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Impact of Internet of Everything Technologies in Sports - Football

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Thesis presented as partial requirement for obtaining the Master's degree in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
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IMPACT OF INTERNET OF EVERYTHING TECHNOLOGIES IN SPORTS - FOOTBALL

by

Marcelo Renato Cavaleiro Pires

Thesis presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Knowledge Management and Business Intelligence

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DEDICATION

Gostaria de escrever este capítulo na minha língua materna devido a quem me tenho de dirigir. Este trabalho não era possíver ser realizado sem a ajuda dos meus pais, a quem devo tudo. Tendo esta tese sido feita em paralelo com a minha carreira profissional, agradeço toda a compreensão e ajuda prestada por eles nesta fase mais ocupada da minha vida. Tentei ter sido sempre correto para com eles, quando não tive muito tempo para fazer companhia ou ajudar no que fosse preciso. O que mais valorizo é o facto de nunca pedirem nada em troca, mas eu sei que lhes devo a conquista de ter um bom trabalho, que lhes possa fazer orgulhosos de mim e do tempo dispendido, sobretudo que tenha valido a pena todo os esforço e as horas dispendidas, desde a realização da licenciatura até ao degrau final, que é a realização da dissertação.
Mãe e Pai, Muito Obrigado por Tudo,

Marcelo Pires

ABSTRACT

Internet of Things has been one of the hottest technology concepts of recent years. It started with the wearable devices and any digital device connected online and evolved to a web connected network linking everything from devices, sensors, machines, people, processes, companies, and so on, creating the Internet of Everything concept. There are many application areas, but one stands out due to its popularization and importance to industry, Sports and specifically Football. Football has been reinventing itself with the implementation of technology, recreating the formula used in the United States Major Sports, where technology helps to enhance the spectacle experience, expand game analysis by coaches, players, and media, provide live refereeing, and improve health recoveries and detection of injuries. This research is a state-of-situation regarding technology in football, recognizing the presently used technologies and what could be implemented, and ultimately measuring the impact of these devices in Football.

KEYWORDS

Internet of Things; Internet of Everything; Sports; Football; Devices

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1. INTRODUCTION

1.1. BACKGROUND

At a time in which there are devices and apps for almost everything in a society's daily activities, it becomes pivotal to assess the impact in user's lives, as well as its growing development in a forecasted future even more advanced and connected than the present. Herein, we will approach the use of these monitoring devices in sports, more specifically, in football.

First, it is mandatory to explain what Internet of Everything really is and to distinguish it from a similar and better-known concept that is Internet of Things. These "things" are real and physical objects that can be used, such as a smartphone, smartwatch or a computer, but must have the ability to become online and connected to the world (Morgan, 2014). But as we know, there is much more beyond these devices, being only a portion of the Internet. For instance, we can consider Google, which has no physical space, instead, it is an intelligent network that enables all smart devices to be connected in only one place, but also, people, users, data, processes, machines, transportation, environment, etc. Ultimately, the "Everything" is a set of these interconnected elements, converging and designing a system able to create Internet of Everything. An example of this is to see "Internet of Things as a rail road line, including the tracks and the connections, whereas the Internet of Everything is all of that, and the trains, ticket machines, staff, customers, weather conditions, etc." (Simmons, 2015).

Sports Technology is in constant expansion and development, as we witness greater involvement of science and technology in sports, more than we have ever seen till now. Nowadays, the best sporting results often lie in the details that can be noticed and forearmed with the use of any kind of technology or device that can make the difference. In the Big Data era, sports are also included in it, because, increasingly, there are large amounts of data collected that can be applied for analysis, thereby creating competitive advantages to be used either in real-time during a competition or during practice, preparation, or recruitment.

Internet of Everything can already be seen in some fields of sports. For instance, technology is being used in live refereeing of an event through sensors and high-definition cameras spread across the sports field (e.g. tennis, American football), monitoring each athlete's movement through inertial sensors (e.g. football, ballet, golf, racewalking and swimming), simulating real competition using Virtual Reality Goggles/Helmets (e.g. boxing) and sensors in the balls for data analysis (e.g. basketball and tennis). Currently, the United States is in the forefront of the inclusion of technology in sports, enhancing the experience of millions of viewers and helping every single intervenient with detailed images and statistics, all thanks to partnerships with software companies (e.g. Microsoft and SAP) or sports television networks that help the television and internet broadcast.

1.2. MOTIVATION/JUSTIFICATION

Internet of Things technologies have the power to make an impact on any aspect of our daily lives. We can no longer live without certain mobile apps, devices, or even concepts, as they are changing our behavior with the world around us. In sports, it is changing the interactions between spectator and spectacle, in which they are soon faced with attractive technology around the stadiums, thematic mobile apps, social media, fantasy sports, and much more, making everything part of the spectacle or competition.

Nowadays on our planet we have more devices than humans and they are multiplying five times faster than we are (Boren, 2014). It is expected that by the year of 2020, Internet of Things industry will reach the trillion-dollar margin and have approximately 26 billion connected devices (Macy, 2015). Sports will have its share, mainly football, by already being a billion-dollar industry through player transfers, advertising contracts, television audience, merchandising, infrastructures for events, and in by the increase of technology implementation that is being invested by international clubs.

