

Towards the Advanced Technology of Smart, Secure and Mobile Stadiums: A Perspective of Fifa World Cup Qatar 2022

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Abstract Innovations in recent years have made technological advancement become a cutting-edge revolution for this modern society. Innovations that are centered on Information Technology, have resulted in disruptive technological revolutions around the world. Smart technology has been one of the game-changing innovations that have highly impacted technological advancements. The Internet of Things being one of the blueprints of smart technologies, has been applied in various multidisciplinary fields including space exploration, agriculture, and soccer stadiums among other areas. In this paper, we present the impact of smart technology in the enhancement of fan experience in football pitches with bias in the FIFA World Cup of 2022. Some technologies adopted during the recently ended FIFA World Cup competitions held in Qatar in the year 2022, were completely new in the history of football. The use of sensor-embedded smart balls, rogue drone hunters, aids for visually impaired fans, air-conditioned stadiums, and automated crowd control systems were all deployed for the very first time since the official World Cup competitions started 92 years ago. The research found that with these new technologies in place, game management by FIFA officials has highly improved and fans irrespective of their physical challenges had more to celebrate and enjoy than before. Lastly, the paper presents an overview of the first ever economical and mobile stadium used and demounted after the World Cup competitions.

Keywords IoT, Smart, Stadium, Demountable, Sensor, FIFA World Cup

1. Introduction

The world is moving towards digital stability where almost everything is digitally controlled [1] and smart technology is at the center stage. Smart technology has been applied in many areas such as homes, cities, agriculture, engineering, and stadiums, among others. Smart technology makes use of sensors to detect the changes in the environment and execute procedures to enhance their functionality under new conditions to improve the performance and efficiency of the monitoring system [2]. Some smart technologies are for sensing any changes in the conditions and reporting the changes to relevant systems while others respond to the changes to stabilize the conditions if they are extreme. The smart technology that senses and responds to the changes in the conditions in a given environment is robotic in nature and made up of sensors, actuators, and gripping abilities making them intelligent and autonomous ready to handle difficult situations [3]. This smart technology has been made possible by the advanced technology of the Internet of Things (IoT). IoT refers to the network of devices,

appliances, and vehicles embedded with sensors, enabling software and network connectivity that allow them to collect and exchange data [4]. For instance, some soccer, basketball, and athletics stadia are employing the Internet of Things to improve the management of sporting activities and enhance the experience of fans in the sports industry. In the early days, there was no use of smart technology in football stadia but technology has been introduced in the recent tournaments. This research focuses on the impact of using enhanced smart technology in all soccer stadiums alongside demountable soccer stadiums.

2. Materials and Methods

This research paper adopted a qualitative research methodology. Materials used in this paper include Smart Technology of the Internet of Things and demountable stadiums. Secondary data published online on related studies were retrieved and used. Analysis was done using thematic analysis methods.

3. Smart Stadiums

Before the 1980s, there was no remarkable technology in the world of football, and it was difficult to monitor individual player performance as well as carry out statistical analysis about ball possession, passes of target player, the success rate of passes, the success rate of forward passes, mean passes, etc. However, during the late 1980s, there was a rise in the technology used in football through match analysis using video [5] whereby coaches and players would later analyze how they played after the game is over by watching the recorded video. They would rely on these recorded videos to make improvements in their games. In the 1990s, the heartbeats of players were monitored due to the improvement in technology, and at the beginning of the 21st century, the Global Positioning System (GPS) was introduced to track individual players in the field [5]. In recent years, technology has even advanced more to include Self-Monitoring, Analysis, and Reporting Technology (SMART). Smart stadiums present a stage to test the latest technological advancements in sports creating a high affinity between sports and big data innovation improving the experience of fans beyond stadium boundaries [6]. This technology makes good use of sensors, cameras, apps, and other digital gadgets placed in various strategic positions in the stadiums all interconnected through high-speed internet, some using Ethernet connections while others use wireless radiations altogether making the Internet of Things a reality. Some common features in these Smart stadiums include triggers for maintenance of washrooms when the count exceeds a certain threshold, sensor detection of cheering fans to display them on screens, and high-speed wireless networks for all fans to post images of stadium events on social media platforms [7]. Smart technology has thus been

