ITU A|Z • Vol 19 No 2 • July 2022 • 471-485

Calculating the safe capacity of a stadium: Applying methods for assessment capacity on example of Konya City Stadium

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Received: December 2020 • Final Acceptance: November 2021

Abstract

Following the Hillsborough disaster (1989) which draws a very clear perspective on the football culture of the 20th century and the status of stadiums around the world, many of decisions about structure and organization were made for the stadiums in the Taylor Report published in England. To prevent recurrence of disasters, the stadium capacity issues were also emphasized among the decisions, and some sets of methods were developed to determine the final (official) capacity. In this paper, the criteria and the methods which are stated in national/international regulations were gathered in a sequence. Then this sequence was implemented in a case study, Konya City Stadium which is one of the Turkey's EURO 2024 Candidate Bid Dossier stadiums. In the regulations, stadium capacity is classified as holding capacity, entry capacity, exit capacity and capacity of emergency exits. The final capacity is determined by whichever is the lowest. The local authorities determine that first three capacities by their subjective opinions. Because of that, mostly the capacity of emergency exits was emphasized in the study. This capacity, which is especially important for emergencies, was emphasized and the stadium was evaluated based on their capacities and evacuation times over all stands. As result, it was determined that the regulation criteria were not provided in some stands, however several suggestions were made based on the existing applications about how already built stadiums can be refurbished to follow the regulation.

Keywords
Crowd control, Emergency evacuation, Safe capacity, Stadium, Stadium regulations.

doi: 10.5505/itujfa.2022.58260

1. Introduction

Football tournaments bringing together people from different cultures brought forward conflicts, racism, social discrimination among groups, therewith hooliganism and violence in stadiums started to grow rapidly (Paramio et al., 2008). If the stadiums of 20th century are analyzed within the framework of their spatial characteristics and management policies, it is seen that most of them consist of unsafe standing terraces, inadequate entry and exit capacities, and weak barriers divide side by side sectors. It is also noticeable that there are barriers between sectors and pitch that higher human average height and that do not let passing in any emergency. In addition, unqualified/inadequate solutions in crowd control, which means that managing spectators to prevent all kinds of chaos, have caused more tragedies in stadiums (Darby et al., 2005). In this context, there were some tragic disasters that deeply affected the football world and were important in literature of stadiums.

After these disasters, global and local authorities have taken important steps to ensure safety and security in stadiums. As a matter of fact, with the Football Spectators Act published after release to the public of *Taylor Report* in 1989, certain regulations were introduced for national football leagues, tournaments, and stadiums in United Kingdom (TSO, 1989). In 1990, with the initiatives of FIFA and UEFA, an international control mechanism was established by determining the technical requirements that should be applied for the stadiums of the member associations. Providing the necessary conditions in stadiums has been accepted as the primary requirement of being a FIFA/UEFA member and organizing international events (FIFA, 1990).

To make a stadium safer, there are a great number of requirements that directly related to stadium capacity in various regulation books. Indeed, in usual or emergency situations, the most important factor in ensuring entries and exits in a stadium is to control capacity. Accordingly, the capacity categories are separated by some certain criteria in regulation books, and safe capacity is determined by choosing the most appropriate category (Kurumak, 2019). The lowest capacity value among the categories is accepted as the limit of final stadium capacity (DCMS, 2008).

In this paper, the demand-creating process of safety and security regulations used related stadium capacity explained in cause-link and a chronological perspective. It is obvious that though there are certain criteria to determine the final capacity of a stadium and how to provide it, there is not sufficient number of clarifications in practice. In addition, the local football authorities' regulations are differed partially by each other. Therefore, this article is set up to present the proper determining methodology of the final capacity by submit the sorted global and local regulations step-by-step and implement in a case study of Konya City Stadium. Afterwards, suggestions will be presented through practices in already built stadium samples on the refurbishment methods that can be made to increase the level of safe capacity and/or to ensure allowable evacuation times in stadiums.

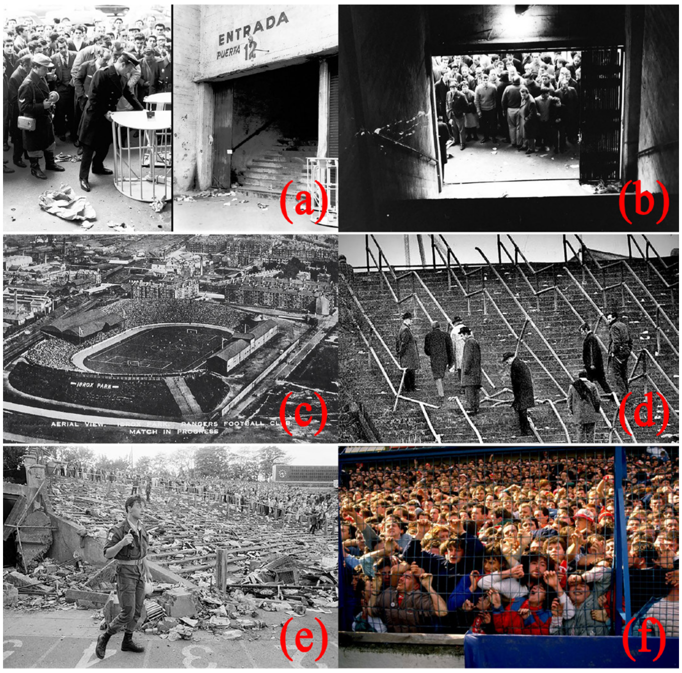

Figure 1. *The Gate 12, as the main scene of el monumental stadium disaster (Lisotto, 2018) (a,b), Stairway 13th of Ibrox Stadium before the disaster (The Sunday Post Newspaper, 1920) (c), Stairway 13th with damaged handrails and steps, after the disaster (Pink, 2018) (d), The collapsed wall in heysel stadium, 1985 (Shennan, 2017) (e), The people are crushed between pitch fences and overcrowd (Begley, 2017) (f).*

2. Prominent stadium disasters

The stadium disasters that took place in various locations of the world have generally been seen in Europe, South America, and Africa. In fact, while the River Plate – Boca Juniors match held at Argentina El Monumental Stadium in 1968, people died by crushing and were injured in Gate 12 as result of the fire and panic. The stadium's standing terraces and narrow exits are the main causes of the disaster (Donuk & Şenduran, 2017) (Figure 1.a,b).

During the match (1971) of Celtic and Glasgow Rangers teams in Scotland Ibrox Stadium, the fans of Glasgow Rangers started to leave the stadium towards the last minutes of the match watched by 80.000 spectators, but with the 90th minute goal scored they turned back. On the stairway 13th (Figure 1.c,d), the fans who wanted to return to stands quickly and were exiting caused an overcrowd due to narrow stairway (Donuk & Şenduran, 2017).