Undoubtedly, football is a worldwide phenomenon and the most famous sport, as we can see by the higher number of members of FIFA (Fédération Internationale de Football Association) compared to the United Nations (Stein et al., 2016). Football success is all about winning games and titles and a club history is fed by the number of championships won. Therefore, scouts and coaches are always looking for new rising prospects outside or within their club or trying to develop young players inside their own football academies by watching hours and hours of tapes to compare and scrutinize new talent around the world. Monitoring players' performance has become a routine to video analysts being very close to the coaching staff, sometimes with its own department in which they can identify weaknesses and strengths of their teams and of their opponents and then help to adjust specific training situations or in game real time decisions. In terms of health and physical aspects, players can also be monitored through data collected in players' bodies to improve medical treatment in case of an injury or to even predict it or to improve any physical weakness such as endurance, speed, reaction capacity, strength, etc.

Technology in football cannot be discussed without mentioning refereeing. Referees are a vital piece of sports and their decision making, whether correct or incorrect, affects the game. With the rise of Information and Communication Technologies a lot has been said about the use of devices that can help referees do their job, helping to better officiate and bring more fairness to live events. Slowly, new equipment and methods are being introduced, audio communications between referees and goal line images, but even if there is more that can be done, ethical questions and impact discussions prevent this from being a reality.

It is undeniable that Internet of Things is present in Sports and in Football, but as we are in the beginning of its implementation, it becomes essential to consider if the future requires further use of these devices and to evaluate the impact that technology can have either as advantages or disadvantages regarding fairness of the game, manipulation of the human body and excessive mechanization of sports, in which from its foundation, the main focus was the athletes and their capabilities.

1.3. OBJECTIVES

The primary objective of this thesis is to measure the impact of Internet of Everything technologies in sports, specifically Football. This will be achieved by, first, getting to know technologies already being used by companies and/or clubs, how they are applied, by whom, and what conclusions can be drawn. Furthermore, we will investigate new devices, methods, and technologies and whether they are feasible and have potential to be implemented in football; we will assess the limitations and reasons why existing technologies have not yet been employed and, lastly, we will consider the pros and cons of technology's prominent role in the football world.

To reach these objectives it is necessary to define the Sports concept and what is the role of Football inside sports and evaluate its problems and challenges regarding fairness, health, performance and so on. Additionally, we enter the Internet of Things/Internet of Everything field and we must describe the concept and how it has evolved through the years and its future. We must analyze associated technologies and in which application areas they exist and are being used and, consequently, we must describe the usage of Internet of Things/Internet of Everything technologies, at this stage, in Sports and Football.

1.4. DOCUMENT ORGANIZATION

This thesis is divided into seven chapters and each one represents and talks about a specific stage of the elaboration of this work. The current and first chapter, starts with a background of the topic as an introduction of what will be discussed, then presents and clarifies the work that will be done throughout this document, the motivations and justifications to the selection of this topic in the master's course, and the relevancy in the present world, and, lastly, designs the objectives that will lead to the development of this subject.

Chapter two defines the two main field areas presented in this document, Internet of Things/Internet of Everything and Sports, specifically Football. First, we will address the concept of

Sports, focusing on Football and its problems/challenges, then, an explanation of Internet of Things/Internet of Everything concept, existing technology, and where it fits in today's modern world. At this point, both Technology and Sports/Football will be merged, and that topic will focus on Technology in Sports, addressing the state of technology in football and its implementation, ideas and examples.

The methodological procedures will be discussed in the third chapter, describing the methodology used and how it was implemented in this work. In the fourth chapter is the start of the creation of the key development of the thesis following the chosen methodology in a recommendations proposal in which a matrix of artifacts belonging to associated technologies will be met to football's problems and challenges that were investigated in previous chapters. Next, it will be time to evaluate the work and the recommendations arising from the matrix conclusions.

2. LITERATURE REVIEW

2.1. SPORTS

2.1.1. Overall Concept

Sports can be defined as a physical activity in a competitive way or only by leisure between people, teams, or organizations where the objective is to improve the physical and skills ability to exceed oneself or an opposition while enjoying oneself or entertaining an audience (*Oxford Dictionaries Online*, 2017). It can be practiced individually or in a group of people as a team, as a professional (being one's daily job) following the rules of events, games, or championships involving, possibly, coaches and referees, or as an amateur included in a person's lifestyle for health purposes, entertainment, or as a social purpose with friends and family. Nowadays, there are many sports invented in recent times, either individual or collective and, according to Almada (2008), sports can be divided into Collective Sports, Fighting Sports, Individual Sports, Sports of the Wide Spaces, Environment Adaptive Sports and Sports of Direct Confrontation.

