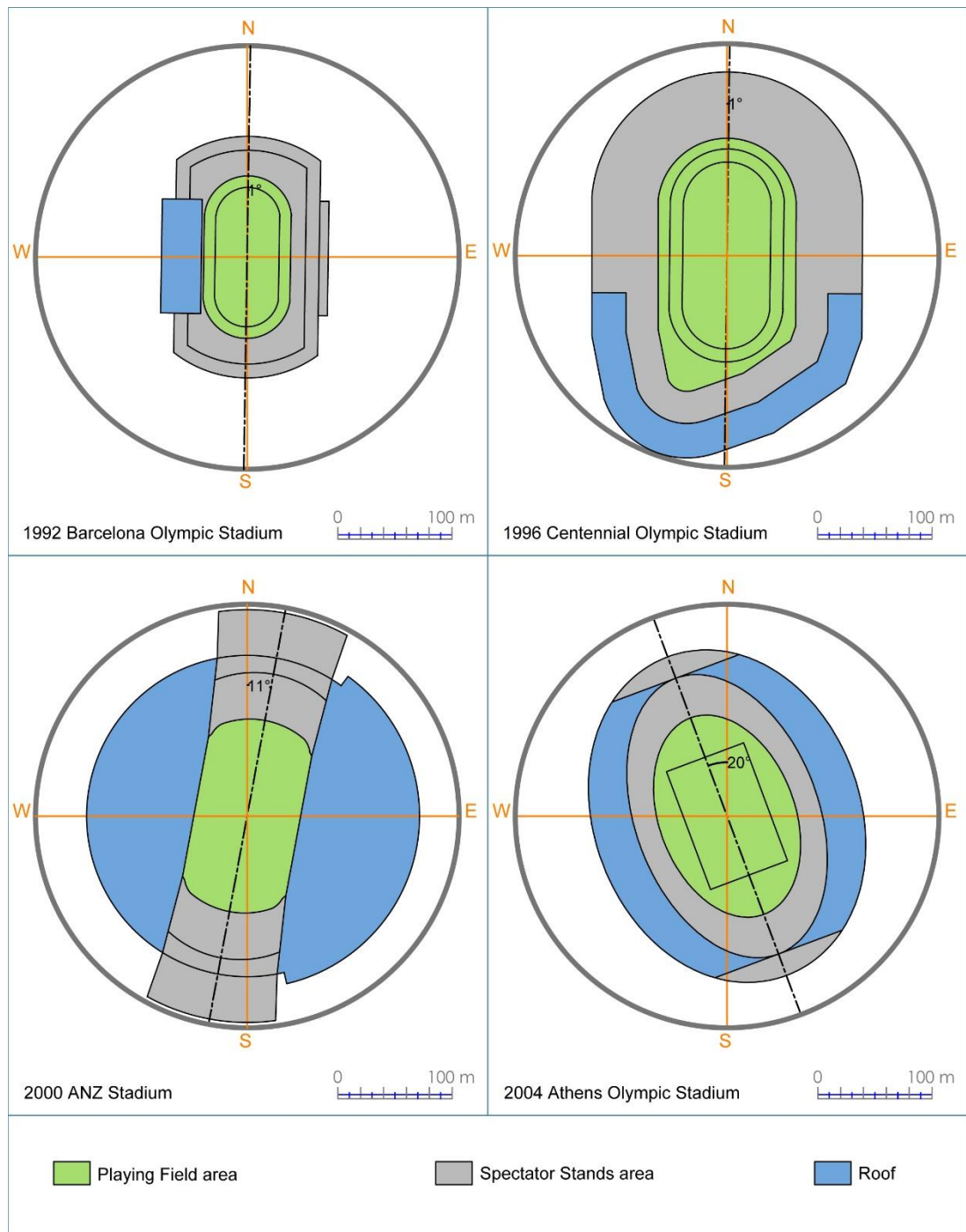


Figure D.6 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 1992 Barcelona Olympic Stadium, 1996 Centennial Olympic Stadium, 2000 ANZ Stadium and 2004 Athens Olympic Stadium which were processed on their plan layouts.