In the European Champions Cup final match between Liverpool (England) and Juventus (Italy) teams at Heysel Stadium, which build in 1920, in Brussels on 29 May 1985, more than 60.000 tickets were sold for stadium with a capacity of 50.000 and no precaution was taken at ingress (Chisari, 2007).

Juventus fans who wanted to escape to protect themselves caused an overcrowd. Also, during this situation, a wall between stands collapsed and many people died. One of the most important reason of tragedy is that fences, which are between the stands and the pitch, were very high to let passing through (Figure 1.e) (Chisari, 2007).

The one of the most tragic stadium disasters in history took place during the FA Cup semi-final match between Liverpool and Nottingham Forest teams at Hillsborough Stadium (England) on April 15th, 1989. There had been currently 25.000 spectators in the 21.000-seat stadium just before the start of the match. The spectators who tried to move to stands caused an overcrowd in the stands and many people died by crushing because of the fences around the pitch (Figure 1.f) (Sawer, 2017).

During the league match between Kayserispor and Sivasspor Football Clubs at Kayseri Ataturk Stadia (1967) took place an important tragedy in Turkey football history. The fans breached the barriers of rival team stands and majority of the spectators started to go towards exit gates. But the exit gates' total width was not enough to receive. Therefore, the fans tried to breach barriers and fences and so many people stuck on them and overcrowd was not prevented (Çolak, 2018).

After the Hillsborough tragedy, P. M. Taylor, Lord Chief Justice of England, ran an inquiry report for causes of the disaster. Taylor stated in their report that the main reasons for the occurrence of the disaster in Hillsborough were the failure of officers control, insufficient turnstiles, and weakness of 'crush barriers'. In addition, although it was specified in the 'Safety of the Sports Ground Act' published by the Football License Authority in 1975, be in force in England and Wales, the regulation that stadiums must be 'all seated' is not provided until that day. Therefore, all stadiums must be providing that regulation until August 1994, according to report. Also, there are important statements in report about alcohol sales, crush barriers, fences around the pitch, turnstiles, and ticket prices (Taylor, 1989).

Taylor Report has had a profound impact on the safety standards provided in UK stadiums. So that fences around the pitches were removed and the stadiums used in high-level leagues were all seated. The new stadium locations have begun to move away from the big city centers, to decrease pedestrian/vehicle density (John et al., 2007). These decisions have been in force for all member associations with the 1998/1999 season with the changes made in UEFA directives (UEFA, 2014).

The first stadium built in full provided regulations in Taylor Report is Deva Stadium (1992), owned by Chester City Club, England. This was followed by The Den Stadium, built in 1993. It is the fact that the number of member football federations has reached 211 (FIFA, 2020), and these federations must comply with all directives set by FIFA, the safety and security regulations are applied in all stadia around the world. After this decision taken in general, the following refurbishments were made to meet the regulations in the existing stadiums operated by all member federations.

- All stands in the stadiums are 100% seated and the total capacity level has decreased accordingly.
- The grandstand is divided into certain sections, and the evacuation routes of all stands are also separated. Thus, the area covered by the routes (as in radial gangways) within the total area of the stand has increased (except for modern sophisticated applications).
- The quality of spectator viewing has become important in the regulations. Solutions with a single lower stand but far from the pitch in old stadiums have been replaced by stand solutions with more floors and a certain distance-height ratio (C Value-Sightline Elevation) to the pitch. Thus, vertical evacuation routes occupied more space in sequential stands. As a result, examples began to appear in which the total area (capacity) of the stand was waived.
- New standards in the regulations have encouraged stadiums to be privatized for a single event type. Thus, previously athletics etc. stadiums where side events are held are designed for only one sport. As a result, the required capacity level has also decreased.

3. Methodology of determining the safe capacity

This section is about the criteria and methodologies used in determining the final (official) stadium capacity, which are specified in several stadium regulations. Although these criteria and methods are in force for stadiums used for high-level international tournaments, most of that kind of stadiums' capacities are changed for local leagues. Indeed, some stadiums in Turkey, which are designed to participate in EURO 2016 and EURO 2024 tournaments, have variable capacity levels for local or international events. Capacity of Konya City Stadium (Figure 2.a), as case of the study, is 42.000 (approx.) for local and 38.529 (TFF, 2018) for international (EURO 2024) tournaments (Kurumak, 2019). The reasons of difference between that capacity levels are explained in subsections.

Figure 2. The west facade (a), a grandstand view of Konya City Stadium (b) and the divided sections of Konya City Stadium and the stands, which the research was applied on (Kurumak, 2019) (c).

Minimum stadium capacities determined for UEFA EURO 2024 tournament are included and the criteria used for the tournament are taken as basis. Thus, existing capacity assessments was conducted over a sample of Konya City Stadium in Turkey. The stadium is nearly 9 km. away from the city center and opened in 2014 on 250.000 m2 actively used area (BKA, 2014; Öztaşkın, 2015). Moreover, the stadium consists of 8 stand sections. Sections are divided as four upper and four lower tiers (Figure 2.b,c). There are four evacuation halls at all corners of the grandstand. The stadium has also various amount of vomitories, which number of five to six for different stands, that between radial gangways and concourses.

The minimum capacity requirements for each tournament are different. According to EURO 2024 tournament requirements, there are at least 3 stadiums of minimum 50.000 capacity (One of them must have min. 60.000), at least 3 stadiums of minimum 40.000 capacity, at least 4 stadiums of minimum 30.000 capacity in candidate countries (UEFA, 2017). On the other hand, stadium capacities should be at a level that does not weaken the safety and security requirements provided (FIFA, 2018). Thus, the following criteria should be applied when determining the max. capacity that can be provided in a stadium where adequate safety measures are taken (FIFA, 2018; DCMS 2008).

3.1. Holding capacity (A)

Holding capacity is determined by the number of seats available under min. safety conditions. A two-step method is applied to calculate the holding capacity. In the first stage, the seats that should not be used according to the safety measures are removed from the final capacity. These seats are partially or completely obstructed with such as structural components, billboards, fences etc.; damaged, or later added; at the points that should be kept clear for emergency evacuation plans and security staff's working areas; that do not provide the standards in seats, stand rows etc. dimensions (FIFA, 2018).

In the second stage, the factors P (physical condition) and S (safety management), which are the indicators of the structural and operational layouts of a stadium, respectively, are determined. These factors, whose controls and calculations are in responsibility of the local football authorities, are determined by the experts at subjective perspective. Each factor should be given a numerical value, which quantified 0.0 to 1.0, and holding capacity of the seated are can thus be calculated as follows (DCMS, 2008) (formula 1).