Additionally, it is essential to mention the health benefits that physical activity brings to human lives, from preventing cardiovascular diseases and regulating heart and lung functions to psychological diseases such as depression, excessive stress, and improving motor skills and cognitive function (Reiner, Niermann, Jekauc, & Woll, 2013). As we know, physical activity is within school programs. This works as an incentive to children to practice any kind of sports in order to prevent sedentary lifestyle, obesity, or any other disease quoted above at such young age, since most children or juveniles would not be able to practice any other kind of physical activity outside school. There is also evidence that physical education programs can be a factor in improved academic performance (ONGs, 2002).

2.1.2. Football

Football is the world's number one sport. It is the sport with the most professional athletes or amateur players where, due to its simplicity of practice, can be played anyplace anywhere, needing only a ball and if we want, two improvised goals in a reasonably flat area. Children around the world seem to find any place to start a football activity by just enjoying running after the ball with some friends in a garden, street, or field. These are some reasons to say Football is the world's most famous sport, but also its large audiences at events and games in television broadcasts or in stadiums and by the importance that football holds as a business to countries, organizations and clubs. Football is the national sport in most countries, but there are some exceptions in Europe, where Finland and Slovenia favor ice hockey and Wales rugby. The United States has four major sports ahead of football, Venezuela

prefers baseball and in the Indian subcontinent and in the former British colonies in the Caribbean, cricket is the main sport (Duke & Crolley, 2014).

Founded in 1904, FIFA (Fédération Internationale de Football Association) is the organization that manages the football world and, as has already been said, has more country members than the United Nations. It is estimated that 250 million athletes play in over 200 countries (Giulianotti & Alegi, 2016) and it is expected that by this year's season (2016/2017), the football industry will exceed 25 billion dollars (Jones, Houlihan, & Bull, 2016). Football clubs are money-making machines and most are owned by wealthy businessmen that invest in these clubs as if they were companies, earning money through sponsorships, merchandising, broadcasting rights and player transfers. That is the case of most successful football teams in England, Manchester United being the world's most valuable club worth 3.69 billion dollars (Ozanian Mike, 2017).

Football's origins are not consensual as many civilizations claim to have some version of a ball-kicking game, for instance the Chinese (*Tsu Chu*), Japanese (*Kemari*), Greeks (*Episkyros*), and the Romans (*Harpastum*). But it was in England, in 1863, the first step of the modernization of football with the creation of a Football Association (Duke & Crolley, 2014). Since then, football competition has been made of national leagues with several divisions in each country due to the high number of teams in regional areas. To be the champion of a league, a team must face every other team in the division in each week and have the highest number of points by the end of the season. Each game is 90 minutes long (except young leagues) with 11 players on each team, with a goalkeeper, defenders, midfielders and forwards. There are also international tournaments between football clubs, the most famous is Europe's Champions League joined by each country's champion and a few other clubs. Players also represent their countries internationally in the World Cup and in continental tournaments, for instance, the European Championship.

Football does not please everyone and it is understandable, as not everyone must like the same things. That is why other sports exist, so anyone can choose what they are most talented for and to exhibit their skills and talent where they like. Instead, football faces other problems and challenges.

i. Fairness

This is one of the major problems throughout the Sports world, and the main topics are Refereeing, including goal problems, illegal betting, and the difference of opportunities between organizations. Money involved in football cannot be measured precisely, and where high stakes of money are involved there is always contestation around sports' results. Referees are in the center of the most recent discussions around fairness. Their job is one of the most scrutinized in football, mostly in a bad way. Decisions made in a football match are crucial to the match's outcome, specifically the football's ultimate objective, scoring a goal, where one team may claim they were not treated in the same way

as the other team, in the referee's criterion or discussing an illegal play that resulted in a goal. The job of a referee, in usual conditions, is to be always fair to any team and not to have special treatments, as they study and practice to always seek to improve their judging and physical condition just like a regular athlete (Luz, 2014). One says "usual conditions" because, as the years passed, there were several scandals involved in football. From now and then, news comes out regarding match-fixing or bribes involving referees and sports judges leading to a rigged match, and is a recurring practice in today's sports. This, ofcourse, leads to special investigations and trials, as is the case of the famous Italian club, Juventus, relegated from Series A (first national division) in 2006 and stripped of two national championships (Dowley, 2016) after the scandal known as *Calciopoli* was uncovered and made public involving, five top Italian teams in a match-fixing scheme and accused of rigging games by selecting favorable referees.

In the last few years another bad trend for football has emerged. Sports betting is one of the reasons that contribute to the high amount of money being transacted in the football industry. People bet on live events and make predictions of the football matches, like any casino and betting game, Consequently, this started to be used as a harmful practice as the punters influence and bribe some players of a team to have a bad game. Whenever high amounts of money are placed in a betting web site it raises suspicions and so, all bets are revoked (Singh, 2013).

As we talk about money, one cannot stop addressing the issue of fairness in terms of comparison between clubs' wealth. Fairness, and most specifically in football, presumes that everyone is at the same level and only the performance of both teams makes the difference and influences the final result of a game. But what if teams have different training conditions because of different levels of prosperity within the club? This disrupts the fairness concept and it is a present fact. As teams are successful, more money will be received. Money generates success and teams can now buy better players, coaches, and scouts and offer their players better training, health and conditions in their own infrastructures. Eventually, this will become a deciding factor when two teams clash, believing the team with higher budget and club's wealth, will have more probability to win a game against a team with lower budget. In the top European national leagues, we know, at the start, which teams are the candidates to win it at the end. By the history and dimension of each club and knowing the squad value in monetary terms we can predict who will win (Hutton, 2015).