applied in various stadiums around the world for some years now. In Qatar, eight stadiums were used for the FIFA World Cup games having met international standards. These stadiums include Lusail Stadium, Al Bayt Stadium, Al Janoub Stadium, Ahmad Bin Ali Stadium, Khalifa International Stadium, Education City Stadium, Stadium 974 and Al Thumama Stadium [8]. FIFA World Cup kicked off on 20th November to 18th December 2022 with the following game-changing technologies being applied in all the games played in Qatar's eight stadiums; some being applied for the first time in world cup history.

3.1. Sensor-Equipped Ball

In the recent past, there has been a rise in demand for the use of technology in determining offsides and goals scored by players to help referees make the most correct judgement. During the World Cup of 2022, FIFA approved a sensor-embedded ball to be played in all 64 matches for the first time in the history of the world cup after six years of testing [9]. Developed by KINEXON, a German AI Corporation, Cairo Technologies, and Adidas, the ball was named Al Rihla ("The Journey"). Al Rihla is equipped with a Near-Field Communication (NFC) chip which is the sensor placed at the center of the ball [10] embedded with an Inertial Measurement Unit (IMU), a sensor that tracks the acceleration and angular velocity of the ball over a period of time. The ball also utilizes the ultra-wideband (UWB) radio frequency [9], which is a short-range wireless communication protocol that uses radio waves to enable it transmit data to connected devices besides providing real-time spatial positioning of the ball. Al Rihla was designed to float longer and spin more while relaying information about its position at a high frequency of (500Hz) 500 times per second. All these sensors and transmitters help the referee determine when the ball has crossed the goal line. When the ball crosses the goal line, the sensors notify the match officials and relay the same information to the smart watch worn by the center referee in real time [9]. If there is any dispute, match officials reach the referee connected through communication equipment worn by the referee (headphones and microphone) by UWB radio frequency. The smart ball enhances the Goal Line Technology that was first used in the 2014 FIFA World Cup in Brazil, which only relied on 12 cameras mounted around the stadium. The cameras would use 3D coordinates to monitor the ball position and relay information to the watch of the referee [11]. A smart ball with a frequency of 500Hz is more accurate and real-time in communication than the cameras because cameras use a lower frequency of 50Hz [12]. In addition, it is the smart ball that helped the referee determine which player scored in the game between Portugal and Uruguay during the 2022 FIFA World Cup [13]. *"In the match between Portugal and Uruguay, using the Connected Ball Technology housed in Adidas's Al Rihla Official Match Ball, we are able to definitively show no contact on the ball from Cristiano Ronaldo for the opening*