Holding capacity (A)=the number of useable seats x (P)or(S), whichever is lower (1)

The following criteria are taken into consideration in calculating the P factor. The P factor value depends on criteria as providing of rows depth and riser height standards, avoiding of usage weak stadium cover or grandstand structure components, and managing strategies towards restricted spectator viewing (DCMS, 2008).

The following criteria are taken into consideration in calculating the S factor. The S factor value depends on criteria as; the official ticket sales should be only for allowed seats according to P factor, the layout of stands and rows should be clear to follow for spectators, the stands should be cleaned/kept clean before each event, the stewarding should be deployed in every necessary point of stands (DCMS, 2008).

3.2. Entry (B) and exit capacity (C)

Entry capacity is calculated with the number of person who can pass through the available turnstiles and/or other controlled ingress points in one hour for usual situations. The factors that determine the entry capacity are number of available turnstiles and other entry points. Exit capacity is determined by the number of persons who can exit a stadium safely in the usual time. The factors that affect the exit capacity are number and size of exit gates (DSMS, 2008; FIFA, 2018).

3.3. Capacity of emergency exits (D)

Emergency exits capacity is calculated based on the number of persons who can reach safety zone by passing the evacuation routes safely, smoothly, and unimpeded within a time in a case of emergency. The time limits determined by FIFA (10 min.) and UEFA (8 min.) for member federations, it is not allowed to exceed (FIFA, 2011; UEFA, 2017).

If stadium design allows for exits to pitch from the stands in emergency situations, the pitch is accepted as a safety zone. However, different strategies should be developed to make more quickly the playing area exits to out of the stadium (FIFA, 2018).

As it is specified in Building and Fire Safety Regulations of Turkey, in Article 33 (1), Annex-5/A and Annex-5/B 'number and width of evacuation routes', the route elements min. total widths are calculated by the formula 2 as follows (MPWS, 2007);

$$\Sigma_w(m)=(Gxw)/P \qquad (2)$$

Figures in formula refer to; Σ_w:min. total width; G:capacity of sample section; w:0,5m. (shoulder width, regulation constant); P:regulation's constant (G/minutes*X*m.). Stairs, vomitories, doors and any part of concourses widths are minimum 110 cm. at restrictive points in a stadium, even if these elements are also used in usual situations, according to Article 33(1) (MPWS, 2007). Minimum widths are specified as 120 cm. in European standards (Nixdorf, 2007; DCMS, 2008).

TSE's standards, which are in force, (TS 7394 and TS 7395) have not any information about relevant regulations. However, the number limits of people who can pass through the evacuation routes in per unit width (1 m.) and per unit time (1 min.) are given as follows;

- According to BS EN 13200-1:2003 and DIN 13200-1:2004, *66 people/min.Xm.* for staircases, *82 people/min.Xm.* for vomitories and concourses (Nixdorf, 2007; DCMS, 2008).
- According to Turkish Building and Fire Safety Regulations (Annex-5/B), *60 people/min.Xm.* for staircases, *100 people/min.Xm.* for vomitories and concourses (MPWS, 2007).

To calculate the evacuation times of a stadium, the number of person (k) that can pass in one second through the minimum width of evacuation routes (1.1 m.) according to the regulation must know in first step. It is calculated by the following formula 3 (MPWS, 2007).

$$k=(Px1.1)/(60((sec.)/(1min.))) \qquad (3)$$

Afterwards the minimum evacuation time is based on the number of spectators of all stadia or a section and on total route width is calculated by the following formula 4 (MPWS, 2007).

$$t(sec.)=G/(\Sigma\_w\, xk) \qquad (4)$$

There are some important factors in usage of calculations are above (DSMS, 2008);

- If there is more than one route that spectators can use in sample sector, the shortest one should be regarded in calculation.
- If there are changes in one of routes width, the evacuation time should be calculated based on most restrictive element (stairs, vomitories or whichever) of route.
- The longest evacuation time within the separate sectors is accepted as the total evacuation time of a stadium.

After the A, B, C and D capacities are determined separately, the lowest capacity value is accepted as the safe capacity of a stadium (DCMS, 2008; FIFA, 2018).

***Table 1.** The official capacity of Konya City Stadium and its sections according to A, B and C Factors.*

Stand	Official Capacity		
Lower West	3797		
Lower East	4269		
Lower South	3754		
Lower North	3748		
Upper West	3153 Spectator	4697 Total	1544 VIP and Press
Upper East	5841		
Upper South	7307		
Upper North	5116		
Total	38.529		

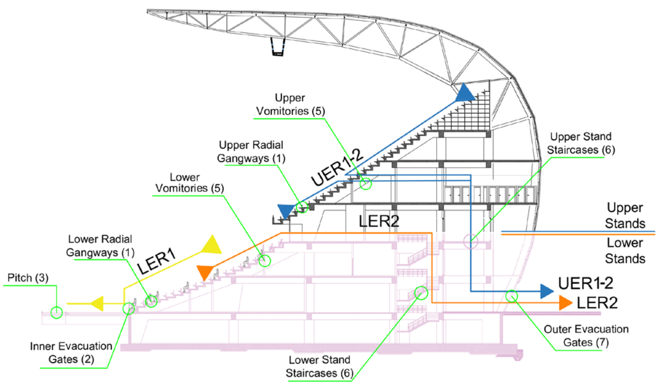

***Figure 3.** The elements of all evacuation routes in the Konya City Stadium, which also in similarly planned stadiums.*

The local football authorities are responsible for accepting the maximum capacity value of stadiums to be used for international tournaments according to the criteria given above. The final capacities are certificated by FIFA and these stadiums cannot be used over official capacities in high-level FIFA/UEFA events. Final capacities are updated every 2 years and in case of changes are made in structural or operational layouts of a stadium (FIFA, 2018).

4. Findings of the case study

The capacity of Konya City Stadium officially determined by UEFA is 38.529 in total. Therefore, the stadium is enabled to use for EURO 2024 tournaments (min. 30.000 capacity is required). The official capacities of the stands are illustrated in Table 1. While calculating these capacity values determined by UEFA, holding, entry and exit types were considered. However, these values are determined subjectively by the local authorities over the P and S factors, UEFA delegate report was used for this capacity data. However, the most important factor in determining