There are some rules regulating financial status of football clubs, preventing they from overspending and getting into debt, and jeopardizing the financial balance of the club. This is called financial fair play, where clubs get punished if they do not present a break-even in accounting. This rule does not fulfill all problems in fairness terms stated above but it is a start ("Financial fair play: all you need to know - UEFA.com," 2015). A regulation that contributes to more fairness in sports can be witnessed in the United States Major Sports Leagues (NBA, NFL, NHL and MLB). Sports teams follow a

Contract Bargaining Agreement that states that each team has a fixed salary cap, meaning, every team has a ceiling on the amount of money they can spend on players' salary, which prevents wealthy teams from signing more top players than the rest of the league. This produces parity between teams and teams can control their costs and avoid overspending (entering in a financial crisis and putting at risk long term stability). By this, each team has roughly the same economic attractiveness to recruit new talented players, which contributes to a more competitive league in which there are no dominant teams who consistently are contenders and win championship. With more tight games, the product becomes more valuable as more people are attracted to stadiums to support their team and more people follow games at home, increasing viewership and television revenues to the league (Brooke, 2013).

ii. Health

Health issues and concerns are directly related to sports and the topics addressed are injuries, resting, and vital signs monitorization. Professional athletes perform day in and day out hoping to be successful. Every practice matters in a process to develop old and new skills either physical or mental. Athletes live to compete, but setbacks might happen caused by physical harm or just misfortune during a competition or practice. Any player wishes that this does not happen. Some players are more injury prone than others and some sports have higher probability of someone getting injured due to violent contact between players, for instance, rugby or American football, or poor physical preparation of a player by coaching staff, or just by past injuries, for instance, when a player severely sprains his/her ankle, there is high probability to happen again (Gribble et al., 2014). This is one of the apprehensions sports faces, as a team or player may not be in their best condition and this could negatively impact a match where the fans want to see both teams and players totally healthy and at full strength. Injuries will always happen, the human body is still not as strong as we would like. Nevertheless, people involved in sports must overcome these issues and work hard to prevent them and to develop new treatments to minimize these negative effects.

Competition in the last decades has become more demanding with the increase of games and events. Players are too exposed to injuries and resting plays an important factor between games, but also in games, as we have been witnessing, star players sit out minor importance matches to be saved for bigger crucial games. In football, we have the example of teams like Real Madrid and Barcelona. These teams are involved in three trophies, Spanish La Liga, Copa Del Rey and Champions League and they play to win them all. However, it is not very likely that every top player performs in every game of the season. Coaching staff must prioritize games and develop a balanced squad, so they can rest star players and let other athletes do the job. This is more often in the last third of the season, when everything is on the line and a simple slip can jeopardize the final goal of conquering the trophy.

Therefore a minutes and games-played management is highly advisable (Davies, 2016). Another example where we can see this is in the NBA, the American Basketball League, where in the regular season each team plays eighty-two games over six months with back to back games in two nights or even three games in four nights. Resting is a major practice especially in older and star players when a playoff spot (where the true championship contention starts) is already secured or when a team thinks they can win a game without their best players. The importance of this for players and coaching staff is understandable, one wants to save the best for when it matters but for the fans it is regretable since tickets are expensive and fans just want to see their favorites perform (Moore, 2017). Another perspective of resting embracing every human, but especially important in an athlete's well-being is sleeping time and cycles. It is known that each individual has different sleeping habits due to different body functionality, but one cannot overlook the importance of quality rest and sleep as many studies indicate the increase of the risk of illness and the weakening of the immune system the fewer hours one sleeps per night. The players' high body stress demands high quality of sleep because it not only affects the physical aspect of the athlete but also the mental, as the brain is the organ that sends movement messages to different parts of the body and also needs a break (Fenn, 2015).

The last health concern is vital signs. These are the body measures by which one can monitor and obtain a health diagnosis; the more often it is extracted from the athletes' bodies the more we are informed of the athletes' condition for faster analysis. Many unfortunate past cases of on-field deaths or incidents make this an even more important topic, since sports organizations, athletes and their families, coaches, and fans always keep in mind that health comes first. Past procedures, medical methods and technology only allow to check vital signs and overall body status every once in a while, but now we are able, through the decrease in price of these procedures, to execute medical inspections almost whenever one desires, benefiting everyone involved in sports and the football world (Euronews, 2014).

iii. Performance

The football performance challenges mentioned were about practices adaptation, post-game analysis, youth development and live coach decisions. Performance is the key point of any sports, and it is the athlete's or team's performance that will be confronted against any other opposition. Many variables can affect an athlete's performance, such as overall environment (weather and stadium's atmosphere), psychological status of the player/team, recent injuries, or even health conditions and personal issues. An overall status formulates the player's performance, and this is what will be tested

in competition, this is what motivates fans to tune in to games of any kind, this is what motivates coaches to contribute to the player's job and growth, and this is what motivates players to work hard and develop as much as possible.