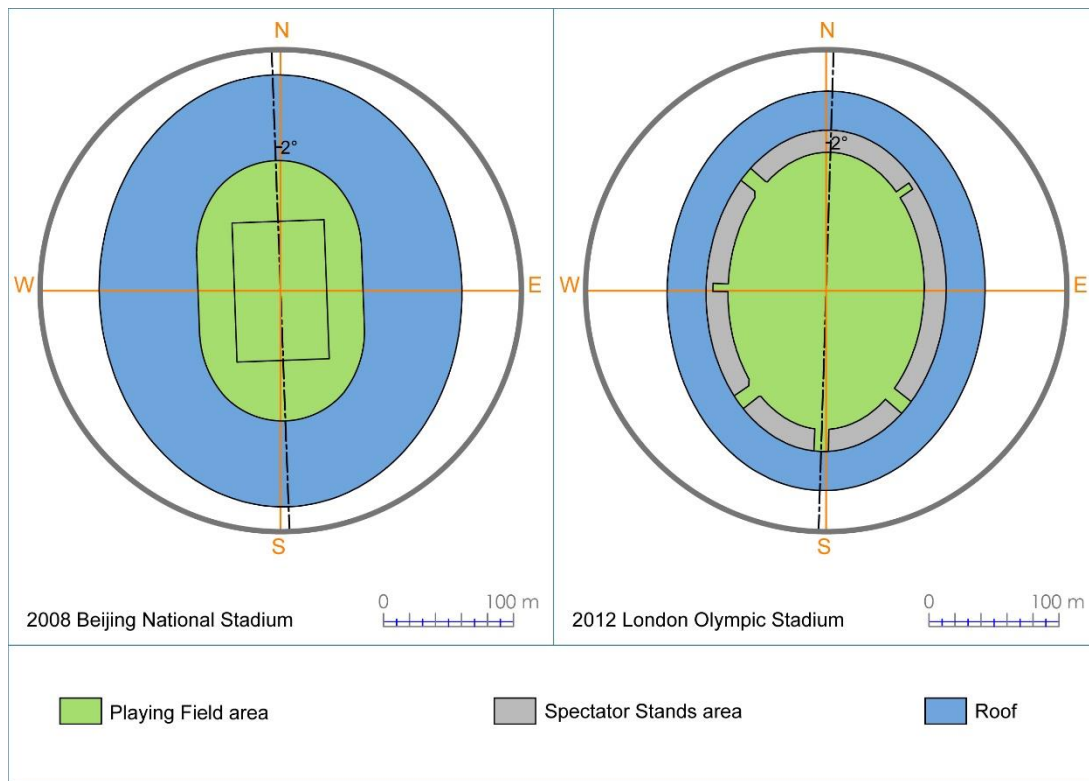


Figure D.7 The orientation of longitudinal central axis for the playing fields and roof positions over stands area for 2008 Beijing National Stadium and 2012 London Olympic Stadium which were processed on their plan layouts.

APPENDIX E

SCALED SCHEMATIC PLAN LAYOUTS OF STADIUMS: BEST VIEWING CIRCLE AND OPTIMUM AND MAXIMUM VIEWING ZONES

The scaled schematic plan drawings for examinations on viewing conditions in stands area of summer Olympic stadiums from 1896 to 2012 are represented on the following pages.