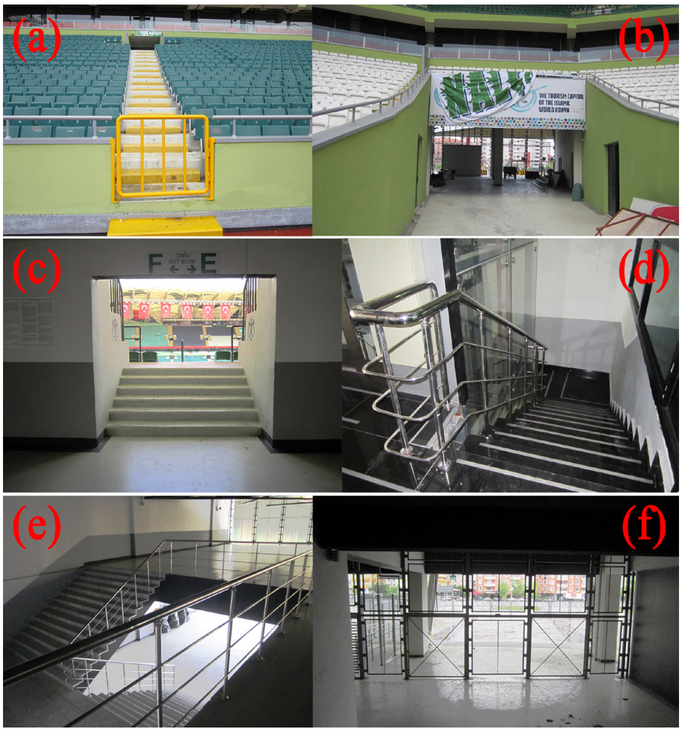

Figure 4. *The sample of radial gangways and inner evacuation gates in the lower stands (a), Pitch evacuation halls (b), Vomitories (c), Stand staircases (d,e), and Outer evacuation gates (f).*

the final capacity is calculation of emergency exits, which is only determined by objective methods in capacity criteria, should not be ignored. So, emergency is the main focused point of methodology in case study. To increase the accuracy of the study, the strictest number limits of people who can pass through the evacuation routes in per unit width (1 m.) and per unit time (1 min.) in the regulations were used.

Konya City Stadium has two evacuation routes for its each upper stand and one evacuation route for its each lower stand in terms of spatial characteristics. Only in the upper west stand, there are many detached sections (VIP, press etc.) due to diversity of the spectators' profile, and an additional route named UER2 (Upper Evacuation Route) is formed. All evacuation, and their elements, which from seats to safety zones, are located as follows. The elements of stadium evacuation routes, which radial-lateral gangways, vomitories, gates, halls etc., on a sample figure 3 within a stand section drawing. In lower stands;

- First lower evacuation route (LER (Lower Evacuation Route) 1) consists of; lower radial gangways (1), inner evacuation gates (2) (Figure 4.a), pitch (3) and pitch evacuation halls (4) (Figure 4.b).
- Second lower evacuation route (LER2) consists of; lower radial gangways (1) (Figure 4.e), lower vomitories (5) (Figure 4.c), lower stand staircases (6) (Figure 4.d) and outer evacuation gates (7) (Figure 4.f).

The minimum width of these halls, which can be used two of them for lower west stands at the same time, is 7,1 meters each. The minimum width of lower east stands is 5,0 meters each. The all-radial gangways (1) widths are 1,2 meters, that provided the minimum width requirement (1.1 m.). On the other hand, inner evacuation gates' (2) width are also 1,2 meters, lower west-east stands have 6 of inner evacuation gates and lower radial gangways, each. However, the north-south stands have only 5 of them. The all vomitories (5) of lower west and lower east stands connect the radial gangways with stand concourses. But in lower north and lower south stands have got any vomitory. The last rows are tied up directly with the hall of stand. Thus, the measures of the vomitories were not included the general calculations. The number of vomitory is the same with radial gangways for remainder stands. Their width is 2,0 meters each for the lower stands and 2,5 meters each for the upper stands. Stand staircases (6) and outer evacuation gates (7) are separated within use for lower and upper stands, different amount and sizes is applied on them. Therefore, all stands in case study are analyzed separately. So, in upper stands;

- First upper evacuation route (UER (Upper Evacuation Route) 1) consists of; upper radial gangways (1), upper vomitories (5) (Figure 5.a), upper stand staircases (6) (Figure 5.b) and outer evacuation gates (7).
- The second evacuation route of the upper west stand (UER2) consists of; upper radial gangways (1), upper vomitories (5), upper hall doors (8), upper stand staircases (6) and outer evacuation gates (7).

The total width of evacuation routes (Σ_w) is 54,2 meters in lower west stand, the requirement criteria is provided with 54,2 meters is above the minimum regulation limits, determined by calculations as follows;

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(3797x0,5)/66 \Rightarrow (3797x0,5)/66=28,76$ m.

Maximum number of persons that is able to use the evacuation route elements in all stands because the class (*66 people/min.Xm.*) of the most restrictive element is the same, which is specified as 1.1 m. unit width, in one second is calculated with equation as follows;

$k=(Px1.1)/(60(sec./(1min.))) \Rightarrow k=(66x1.1)/(60) \Rightarrow (66x1.1)/(60)=1,21$

The most restrictive elements in LER1 of lower west stand are lower radial gangways (1) and inner evacuation gates (2) with 7,2 meters total width. Also, one of the other elements is pitch evacuation halls (4) with 14,2 meters total width. Thus, 7,2 meters value is accepted as the lowest width on LER1. There are two stairs with 1,2 meters each width in lower west stand. These lower stand staircases (6) are the most restrictive elements on LER2 with 2,4 meters total width. So, 9,6 meters value (7,2+2,4) is accepted as the lowest width on all lower west stand (Table 2). The total evacuation time was determined by the equation as below. According to the equation results, total evacuation time of the lower west stand is 5,44 minutes and it is provided the regulation criteria by under 8 minutes. Thus, the official capacity of the stand could be accepted as the final capacity.

$t(sec.)=G/(\Sigma_w xk) \Rightarrow t=3797/(9,6x1,21) \Rightarrow 3797/(9,6x1,21)=326,87$ sec.=5,44 min.

The total width of evacuation routes (Σ_w) is 59,6 meters in lower east stand, the requirement criteria is provided with 59,6 meters is above the minimum regulation limits, determined by calculations as follows;

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(4269x0,5)/66 \Rightarrow (4269x0,5)/66=32,34$ m.

The most restrictive elements in LER1 of lower east stand are lower radial gangways (1) and inner evacuation gates (2) with 7,2 meters total width. Also, one of the other elements is pitch evacuation halls (4) with 10,0

Figure 5. The Sample of Vomitories, Radial Gangways (a), and Stand Staircases (b) in Upper Stands.

Table 2. The Information of LER1 and LER2 in lower stands.