Better life conditions for the modern world and specifically for the athletes, more money involved in the sports world, and more publicity around fans and media, are many of the reasons justifying the exponential growth of sports. Nowadays, professional athletes have everything at their service and the best conditions ever to succeed, which is why oftenthe best results and performances depend on the simple details. We are in a time of Usain Bolt, Michael Phelps, Cristiano Ronaldo, Leonel Messi, Rafael Nadal, and Lebron James, all world class athletes and all-time greats who constantly broke or are breaking world, Olympic, and all-time records in their corresponding sport. This is not just talent, their hard-working ethics since day one, enjoying the best training methods, and the existing sports technology are one of the major reasons. Practice adaption is one of the techniques that top athlete's implement. In football, this is one challenge every successful team must consider; after every game or event, a critical analysis of the team's and individual performance must be run through a post-game analysis done by the coaching staff as well as the sports analysis department (if there is any). Then one can show the final conclusions to the players with the explanation of what went wrong or according to the team's strategy. This is already largely done throughout the football world, as teams have implemented these techniques even more sophisticated with advanced software, analysis, and data extraction. After these analyses, one must design practices according to what was concluded. Of course there already is a practice plan, but certain things and drills can be added in order to work on observed weaknesses or develop the strengths of the team or individual technique. With this they can have constant performance and health condition monitorization to put into practice revolutionary and specific practice methods to further development if possible (e.g. the prevention of injuries or even watching recording already analyzed by the coaching staff the last game).

Furthermore, if a football player desires to reach a world class level, the motivation of development must be created at a young age. All these techniques that professional teams implement in their staff can also be applied in youthful players. Every team that wants to develop youths with the club's culture and playstyle, so they can be promoted to professional status and feed the main team with players, must support the same techniques used in adult players. Recording of the games, post-game analysis, practice adaptation and discussion of the conclusion, should always be executed, especially in young teams, where they are eager and have so much to learn and they have the potential for exponential growth of the learning of the football game. Technology is only a tool to reach new heights, for instance the recording of personal analytics of the player, like statistics regarding physical condition and health, football technique and mental aspect of sports. All of this can be used to create a historic report of every player and monitor development.

Coaches can also take advantage of the data extracted from the players' performance. In live games, coaches are always trying to communicate their feedback to players either in positioning, strategy, pace of the game, or overall decision-making. With the help of their assistant coaches, the decisions of substitutions or changes in the formation are made, discussing the points of view and advice of each one. One only wishes that the thoughts and changes made will result in successful outcome as these are based on knowledge and experience through the years of coaching or perhaps playing. Nowadays, coaching decisions may use the help of technology to support and justify them. Coaches have access to live analytics of the players' physical condition and overall performance made accessible by the analytics department that are also working in real-time in the stands. Imagine coaches with tablets with full reports made in real-time, so they can give feedback and insights to the players on the field or the ones that are going in, they could also make team adjustments by these analysis and make a good impact on the game (Korte, 2014).

iv. Fans' Experience

Lastly, the challenge regarding the audience aspect of football that will be discussed are home spectatorship and live attendance. Sports, specifically football, is a worldwide phenomenon when one talks about fan appeal due to the rise of globalization, which allows national football watches to be broadcast all over the world even when time zones are a minor barrier. Fans from any part of the world tune in just to see their favorite team play even if they are far away, as national television broadcasters often acquire the most famous games and teams' television rights. However, television channels face new challenges to keep attracting audiences, since in the present social media era, the new generation of consumers are changing their habits ("How Consumer TV Habits Are Changing," 2016). Television is losing its strength and power and the Internet as a service is becoming more and more the most important video provider to the sports consumers (Manterola, 2017). Estimates are that Internet users in the United Kingdom and in the United States are watching, on average, 17 hours of online video per month (Rowe & Hutchins, 2012). Internet has the advantage of having the possibility to allow to choose whatever the user wants to see, since there is no scheduled programming and one can select what one wants to watch (with streaming services such as Netflix or Amazon Prime). Fans are now watching live games on the Internet instead of the television, in large part because it is not worth having a subscription of a sports channel, as every game is accessible online freely at every time and place (though most of the times through illegal streams). Television faces the challenge of losing even more audience if it does not reinvent itself. Broadcasters should not be stuck in the past and try to provide the same product as in the last few decades, it must innovate in order to captivate the fans to tune in to sports events through the television. The same applies to live attendance, where the ticket price might not be affordable for everyone and in some cases not worth the money. Football event

organizers must also innovate and modernize the spectacle. There are always new ways of contributing to the show, either with new technology to support and help the fan in the live attendance or new ideas to attract the attention of them. Smartphones and Internet might be major problems that our modern society faces (Brody, 2017), because, generally, a clue that someone is bored or not having a good time is when she or he is checking the telephone, or when fans are obsessed with recording the live event instead of actually enjoying it, as often it is made public that some artist stopped a concert for having too many people staring at their phones (Sax, 2016). We see this in any kind of live show and the effort of events organizers to keep an audience into the show is getting harder.