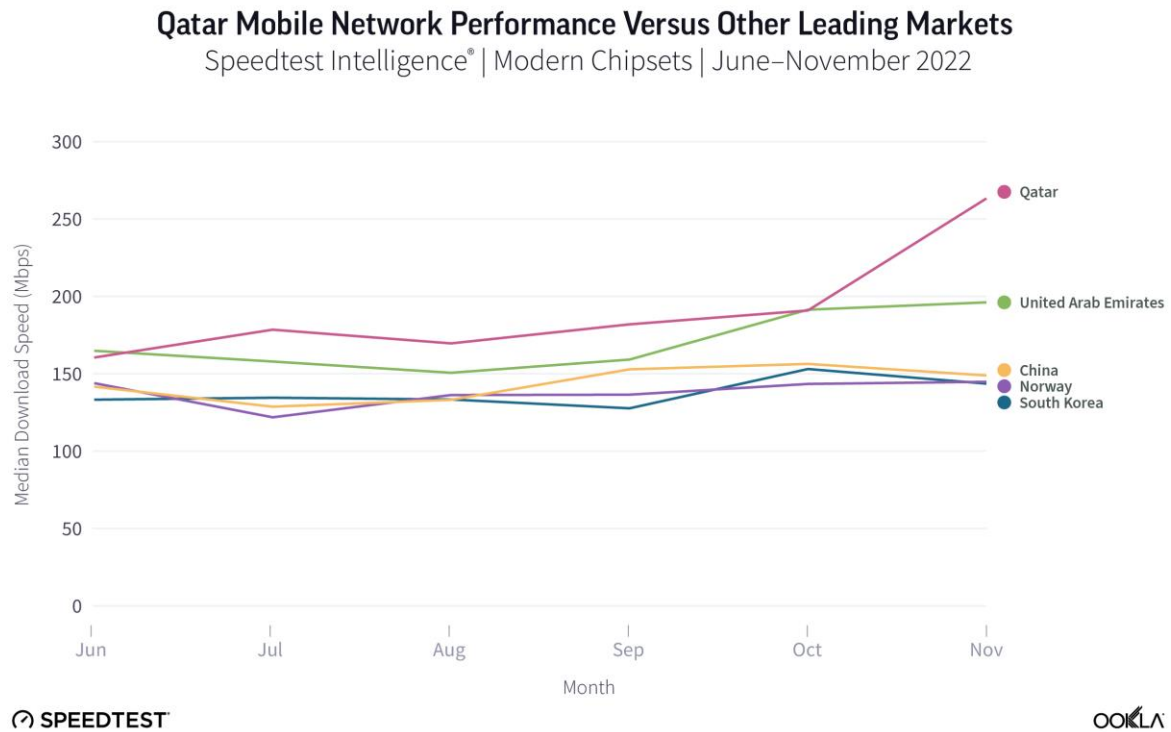


Figure 2. Network performance of various countries against month of the year [18]

3.3. Visually Impaired Soccer Fans

Visually impaired people have the right to access among other things, entertainment facilities just like everyone else. However, for a long period, they have had challenges in enjoying the entertainment of soccer, especially the most coveted world cup competitions. Nevertheless, for the first time, FIFA in partnership with Doha-based Bonocle and Oxford-based Felix technological companies provided an answer to the challenges faced by visually impaired soccer fans [19]. Visually impaired people can read or capture information by braille using their fingers. Bonocle has become the first ever braille entertainment platform in the world to have assistive technology to assist visually impaired people to access digital content [20]. The platform works like a smart tablet controller which converts all the contents on the viewer's screen into braille in real time as the game continues [10]. Bonocle provided the first experience for visually impaired people to watch live matches of the Qatar World Cup 2022. On the other hand, Felix is a device wearable by soccer fans. It is a palm communicator that uses tactile electrical impulses to communicate braille-like information to visually impaired people. The developers said that Felix helps fans get more immersed in their sporting environment by getting quick feedback on the palms of their hands.

3.4. Crowd Control

FIFA World Cup competitions play a big role in

fostering global relationships between players, fans, and hosting countries [21]. Many soccer fans from all over the world travel to the hosting countries to watch the games from the selected stadiums filling the arenas to the brim. Therefore, controlling the crowds in these stadiums can be a daunting task as many fans turn out to support their teams. For example, on 28th May 2022, during the Champions League final football match between Liverpool and Real Madrid at the Stade de France Stadium in Paris, chaos erupted as fans who were overcrowded in tight spaces tried to jump over the fence and were teargassed by police delaying the game for 36 minutes [22]. French interior minister said there was poor management of fans by the stadium officials as between 30,000 to 40,000 fans came in with fake tickets overcrowding the spaces [23]. Secondly, in October 2022, there was a deadly football stampede at Kanjuruhan Stadium in Indonesia that left at least 125 people dead and hundreds injured as some fans were teargassed by police after storming onto the pitch [24] while others died as they were running into locked exits in trying to exit the stadium [25]. To avert and prevent such instances brought about by overcrowded fans in stadiums, Qatar set up the first-ever Aspire Command and Control Centre (ACCC) in its capital Doha with 22,000 security cameras and over 200,000 integrated units [25] monitoring all eight stadiums identified to host the FIFA World Cup games [10]. Over 100 Technicians at ACC Centre were equipped with big screens to monitor the population of all the stadiums, especially at Lusail Stadium which had the