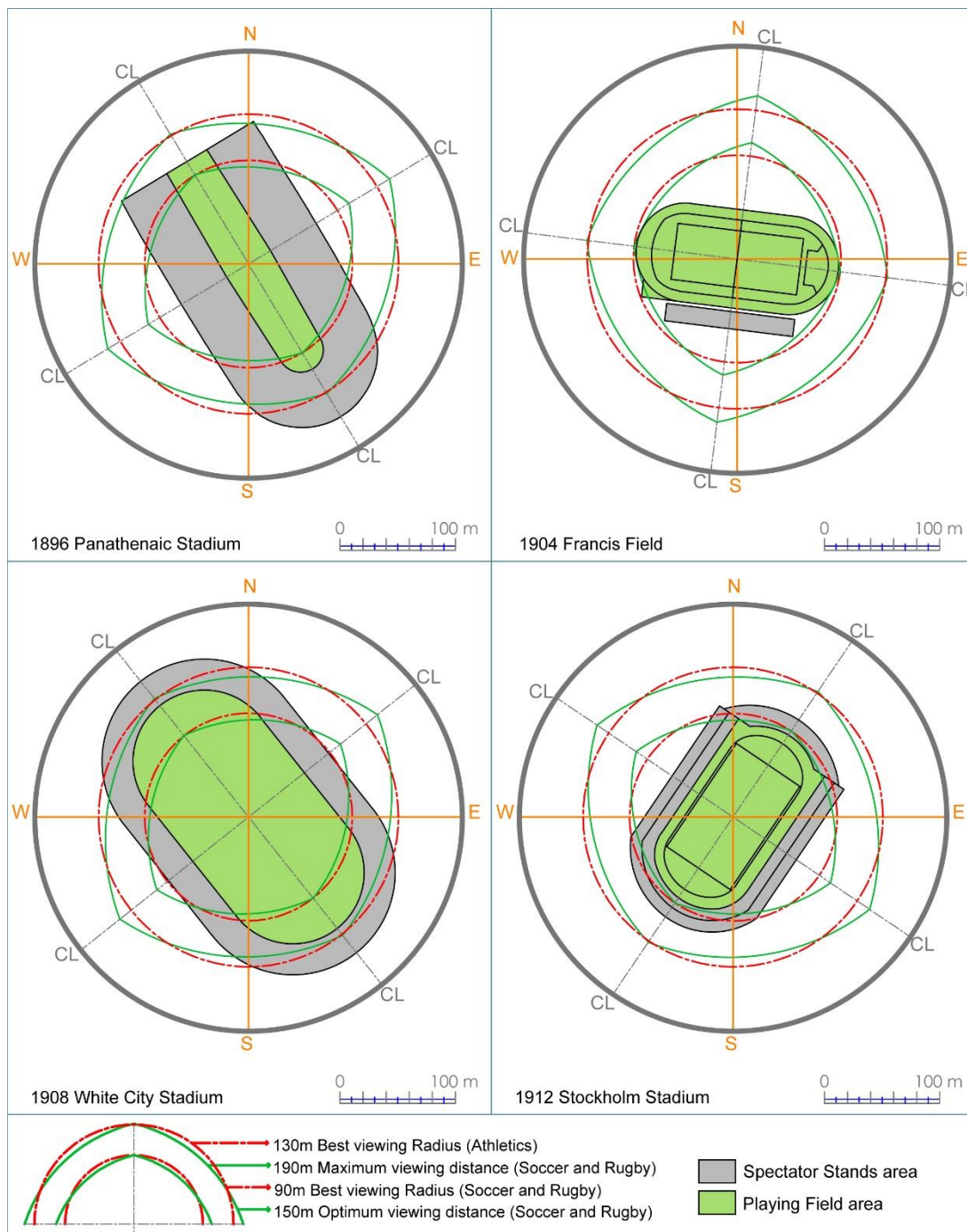


Figure E.1 The plan layout of 1896 Panathenaic Stadium, 1904 Francis Field, 1908 White City Stadium, and 1912 Stockholm Stadium, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.