2.2. INTERNET OF THINGS/INTERNET OF EVERYTHING

2.2.1. Concept

Internet of Things and Internet of Everything are linked concepts. Internet of Everything is the evolution of Internet of Things. Internet of Things might also be known as Internet of Objects because the things we talk about are indeed physical objects connected with each other and to the internet forming a networked interconnection framework. These devices will be an extension of the internet, establishing a ubiquitous intelligence between human beings and technology and being connected anytime, anyplace, with anything and anyone. The best known devices used by common users are smartphones and wearables like smartwatches or wrist bands (Xia, Yang, Wang, & Vinel, 2012). Internet of Things seeks to implement microcontrollers in our daily life objects in order to make them communicate with the surrounding objects as well as, generate, collect and analyze data to provide useful information and insights to the users, citizens, companies and public administrations (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014). We are slowly creating a smart world by converging the real, the digital, and the virtual to create smart environments that make energy, transport, cities, sports, and many other areas more intelligent complementing with approaches like cyber-physical systems, cloud technologies, big data, and future networks like 5G. Nevertheless, there are some challenges these kinds of technologies generate, the world must regulate and be aware of privacy issues, as well as trust, identification, and security (Vermesan & Friess, 2014).

Internet of Everything is the next step. In addiction to connecting things, it also, connects people, places, companies, data, machines, and processes, producing billions or even trillions of connections in a massive network. Imagine a world connected at this level and where all data are analyzed and used intelligently, increasing processing power and efficiency, gaining context awareness and greater sensing abilities. Consequently, there will be created unprecedented opportunities giving things that were silent a voice (Clarke, 2013) (Evans, 2012).

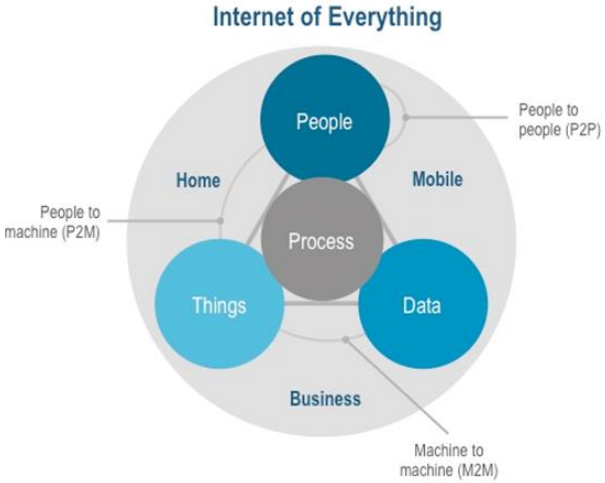

Figure 1 - Internet of Everything scheme (Evans, 2012)

2.2.2. Application Areas

Having defined Internet of Things/Everything, it is mandatory to enumerate where these technologies can be put into practice and be developed to create a dynamic and smart sector. The first big potential area is Smart Cities, a designed and connected city with technology integration and quicker data analysis that will result in a much more resourceful, well-organized, and coordinated place to live and work with great impact in security and safety, traffic, urban organization, and quality of life. Smart Cities also aggregate Smart Houses, where all household appliances can be integrated into one single ecosystem giving the chance to the users to follow everything that happens inside their own houses, from notifications about security, automation, telecommunication, to energy-saving help and computers and entertainment monitoring. Following this, one can talk about smart cars, which is a very recent invention, regarding the possibility to have self-driving systems and with the help of Smart Cities improve mobility issues and the overall environment by creating electric cars with zero emissions of carbon.

This would not be possible without Smart Industry or Industry 4.0, in which automation of processes and data exchange allows, then again, to improve the proficiency of the systems, improve machine performance by using and analyzing enormous amount of data, use more sustainable sources of energy such as renewable ones (Smart Grids), and implement other smart building systems. In this sector, much can take advantage of this evolution such as Distribution, Transportation, Logistics and Retail, Agriculture, Livestock, and Tourism.

We cannot forget about Health, to which Internet of Things has been contributing and helping develop new discovered techniques and technologies for the greater good of humanity.

With the evolution and development of Internet of Things into Internet of Everything, concepts such as Cloud Computing, Future Internet, Big Data, Robotics, and Semantics will be even more investigated and impact many more sectors and we hope that this is only the beginning (Vermesan & Friess, 2013).