STAND		LOWER WEST						
	Elements of Evacuation Route	Unit Width (m)	Amount	Total Width (m) Σ_w	Unit's Lowest Width (m)	The Lowest Width on Entire Route (m)	The Most Restrictive Element and Its Code	The (P) Value of Restrictive Element
LER1	Lower Radial Gangways (1)	1,2	6	7,2	7,2	**7,2**	**Lower Radial Gangways (1)** *and* **Inner Evacuation Gates (2)**	66 pers./min. *x* m.
	Inner Evacuation Gates (2)	1,2	6	7,2	7,2			
	Pitch (3)	-	1	-	-			
	Pitch Evacuation Halls (4)	7,1	2	14,2	14,2			
LER2	Lower Radial Gangways (1)	1,2	6	7,2	7,2	**2,4**	**Lower Stand Staircases (5)**	66 pers./min. *x* m.
	Lower Vomitories (5)	2,0	6	12,0	12,0			
	Lower Stand Staircases (6)	1,2	2	2,4	2,4			
	Outer Evacuation Gates (7)	2,0	2	4,0	4,0			
TOTAL				54,2		**9,6**		
STAND		LOWER EAST						
LER1	Lower Radial Gangways (1)	1,2	6	7,2	7,2	**7,2**	**Lower Radial Gangways (1)** *and* **Inner Evacuation Gates (2)**	66 pers./min. *x* m.
	Inner Evacuation Gates (2)	1,2	6	7,2	7,2			
	Pitch (3)	-	1	-	-			
	Pitch Evacuation Halls (4)	5,0	2	10,0	10,0			
LER2	Lower Radial Gangways (1)	1,2	6	7,2	7,2	**7,2**	**Lower Radial Gangways (1)**	66 pers./min. *x* m.
	Lower Vomitories (5)	2,0	6	12,0	12,0			
	Lower Stand Staircases (6)	4,0	2	8,0	8,0			
	Outer Evacuation Gates (7)	2,0	4	8,0	8,0			
TOTAL				59,6		**14,4**		
STAND		LOWER SOUTH						
LER1	Lower Radial Gangways (1)	1,2	5	6,0	6,0	**6,0**	**Lower Radial Gangways (1)** *and* **Inner Evacuation Gates (2)**	66 pers./min. *x* m.
	Inner Evacuation Gates (2)	1,2	5	6,0	6,0			
	Pitch (3)	-	1	-	-			
	Pitch Evacuation Halls (4)	5,0	2	10,0	10,0			
LER2	Lower Radial Gangways (1)	1,2	5	6,0	6,0	**6,0**	**Lower Radial Gangways (1)**	66 pers./min. *x* m.
	Lower Vomitories (5)	0	0	0	0			
	Lower Stand Staircases (6)	3,5	2	7,0	7,0			
	Outer Evacuation Gates (7)	2,0	4	8,0	8,0			
TOTAL				43,0		**12,0**		
STAND		LOWER NORTH						
LER1	Lower Radial Gangways (1)	1,2	5	6,0	6,0	**6,0**	**Lower Radial Gangways (1)** *and* **Inner Evacuation Gates (2)**	66 pers./min. *x* m.
	Inner Evacuation Gates (2)	1,2	5	6,0	6,0			
	Pitch (3)	-	1	-	-			
	Pitch Evacuation Halls (4)	5,0	2	10,0	10,0			
LER2	Lower Radial Gangways (1)	1,2	5	6,0	6,0	**6,0**	**Lower Radial Gangways (1)**	66 pers./min. *x* m.
	Lower Vomitories (5)	0	0	0	0			
	Lower Stand Staircases (6)	3,5	2	7,0	7,0			
	Outer Evacuation Gates (7)	2,0	4	8,0	8,0			
TOTAL				43,0		**12,0**		

meters total width. Thus, 7,2 meters value is accepted as the lowest width on LER1. The lower radial gangways (1) are the most restrictive elements on LER2 with 7,2 meters total width. There are 4,0 meters each wide two stairs in lower east stand. So, 14,4 meters value (7,2+7,2) is accepted as the lowest width on all lower east stand (Table 2). The total evacuation time was determined by the equation as below. According to the equation results, total evacuation time of the lower west stand is 4,08 minutes and it is provided the regulation criteria by under 8 minutes. Thus, the official capacity of the stand could be accepted as the final capacity.

$t(sec.)=G/(\Sigma_w xk) \Rightarrow t=4269/(14,4x1,21) \Rightarrow 4269/(14,4x1,21)=245,00$sec.=4,08 min.

Table 3. The information of UER1 and UER2 in upper stands.

STAND		UPPER WEST						
UER1	Elements of Evacuation Route	Unit Width (m)	Amount	Total Width (m) Σ_w	Unit's Lowest Width (m)	The Lowest Width on Entire Route (m)	The Most Restrictive Element and Its Code	The (P) Value of Restrictive Element
	Upper Radial Gangways (1)	1,2	4	4,8	4,8	4,8	Upper Radial Gangways (1)	66 pers./min. x m.
	Upper Vomitories (5)	2,5	2	5,0	5,0			
	Upper Stand Staircases (6)	4,0	2	8,0	8,0			
	Outer Evacuation Gates (7)	2,0	4	8,0	8,0			
TOTAL				25,8		4,8		
STAND		UPPER WEST (VIP and Press Areas)						
UER2	Upper Radial Gangways (1)	1,2	8	9,6	9,6	5,4	Upper Stand Staircases (6)	66 pers./min. x m.
	Upper Vomitories (5)	2,5	4	10,0	10,0			
	Upper Hall Doors (8)	2,0	3	6,0	6,0			
	Upper Stand Staircases (6)	1,8	3	5,4	5,4			
	Outer Evacuation Gates (7)	2,0	3	6,0	6,0			
TOTAL				37,0		5,4		
STAND		UPPER SOUTH						
UER1	Upper Radial Gangways (1)	1,2	10	12	12	7,0	Upper Stand Staircases (6)	66 pers./min. x m.
	Upper Vomitories (5)	2,5	5	12,5	12,5			
	Upper Stand Staircases (6)	3,5	2	7,0	7,0			
	Outer Evacuation Gates (7)	2,0	2	8,0	8,0			
TOTAL				39,5		7,0		
STAND		UPPER NORTH						
UER1	Upper Radial Gangways (1)	1,2	10	12	12	7,0	Upper Stand Staircases (6)	66 pers./min. x m.
	Upper Vomitories (5)	2,5	5	12,5	12,5			
	Upper Stand Staircases (6)	3,5	2	7,0	7,0			
	Outer Evacuation Gates (7)	2,0	4	8,0	8,0			
TOTAL				39,5		7,0		
STAND		UPPER EAST						
UER1	Upper Radial Gangways (1)	1,2	12	14,4	14,4	7,0	Upper Stand Staircases (6)	66 pers./min. x m.
	Upper Vomitories (5)	2,5	6	15,0	15,0			
	Upper Stand Staircases (6)	3,5	2	7,0	7,0			
	Outer Evacuation Gates (7)	2,0	4	8,0	8,0			
TOTAL				44,4		7,0		

The total widths of evacuation routes (Σ_w) in lower south and lower west stands are 43,0 meters, the requirement criteria are provided in both of stands with 43,0 meters is above the minimum regulation limits, determined by calculations as follows;

For the lower south stand:

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(3754x0,5)/66 \Rightarrow (3754x0,5)/66=28,44$ m.