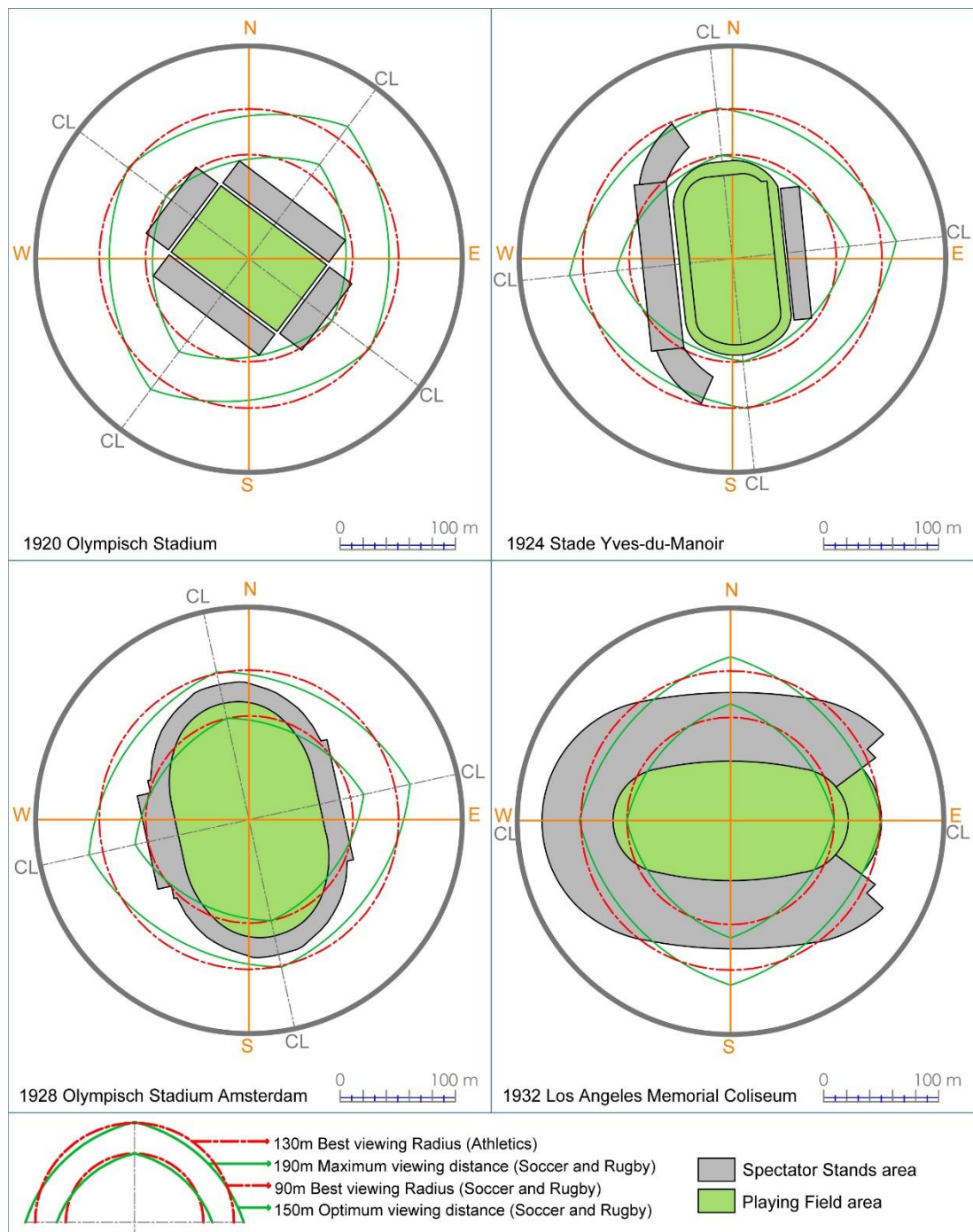


Figure E.2 The plan layout of 1920 Olympisch Stadium, 1924 Stade Yves-du-Manoir, 1928 Olympisch Stadium Amsterdam and 1932 Los Angeles Memorial Coliseum, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.