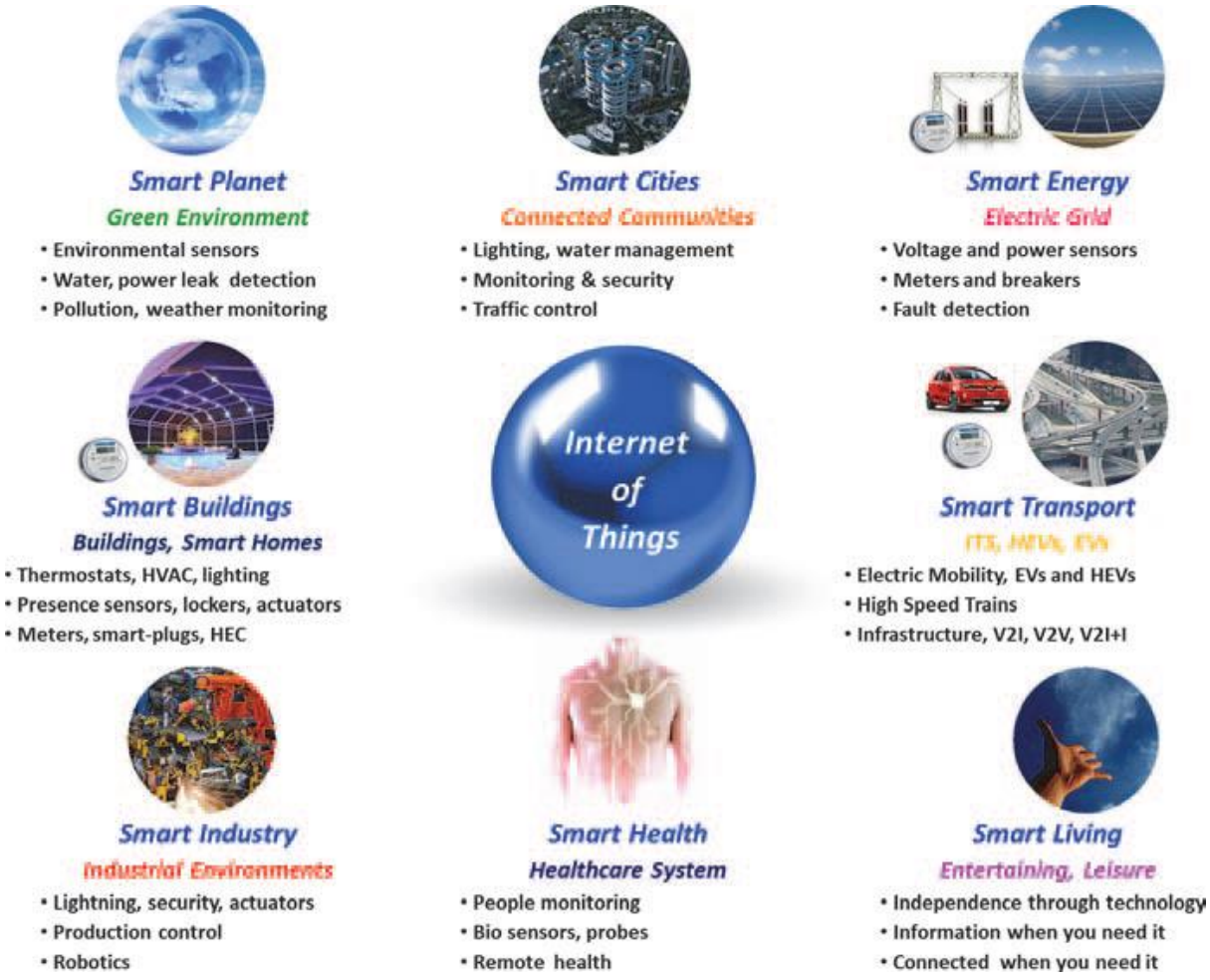

Figure 2 - Internet of Things Applications (Vermesan & Friess, 2013)

2.2.3. Associated Technologies

Internet is no longer a network of computers, we now have internet access and connectivity in multiple devices and platforms due to adaptations in our everyday objects, opening a tremendous range of opportunities that promise to revolutionize and improve the quality of life of the population (Xia et al., 2012). The network of devices that is talked about can be of different types and sizes, can be vehicles, smartphones, home appliances, toys, cameras, medical instruments, industrial systems, and so on (Vermesan & Friess, 2013). As explained in the previous section, Smart Cities has plenty of

development space available, from Smart Houses to Smart Cars. It is now time to elaborate the specific technologies associated with these areas. One can have monitoring sensors in almost any object used in a day. At home we can have smart household appliances where we can check through a centered interface any malfunction of any machine; we can, for instance, monitor the temperature of a refrigerator and check what it has inside through sensors or even cameras; we can program remotely the washing machine and dishwasher to start working and check its status; we can also monitor the overall status of a house, in terms of temperature, lights, energy, and water consumption, even music throughout the house.

All of this is in a small environment, but we can project this to a bigger scene, to a whole city, where waste and sewers management can be improved through sensors displaying the amounts and frequency of the last records and make predictions and, for instance, optimize garbage truck routes according to the levels of each garbage bin; traffic congestion can be reduced through better directions for essential locations with cameras analyzing every access and communicating with the cars and redirecting them to the best options; resources optimization such as electricity by smart lights that only work when there is movement or water management in irrigation issues; Smart Buildings with a centralized monitorization of security, energy with the use of presence sensors, thermostats and a Smart Grid which is also used in Smart Cities; Smart Transports as public transportation with high speed trails and all moved with renewable energy; and Smart Industry with robotics automating manufacturing processes having all kinds of devices to optimize industrial procedures and monitor the status of the machines and production control. Another issue that must be discussed is Smart Health as in the years to come we can have remote health that can be used for disease prevention, avoiding losing time in a medical appointment being more efficient in serious cases; we can have Artificial Intelligence making more accurate diagnosis in less time and also use bio sensors and probes to reduce waiting time for medical exams results.