largest capacity of 80,000 people. The technicians were able to see which gates were overcrowded and were able to control the closing and opening of gates with a click of a button directly from ACCC [26]. Additionally, the ACCC could zoom in on each of the 80,000 spectators at Lusail Stadium and capture information about what the person is doing. Using AI, ACCC was able to predict the patterns of crowds, potential stampede formation, and crowd surges using data such as arrival time, entry points, and the movement of people within the stadium [10]. Staff at the Command Centre could also count the number of people present in a space and apply a maximum threshold needed. With this automated management of stadiums, overcrowding and the formation of potential stampedes could be easily controlled, pre-empted, or even avoided [26]. Figure 3 below shows a photo of part of the technicians at ACC Centre monitoring different stadiums using big screens interconnected by cameras placed in all the stadiums [26].



Figure 3. The Aspire Command and Control Centre (ACCC). Image courtesy of SuperSport [26]

A lot of fans were expected at all the eight stadiums in Qatar filling arenas to the brim. Controlling this crowd in all the eight stadiums would not have been easy without the use of technology [10]. Table 1 below shows the number of seats available in each stadium thereby clearly showing the total number of fans expected in each stadium.

Table 1. Stadiums of the 2022 FIFA World Cup in Qatar, by capacity. Source Statista

STADIUM	CAPACITY
Lusail	80,000
Al Bayt	60,000
Education City	40,000
Khalifa Int	40,000
Stadium 974	40,000
Al Janoub	40,000
Ahmad Bin Ali	40,000
Al Thumana	40,000

3.5. Automated Surveillance and Security Control

The security of an individual is as paramount as the

security of a group of people. In events where people are crowded, it is the responsibility of event organizers and hosts to guarantee security to the participants or spectators. More often, soft targets and crowded places tend to be vulnerable to attacks using simple tactics and readily available weapons [27]. In the UK for example, between 2016 and 2019, the country suffered six attacks from terrorists all targeting only crowded places [28]. Soccer pitches are an example of crowded places where thousands of spectators come to support their teams and enjoy the fascinating game. In the year 2015, during an exhibition match between France and Germany at the Stade de France Stadium in Paris, terrorists attacked people outside the stadium shot and dropped explosives that killed at least 129 people and injured many others [29]. Qatar was expecting 1.2 million spectators and fans to come in the country to watch the 2022 FIFA World Cup [25], it was obvious that the stadiums would have many crowds posing a security threat. To prevent any kind of air attacks, the Ministry of Interior of Qatar and the US Department of Homeland Security entered into an MOU to enhance the security of the World Cup competitions [30]. Early 2022, US-based Fortem Technologies a leading company in airspace security and defense for detecting and neutralizing dangerous drones, announced their partnership with Smart Communication Systems (SCS) Company to deploy Counter-Unmanned Aircraft Systems (C-UAS) to secure the Qatar FIFA World Cup events. Figure 4 displays the Drone hunter and C-UAS system developed by Fortem Technologies [28].



Figure 4. Fortem Technologies DroneHunter and C-UAS system [31]

Fortem Technologies developed SkyDome System which is an advanced C-UAS system that can monitor and protect airspace all the time and in all weather conditions [31]. SkyDome comprises of TrueView sensors, SkyDome Manager Software, and DroneHunter interceptors. TrueView sensors comprise of AI-enabled and networked radar systems that view the protected environment in 3D forming a dome-shaped protection area [30]. Immediately after an unfamiliar drone enters the protected area, it is detected, classified, and presented on the screens of security officers at the control station [31]. On the other hand, SkyDome Manager Command and Control software uses AI to give the officials tips to make a quick and smart decision on the rogue drone starting with automatic threat analysis, followed by a series of video streams from thermal cameras as transmitted by real-time radar feeds [31]. Finally, if the operators with the help of AI determine