For the lower north stand:

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(3748x0,5)/66 \Rightarrow (3748x0,5)/66=28,40$ m.

The most restrictive elements in LER1 of these stands are lower radial gangways (1) and inner evacuation gates (2) with 6,0 meters total width. Also, one of the other elements is pitch evacuation halls (4) with 10,0 meters total width. Thus, 6,0 meters value is accepted as the lowest width on LER1. The lower radial gangways (1) are the most restrictive elements on LER2 with 6,0 meters total width. There are 3,5 meters each wide two stairs in both of stands. So, 12,0 (6,0+6,0) meters value is accepted as the lowest width for lower south and lower north stands separately (Table 2). The total evacuation time was determined by the equation as below. According to the equation results, total evacuation times of the lower south and the lower north stands are 4,30 minutes and that is provided the regulation criteria by under 8 minutes. Thus, the official capacity of the stands could be accepted as the final capacity.

For the lower south stand:

$t(sec.)=G/(\Sigma_w xk) \Rightarrow t=3754/(12,0x1,21) \Rightarrow 3754/(12,0x1,21)=258,54$ sec.=4,30 min.

For the lower north stand:

$t(sec.)=G/(\Sigma_w xk) \Rightarrow t=3748/(12,0x1,21) \Rightarrow 3748/(12,0x1,21)=258,13$ sec.=4,30 min.

There are two separated evacuation routes (and sections) in the upper west stand. One of them (UER2) is used by VIP and press members, the other one (UER1) is used by ticketed spectators. The capacity value also varies in different sections. The total evacuation routes' width (Σ_w) for ticketed spectators is 25,8 meters and 37,0 meters for VIP and press members in the upper west stand, the requirement criteria is provided with both evacuation routes as are above the minimum regulation limits, determined by calculations as follows;

UER1: $\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m) = (3153x0,5)/66 \Rightarrow (3153x0,5)/66=23,89$ m.

UER2: $\Sigma_w(m) = (Gxw)/P \Rightarrow \Sigma_w(m) = (1544x0,5)/66 \Rightarrow (1544x0,5)/66=11,70$ m.

The most restrictive elements in UER1 of upper west stand are upper radial gangways (1) with 4,8 meters total width. Also, the other elements are upper vomitories (5) with 5,0 meters, outer evacuation gates (7) and upper stand staircases (6) with 8,0 meters total width. Thus, 4,8 meters value is accepted as the lowest width on UER1 for upper west stand (Table 3). The total evacuation time for UER1 was determined by the equation as below;

$t(sec.)=G/(\Sigma_w xk \Rightarrow t=3153/(4,8x1,21) \Rightarrow 3153/(4,8x1,21)=542,87$ sec.=9,05 min.

Total evacuation time of the upper west stand for UER1 is 9,05 minutes and it is not provided the regulation criteria by above 8 minutes. The official capacity of the stand could not be accepted as the final capacity. So, the new final capacity, which should be applied, is calculated with formula as follows;

Gmax=480(8 min.)x4,8x1,21 ⇒ Gmax=2787 seats instead of 3153

On the other hand, the most restrictive elements in UER2 for the upper west stand are upper stand staircases (6) with 5,4 meters total width (Table 3.). Also, the other elements are upper radial gangways (1) with 9,6 meters, upper vomitories (5) with 10,0 meters, upper hall doors (8) with 6,0 meters and outer evacuation gates (7) with 6,0 meters total width. The total evacuation time for UER2 was determined by the equation as below;

$t(sec.)=G/(\Sigma_w x k) \Rightarrow t=1544/(5,4x1,21) \Rightarrow 1544/(5,4x1,21)=236,30$ sec.=3,94 min.

The total width of evacuation routes (Σ_w) is 39,5 meters in the upper south and the upper north stands, the requirement criteria is not provided in the upper south stand, because 39,5 meters is under the minimum regulation limits, determined by calculations as follows;

For the upper south stand:

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(7307x0,5)/66=55,35$ m.

For the upper north stand:

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(5116x0,5)/66=38,75$ m.

The most restrictive elements in UER1 of these stands are upper stand staircases (6) with 7,0 meters total width. Also, the other elements are upper radial gangways (6) with 12,0 meters and outer evacuation gates (7) with 8,0 meters total width. In addition, there are only 5 radial gangways in either stands. But since the vomitories are in the middle of the radial gangways, there is a degradation in the evacuation route for the spectators at the upper and lower rows of the stands. 7,0 meters value is accepted as the lowest width on UER1 for all upper south and

Table 4. *The emergency exits capacities and related values of the Konya City Stadium Stands.*

Stands / Elements	Lower West	Lower East	Lower South	Lower North	Upper West	Upper West (VIP)	Upper East	Upper South	Upper North
Essential Minimum Total Width (Σ_w) (m)	28,7	32,3	28,4	28,4	23,8	11,7	44,2	55,3	38,7
Total Width of Evacuation Routes (m)	54,2	59,6	43,0	43,0	25,8	37,0	34,2	39,5	39,5
The Lowest Width of Entire Route (m)	9,6	14,4	12,0	12,0	4,8	5,4	7,0	7,0	7,0
Total Evacuation Time (min.)	5,44	4,08	4,30	4,30	9,05	3,94	11,49	14,38	10,07
Regulation Criteria (8 min.) is	Provided	Provided	Provided	Provided	Not Provided	Provided	Not Provided	Not Provided	Not Provided
Regulated Capacity	-	-	-	-	2787	-	4065	4065	4065
Capacity Gap	-	-	-	-	366	-	1776	3242	1051

upper north stands (Table 3). The total evacuation time was determined by the equation as below;

For the upper south stand:

$t(sec.)=G/(\Sigma_w x k) \Rightarrow t=7307/(7,0x1,21)=862,69$ sec.=14,38 min.

For the upper north stand:

$t(sec.)=G/(\Sigma_w x k) \Rightarrow t=5116/(7,0x1,21)=604,01$ sec.=10,07 min.

Total evacuation times of the upper south and upper north stands are respectively 14,38 and 10,07 minutes. These are not provided the regulation criteria by above 8 minutes. The official capacity of the stands could not be accepted as the final capacity. So, the new final capacities, which should be applied, is calculated with formula as follows;

Gmax=480(8min.)x7,0x1,21⇒Gmax=4065 seats instead of 7307 and 5116

The total width of evacuation routes (Σ_w) is 34,2 meters in upper east stand, the requirement criteria is not provided with 44,4 meters is just above the minimum regulation limits, determined by calculations as follows;

$\Sigma_w(m)=(Gxw)/P \Rightarrow \Sigma_w(m)=(5841x0,5)/66 \Rightarrow (5841x0,5)/66=44,25$ m.