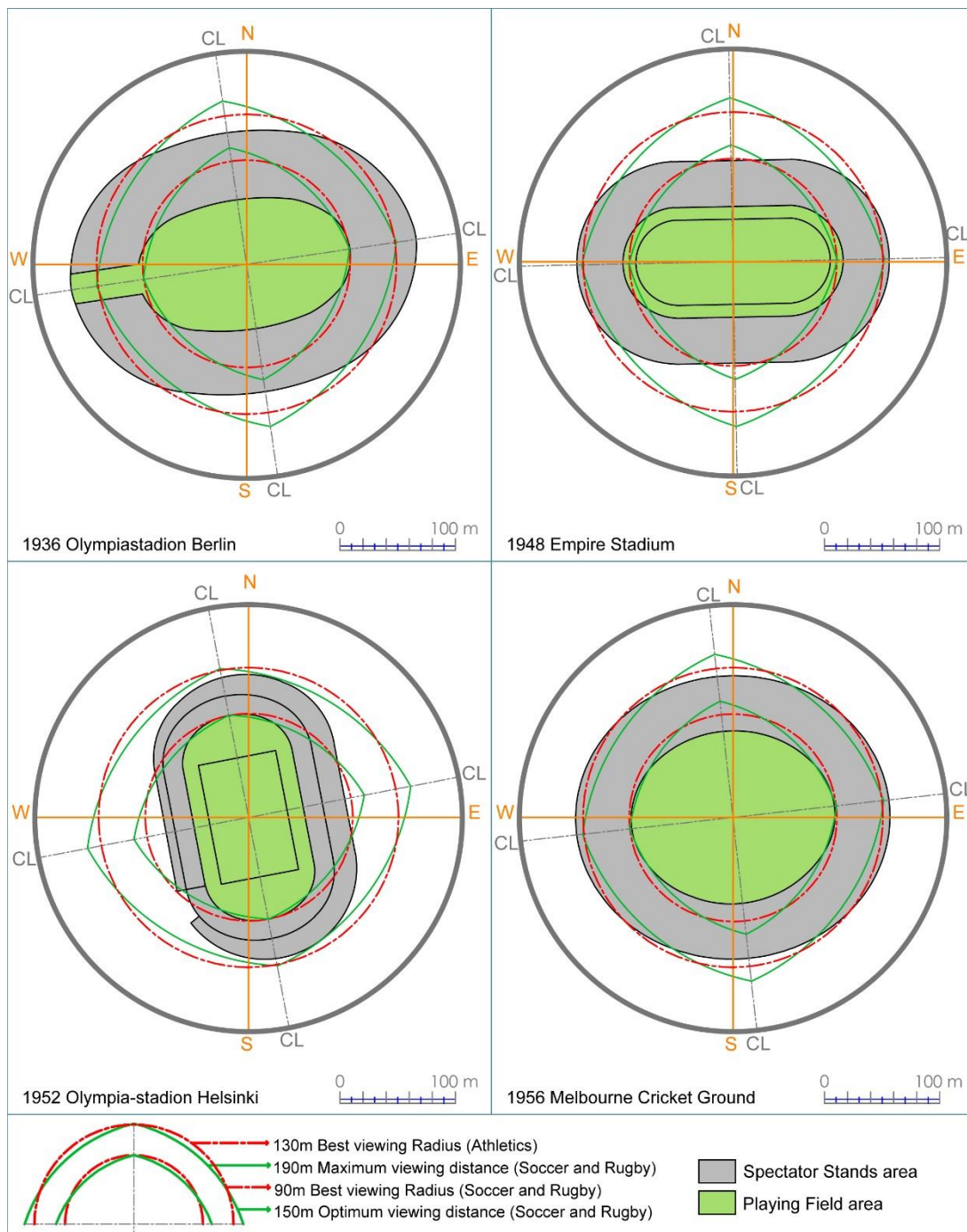


Figure E.3 The plan layout of 1936 Olympiastadion Berlin, 1948 Empire Stadium, 1952 Olympia-Stadion Helsinki and 1956 Melbourne Cricket Ground, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.