that the drone is a threat to security, DroneHunter interceptors from the closest unit are launched within seconds and race towards the target before it breaches airspace security. Armed with several NetGuns alongside DroqueNet, the DroneHunter captures the rotary and fixed-wing craft of the intruder drone and takes it far away from the scene. Larger drones are forced to land hence giving an allowance for the crowds to disperse smoothly. Figure 5 below shows a model of SkyDome area protection system deployed in all eight Qatar stadiums to protect players and fans during the FIFA World Cup [30] [31].

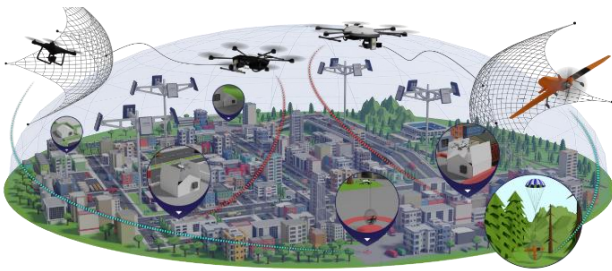


Figure 5. SkyDome® Protection: “Nothing Comes Close”. Photo by Fortem [31]

3.6. Facial Biometrics Payment System

Facial recognition is a biometric system that has been used by people and companies in recent years. It is the process of identifying the identity of a person through capturing, analyzing, and comparing patterns of the facial details of a given person. A sensor captures the facial details and then transforms them into digital data by use of an algorithm then compares the captured image with the one stored in the database through identification and authentication mechanisms [32]. The main aim of this technology is to prevent fraud through impersonation and to speed up the process of verification. In FIFA World Cup 2022, Visa, FIFA, and PopID partnered to deliver a contactless biometric payment system for over 1 million fans expected at the world cup competitions [33]. Visa piloted the pay-with-your-face technology allowing customers to authenticate their payment without using mobile phones or smart cards [34]. PopID which is a leading digital company for designing biometric technology systems for facial recognition, collaborated with Qatar National Bank and was supported by Visa via tokenization [33]. This led to the installation of 5,300 contactless payment terminals by Visa to serve all the world cup fans in Qatar [35]. Facial recognition systems have a near-perfect accuracy and thus can achieve an accuracy of up to 99.97% in ideal conditions [36]. This move helped to save on service time and fend off fake tickets as witnessed in the chaotic match in May 2022, during the Champions League final between Liverpool and Real Madrid at the Stade de France Stadium in Paris [22]. Before that match kicked off, tens of thousands of fans entered the sports field with fake tickets leading to

overcrowding and eruption of chaos [23].