The most restrictive elements in UER1 of upper east stand are upper stand staircases (6) with 7,0 meters total width. Also, the other elements are outer evacuation gates (7) with 8,0 meters and upper radial gangways (1) with 14,4 meters (7,2 m. for upper rows; 7,2 m. for lower rows) total width. Thus, 7,0 meters value is accepted as the lowest width on UER1 and all upper east stand (Table 3). The total evacuation time was determined by the equation as below;

$t(sec.)=G/(\Sigma_w xk) \Rightarrow t=5841(7,0x1,21) = 689,61$ sec.=11,49 min.

Total evacuation time of the upper east stand is 11,49 minutes and it is not provided the regulation criteria by above 8 minutes. The official capacity of the stand could not be accepted as the final capacity. So, the new final capacity, which should be applied, is calculated with formula as follows;

G_{max}= 480 (8min.) x7,0x1,21⇒G_{max} = 4065 seats instead of 5841

5. Conclusion and suggestions

The emergency exits capacities and evacuation times of Konya City Stadium are analyzed. These are illustrated within certain criteria in Table 4. Accordingly, in the lower tier stands of the stadium, the capacity values are in accordance with regulations. Indeed, the capacity of lower west stand is 3979 and its evacuation time is 5,44 minutes. The capacity of lower east stand is 4269 and its evacuation time is also under 8 minutes by 4,08. The lower holding capacities and the higher number of evacuation route alternatives are the most important factors to diminishing the evacuation times in these stands. In addition, the relatively narrow stand staircases (6) in lower west stand could be considered as the biggest reason for the difference between lower west and lower east stands' evacuation times.

The upper tier stands have higher evacuation times than lower tier ones, because the pitch and its evacuation halls is not available to use for upper tier stands. While the total width of evacuation routes in lower tier stands is nearly 20 meters more than ones in upper tier stands. At this point, the upper west VIP stands is evaluated in different aspects. Because in this stand there are 4 vomitory 2,50 meters wide each and the capacity/total bottleneck width ratio is respectively more than any stands in the stadium. On the other hand, the ticketed spectators can use only 2 vomitories in stand. Otherwise, they must pass along the rows to access other vomitories, and this is not ideal for faster evacuate because there will be probably overcrowded in extraordinary situations. Thus, although the upper tier minimum evacuation time is calculated in upper west stand by 9,05 minutes, this time is not provided by regulations as it is above the 8 minutes limit. It is followed by 10,07 minutes in upper north stand. The regulation criteria should be provided by remove 1051 seats in upper north and 3242 seats in upper south stands. Thus, the evacuation times could be exact 8 minutes. The highest evacuation time of case study is 14,38 minutes in upper south stand. The most important factor for this situation is the high number of seats. The evacuation time of the upper east stand is also 3,49 minutes higher than regulation limits because of the same reasons.

As a result, all 8 stands that analyzed for the case study, the final capacity of the stadium should be up to 32,094. So, 6435 seats at least should be removed. Although the measures to be taken to determine safe capacity are specified in the regulations, the occurrence of different results in case study is based on some reasons below arising from the safety audit and certification process;

- Some requirements and standards specified in regulations are open-ended such as P or S factors used to determine holding capacities. These could be applied partially by subjective opinions of local authorities. Thus, the implementations vary across stadiums in different cities or countries.
- The safety audits are approved based on various titles/items varying according to their degree of importance on the stadiums, the approving the stadiums at certain threshold values based on the percentage calculations made on these items, and therefore the number of the criteria that are approved, could be reduce the negative

effect of criteria are not provided.

- The possibility of the differences between the standards that are regularly updated in the process and the standards applied in the last safety audit. In this situation, some stadiums could be used with former standards for a brief time.
- International football authorities, such as FIFA and UEFA, may tolerate local authorities in stadium capacities, which are used in local leagues.

Each stadium that is planned to be used in the competitions organized by FIFA and/or UEFA is inspected by the football authorities in line with the regulations since the project process. In addition, as mentioned above, these stadiums are regularly re-inspected, capacity and safety data are checked, and necessary changes are made. In this study, the fact that the Konya City Stadium capacity data are different does not mean that the stadium is not built-in accordance with the regulations. Since the contracts between the UEFA officials and the local football federation are completely closed to the public or it has been a long time since the last inspection, the capacity values in the stadiums may vary at the levels determined in the study. The main goal of the study is to evaluate the interventions that can be made to increase the existing capacity and/or to make the stadiums safer, to the spatial arrangement methods made to achieve safe capacity in an international degree stadium.

Nevertheless, the results obtained from the study were evaluated in different perspectives. Accordingly, two main actions are recommended for stadiums that need to be refurbished in terms of security and meet the regulation standards in total evacuation times. The first of these; each independent section is evaluated within itself, and the number of available seats is gradually reduced, especially starting near the evacuation routes. Because, as seen in Konya city stadium, the most restrictive elements, especially in the lower stands, are the radial gangways. The least costly and most practical way to increase the width of these elements may be to reduce the seats around these routes as necessary. Thus, both the total route widths increase and the capacity decreases. On the other hand, it may be quite reasonable to place retractable seats in these areas in local leagues.

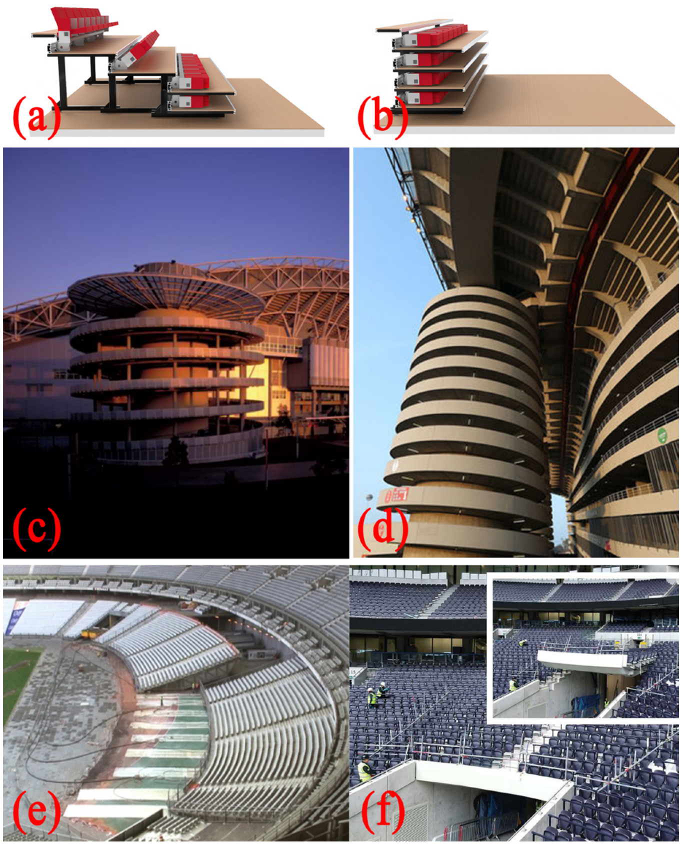

Figure 6. The Open (Closing) (a) and Closed Position (b) of a Stadium Seats, which have Retractable Telescopic Frames (Figueras Engineering, 2021), The Circular Ramps in the Telstra Stadium Sydney (John et. al., 2007) (c) and the San Siro Stadium Milan (Deiana, 2019) (d), The Retractable First Ring Stands in the Stade de France (Whetstone, 2011) (e), The Pivoting Stand Parts of Tottenham Hotspur Stadium (SCX, 2021) (f).