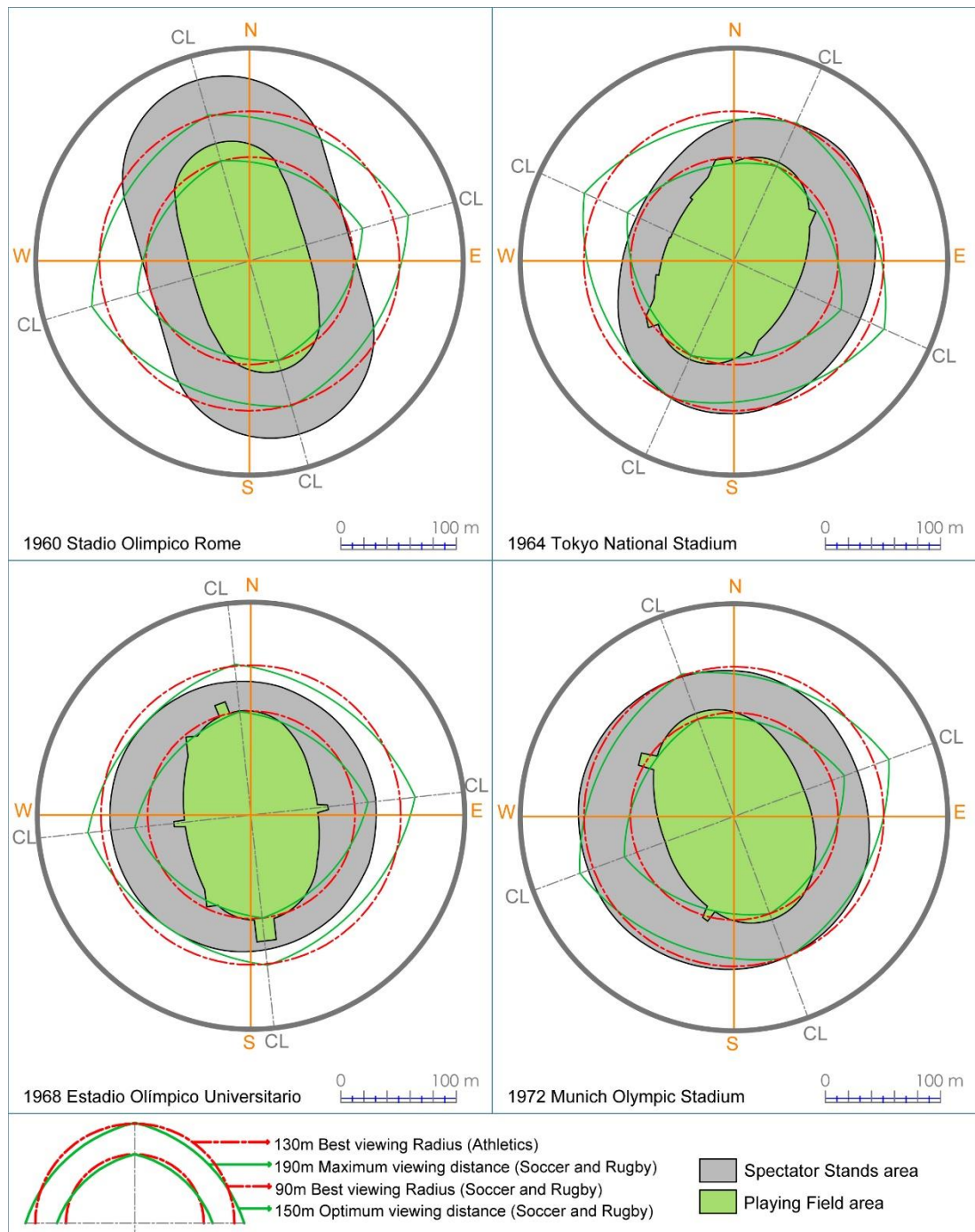


Figure E.4 The plan layout of 1960 Stadio Olimpico, 1964 National Olympic Stadium, 1968 Estadio Olímpico Universitario and 1972 Munich Olympic Stadium, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.