3.7. Automated Climate Control System

Qatar is a country found in the Middle East occupying a flat peninsula in the Arabian/Persian Gulf, a region whose climatic conditions are desert-like having mild winters and extremely hot summers [37]. FIFA World Cup competitions normally take place around the months of June and July; however, this was not the case for Qatar as these months are always extremely hot averaging at about 100 F (37 °C) [38]. Due to the high temperatures, FIFA pushed the competitions to November and December 2022 as this is the winter season and the months of November to April have a lower temperature of as low as 20.4 °C (68.7 F) to 29.6 °C (85.3 F) high [39]. This temperature is still high and thus football players cannot give their best performance as well the fans won't be comfortable with such heat [40], therefore all eight stadiums were fitted with state-of-the-art air conditioning technology [41]. Developed by Qatar University under the leadership of Dr. Saud Abdulaziz Abdul Ghani, the Professor of Mechanical Engineering at the university, the technology made use of solar-powered photovoltaic modules [42]. The use of solar panels came in handy as it saved on energy production costs, no air pollution as a result of using renewable energy as well as making use of the free solar energy which would otherwise have been wasted. The biggest challenge of this Qatar National Research Fund project was cooling an open-air stadium by preventing the warm outside air from entering into the stadium. To handle this challenge, Dr Ghani's team developed 3D printing scale models of the proposed eight stadiums which were then placed in a wind tunnel for advanced aerodynamic analysis [43]. According to Dr. Ghani (nicknamed Dr. Cool), after placing the models in the wind tunnel, smoke that represented wind was pushed out at different pressures then they used cameras and laser sheets to analyze the flow of air as it enters and exits the stadium [44]. These measurements were then processed using Computational Fluid Dynamics (CFD) software to evaluate the temperature readings at each part of the stadium [43]. Other variables were considered and numerical simulations were done to see their effect on temperature including the amount of sweat produced, the number of spectators available in the stadium, and the size of the opening at the top of the stadium [43]. The technology made use of water tanks placed outside the stadiums with cold water of about 5-7 °C cooled by solar panels placed in the desert outside the city of Doha [45]. Sensors were installed in the stadiums to automatically detect changes in temperatures and regulate them. This was done by jet nozzles that pumped cool air onto the pitch and under the seats of fans [46]. The rising warm air was sucked into the water tanks to cool it and clean it before pumping it back into the stadiums again, keeping the atmosphere cool and fresh [42]. Figure 6 below shows

nozzles for cooling air alongside the pitch inside Al Bayt Stadium [43] while Figure 7 shows Dr. Ghani examining nozzles for cooling fan seats at Al Janoub Stadium [41].



Figure 6. Nozzles alongside the pitch: Photo by [43]



Figure 7. Dr. Ghani examines nozzles for cooling fan seats at Al Janoub Stadium: Photo by [41]

4. Mobile Stadiums

Mobile (demountable) stadiums have never been a reality in the history of the world cup until recently in the just-ended 2022 FIFA World Cup held in Qatar. The Qatari's Ras Abu Aboud Stadium commonly known as 974 Stadium was the first demountable stadium ever developed [47]. Designed by Spanish firm Fenwick Iribarren Architects, the arena could accommodate 40,000 spectators [48]. It was constructed using old shipping containers from Doha port and is situated at the portside near Doha's coastal area, an ideal location where fans enjoyed the cool breeze from Arabian Gulf [49]. The stadium was made to be a perfect match between the total number of shipping containers used to make the stadium and the international dial code for Qatar which is 974 [50]. The stadium had the necessary features that were in the other 7 stadiums yet it was cheaper to construct than all others since most of its parts were made from recyclable materials. The arena hosted 7 matches during the FIFA World Cup competitions which included six group-level matches and one round of 16 knockout match [51]. After being dismantled, the seats, containers, and most parts of the stadium would be transported to Uruguay to help their bid of hosting the 2030 FIFA World Cup [48]. Thereafter, the land previously occupied by the stadium will be used for making a waterfront overlooking the iconic West Bay district of

Doha [47]. Below is Figure 8 showing the aerial view of stadium 974, the world's first mobile stadium put up in Qatar ahead of the 2022 FIFA World Cup competitions [48].



Figure 8. Stadium 974, the arena near Doha's coastal area [48]

5. Conclusions

Technology has revitalized almost everything and, in every area, or field. From the findings of this paper, it is evident that soccer stadiums are increasingly becoming a fertile field to showcase some of the highly sophisticated innovations in the field of IT. With the introduction of new inventions in soccer management and enhanced user experience as witnessed in the FIFA World Cup in Qatar, a lot is expected going into the future. Block Chain technology could be what we are waiting for in the future of soccer stadiums because data about fans and players is paramount. This is because FIFA officials and event organizers may need to know the medical records of millions of fans attending the competitions, and which foods they prefer so that they avail them. Secondly, data mining techniques can play a good role for FIFA through analysis of previous data gathered during several years of experience to produce valuable knowledge for FIFA officials' decision-making process. Finally, we wait to experience more advanced technological rollout by FIFA in the oncoming FIFA World Cup 2026 to be held in the US, Canada, and Mexico.

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