The second action is to increase the spatial size, or the number of bottlenecks identified in the evacuation plans. It is quite easy to carry out these interventions in accordance with the instructions in a stadium structure that has not yet been built and is in the planning stage. However, the methods that can be used to achieve the required level of security in an already built stadium are becoming more sophisticated. In FIFA's 'Football Stadiums Technical Recommendations and Requirements', DCMS's 'Guide to Safety at Sports Grounds', and in the USA, Germany, UK etc. in the design guides of private sector veterans, the most common solution method focuses on demountable structures. With this method, both the capacity level can be controlled, and the dimensions of the evacuation routes can be changed simultaneously.

Some structures in stadiums may be erected for a single event only and may be commissioned at short notice. Structural components are lightweight, rapidly assembled, readily dismantled, and reusable. The most common method is to make some seats demountable/ retractable. This idea evolved in the 1960s from the attempt to house American football, played on a rectangular pitch, and baseball, played on a diamond shaped pitch, in the same building. Movable seating can be supplied in any numbers, from a few hundred to several thousand, to suit the types of events anticipated and the configurations required. The most usual type is retractable seats on folding or telescopic frames (Figure 6.a,b).

The dual stadia complex of Kansas City, Missouri was opened; this included two stadia, one of 78.000-seat (some of them are movable seats) capacity to be used for American football, the other of 42.000-seat capacity for baseball. Thus, the most ideal and safest capacity-seat arrangement has been provided for two types of events that require different spectator viewing angles. Toronto Skydome which opened in 1989 and can be adapted, by movable seating, to the following uses. The stands configurations allow 10.000 to 68.000 spectators for different exhibitions. One another example is the Pro Player stadium in Miami which accommodates football as the primary sport, and baseball as a secondary use in different capacity levels by using movable seats. Another example of pre-construction methods is the Telstra Dome stadium in Melbourne. While the upper stands of the stadium are reinforced concrete and fixed, the lower stands are planned with a steel structure and can be moved to obtain different capacity values. However, this solution cannot be considered for fieldwork as it requires the reconstruction of some of the stands in the already-built stadiums.

Stairs have the advantage of being the most compact method of vertical circulation in plan and as a result the easiest to design according to a scheme. But they have the disadvantage of being arguably more dangerous than ramps in an emergency. It should be planned in pairs, if possible, the two stairs preferably sharing a common landing so that there is always an alternative route if one of the stairs is blocked. Furthermore, spectators are less likely to lose their feet on a ramp than on a ladder, and if they stumble or fall, the consequences will be less serious than on a ladder. Ramps are an ideal method to allow service vehicles to move from one level to the next. Also, they allow easy passage for wheelchairs and transportation of sick or injured spectators to the exits during events. Shortly, ramps are a safe, convenient, and increasingly popular way of transporting large numbers of people to different levels of the stadium, and circular ramps are the most common form. The corners of the stadium are the most usual position and successful examples include the circular ramps in the Telstra Stadium Sydney (its capacity is 82.500) (Figure 6.c), the Joe Robbie Stadium USA (65.000), and the San Siro Stadium Milan (80.000) (Figure 6.d).

Most restrictive elements in the upper stands' evacuation routes, which do not meet the 8-minute regulation requirement in Konya City Stadium, are mostly upper stand staircases. The reason for this situation is that the dimensions of these elements are not sufficient and the number of spectators who can use it per meter-per minute as a regulation constant is limited to 60/66 since they are stairs. If circular ramps are used instead of stairs for these stands, both the unit widths can be increased, and the regulation constant can be increased to 82/100. Thus, the total evacuation times will be greatly reduced. Aside from reducing the capacity, it is highly probable that even capacity increase in these stands can be allowed.

Apart from the specified capacity control applications, there are also stadiums that offer different capacity solutions around the world. Manchester City Stadium was designed to host the 2002 Commonwealth Games and was home to Manchester City Football Club in August 2003. Following the Commonwealth Games, a long-term future for the stadium was secured with its conversion into a football stadium capable of hosting rugby matches as well as other performance and community events. This transformation was achieved by completing the northern section of the bowl and excavating to create a lower seating layer, increasing the seating capacity from 38 000 to 50,000. The entry-exit and evacuation routes of the new stands are completely separated from the other stands. Thus, there is no disadvantage in terms of total evacuation time. However, to carry out this application, an athletics track, etc., must be established between the pitch and the stands beforehand. It is necessary to have add-ons and provide the necessary free space. This situation cannot be applied to Konya City Stadium. A similar example is the Stade de France, originally built in 1998. Multifunctional 80,000-seater stadium originally built for both football and rugby due to the elliptical shape of the stepped seating arrangement. Naturally, it allows the spectators to get closer to the field and especially to the goals. But it can also be adapted to a wide variety of athletic events. The 25,000 seats of the first ring stands are movable and can be mechanically retracted 15 meters and rolled on a cushion of air, steel, and Teflon cylinders (Figure 6.e). It is possible to apply this method with smaller stand parts for the Konya City Stadium. Especially on pitch evacuation gates (as can be seen in Figure 6.f of Tottenham Hotspur Stadium). However, the cost is the biggest question mark in this solution.

Based on the conclusions of this study, to prevent local football culture from stadium disasters, the structural and operational audits in the stadiums should be more qualified and the community should be continuously informed about all kinds of scenarios that may occur in the stadiums. The absence of a similar tragedies in the process from past to the present has caused the possible disasters could be happen in stadiums to be forgotten over time. This study, which includes capacity evaluations and calculations over Konya City Stadium, emphasizes the importance of the stadium on an international scale, in a way, with its use in international competitions and its inspection/approval by UEFA. FIFA and UEFA maintain similar procedures for large-scale competitions at these stadiums of their member federations. Thus, all official regulation standards valid for Konya City Stadium are also valid for stadiums at the same level around the world. For this reason, it is desired to contribute to the international literature with the calculations, evaluations, and refurbishment suggestions within the scope of the study.

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