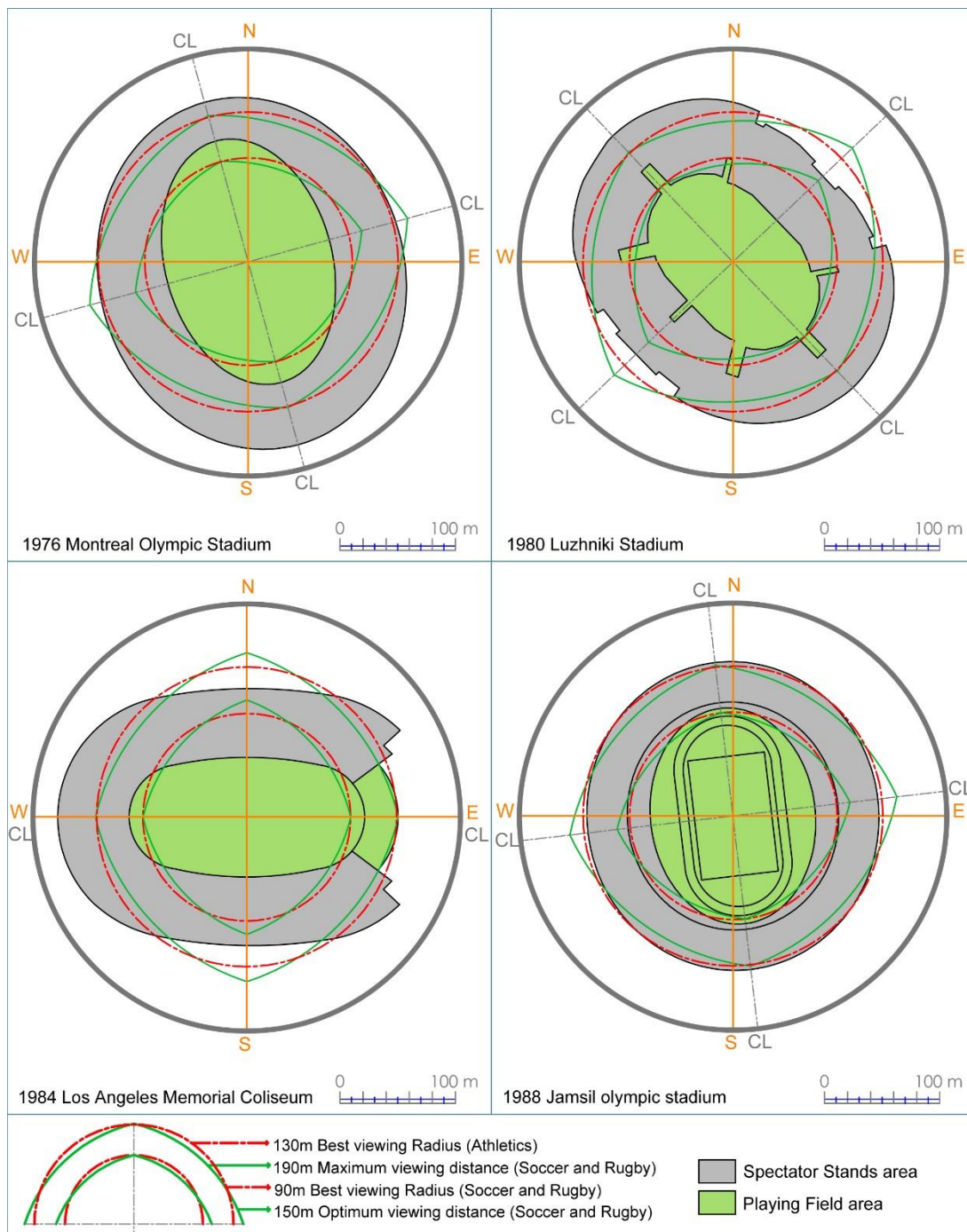


Figure E.5 The plan layout of 1976 Montreal Olympic Stadium, 1980 Luzhniki Stadium, 1984 Los Angeles Memorial Coliseum, 1988 Jamsil Olympic stadium, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.

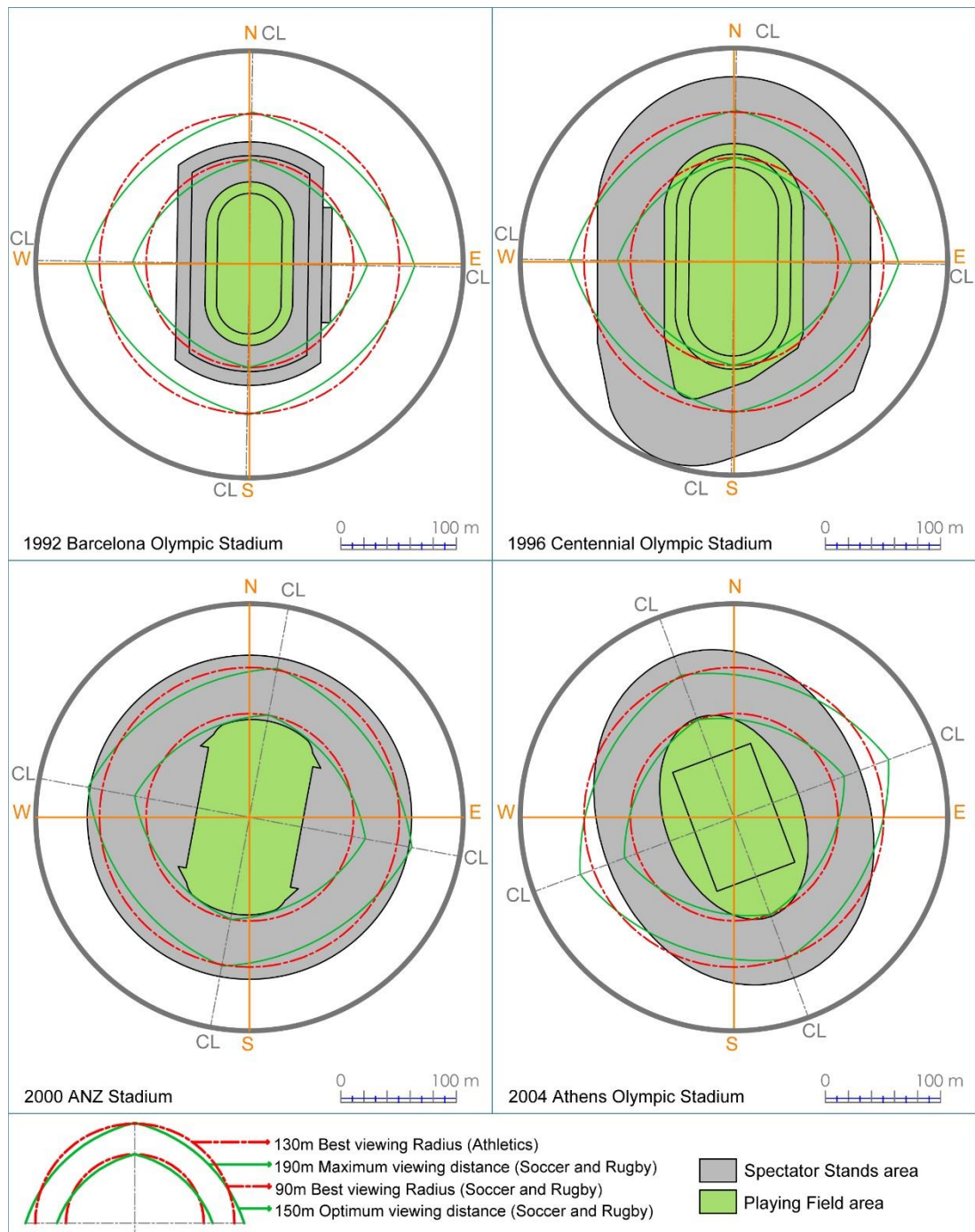


Figure E.6 The plan layout of 1992 Barcelona Olympic Stadium, 1996 Centennial Olympic Stadium, 2000 ANZ Stadium and 2004 Athens Olympic Stadium, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.

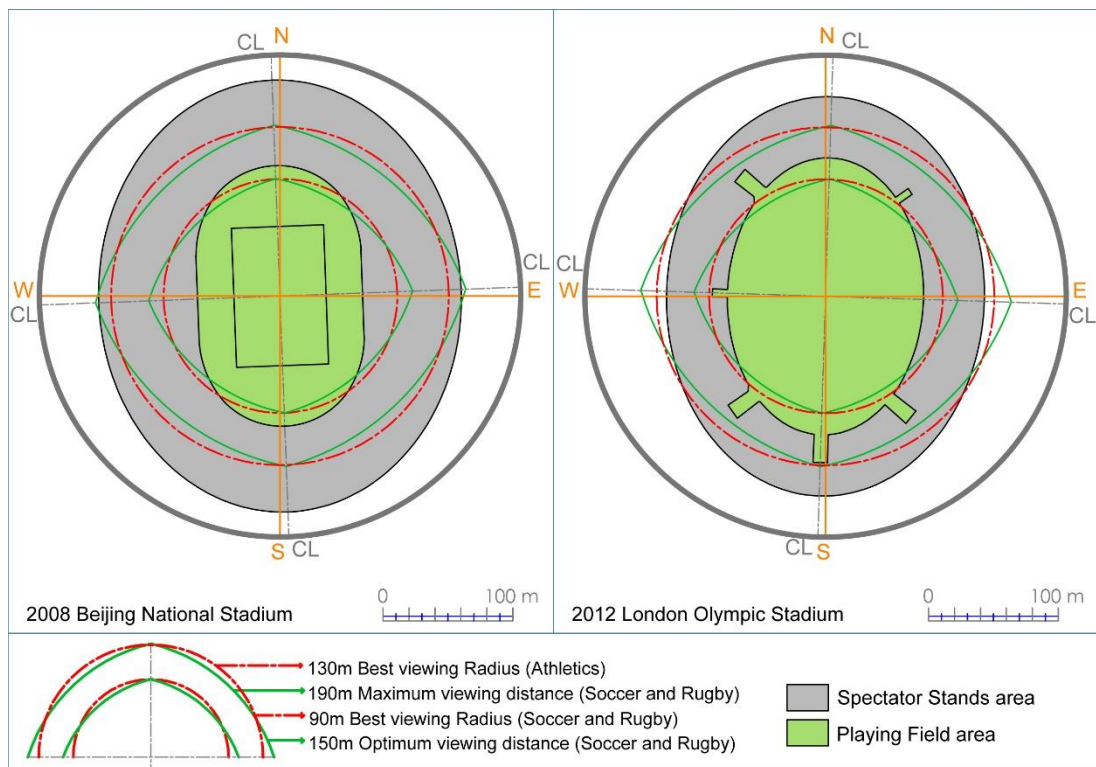


Figure E.7 The plan layout of 2008 Beijing National Stadium and 2012 London Olympic Stadium, showing relationships between their playing field and best viewing, optimum and maximum viewing circles recommended for soccer/rugby and athletics games.