We almost already live in a Smart Living world. When we use the word “Smart” we are referring to the improvement of that area, turning it into a more technologic and connected sector and when we talk about Smart Living it is all things connected in our daily basis, including ourselves through social media, email, etc. Smart Living is having all information when and where we need it and using technology to improve our tasks throughout the day, be it our health, leisure, work, education, or relationships with people. Smart Living is also incorporated in Smart Environment since one cannot have a good quality of life without a stable environment. Climate Changes are a reality and one can only hope that these advances in technology can contribute to reverse and help the world environment in terms of pollution, weather monitoring and resources management optimization, by means of the conclusions of today’s studies being applied in the decades to come.

2.3. TECHNOLOGY IN SPORTS – FOOTBALL

Innovation and Invention are in every aspect of our society. Human kind is always trying to reinvent itself, competing to be better with the ambition of its hard work paying off in the end. Sports is no stranger in this; competition is the main core of sports as teams and players desire glory and recognition for their results. That is why they become professionals, so they can practice and put the work on their game in order to reinvent and innovate themselves having healthy rivalries with sports colleagues. This is where technology comes into play. This innovation and invention of players' and teams' performance and results would not be possible without the use of technology in practices, competitions, players' daily life, and games. Players seek the evolution of their physical and psychological skills and technology is a big contribution. As technology also evolves, sports benefits from new inventions, techniques, and knowledges extracted from new studies and investigations and then implements it as fast as possible to gain advantage against the competition (competitive advantages).

If we take account at an individual level, evolution of technology is changing the way we practice and interact with sports. With the high use of technology, mainly smartphones and tablets, in our everyday life, sports are also included, and innovative uses of technology are helping amateurs in their practice and helping professional athletes and coaches to spread expert knowledge about best practice skills. We can also address the entertainment side of sports, in which further media and information technologies are changing the way fans interact with sports, being more inclusive and closer to the show either by social media or in interactive stadiums with access to every single detail (Ringuet-Riot & James, 2013).

P. P. Ray (2015) proposes a framework for Internet of Things for Sports and Recreational Activities which looks to answer and solve problems associated to technology in sports and recreations through real world applications of Internet of Things. It is a platform organized to explain the stages of an athlete's performance data collection, so the players and recreationists can have at their disposal real-time data on pace, power, drive, and more and use it to step up their game or activities with the use of objective and relevant data analytics. This framework uses the ITPD ring composed of Interaction, Things, Processes, and Data. As Interaction is the use of devices by the athlete, for instance, wearing an accelerometer to measure the speed of their movement; Things are the actual sensors, actuators, meters, and measuring devices attached to the athlete or to any object that is connected to the Internet anytime anywhere and collecting information and data about what is happening, and saving it in an internal storage, cloud, or social media application; Processes are the business and technological procedures involved, and need to be changed in a meaningful way to automate rapid growth in connections. Accumulation, Communication, and Analysis are the main jobs to be processed.

Data is the information collected from the devices and sensors attached or not to the athlete's body to be later processed and analyzed either in real-time or stored for later processing. Nowadays, one is allowed to stream this data online to any servers through the Internet.

The architectural aspect of this framework is divided in seven slabs of layers from the data collection to the final data analysis and implementation. Its starts with the Physical Sensing Layer where the sensors are located on the athlete or in any object about the sport; Communication Protocol Layer where the connection of the signals to computers or any tool is made; Data Processing Layer works as an intermediary of data processing to the higher strata; Internet Layer is the connection online made to the cloud or any server to store and process data; Storage and Preview Layer uses Application Programing Interface (API) to serve as bridge between the Internet Layer and smartphone devices, where it can store for further usage; Visualization and Service Layer is the visualization of the data, such asinjury risk reports, contextual awareness and compact analysis of sports equipment and athletes; User Application Layer which is where the final user gets in touch with the data analysis, including coaches, doctors and athletes. This whole framework attempts to standardize the processes of technology in sports in the center of Big Data usage (Ray, 2015).

One of the first technologies used by coaches, teams and athletes is the recording of practices, matches, games, and competitions for further analysis. These events would be taped and afterwards people involved would go, manually, through the whole video to watch for details that were not observed at the time. These were the first analyses made taking conclusions about a performance and (Polk, Yang, Hu, & Zhao, 2014) an outcome. Video recording is a technique still used in sports but with the evolution of technology it is no longer as it was before.

Currently, analytics complements video recording, and this is discussed by where it is presented TenniVis, a novel tennis match visualization system that uses statistics collected from a tennis match, such as score, point outcomes, points lengths, service information, and a single recording camera. TenniVis is focused on non-professional players since it is easier to collect the data than a multi-camera recording and expensive software used by professional coaches and players. The software provides, after the collection of the data, an easy access to

Figure 3 – Image Acquisition in tennis court. (Reno et al., 2017)

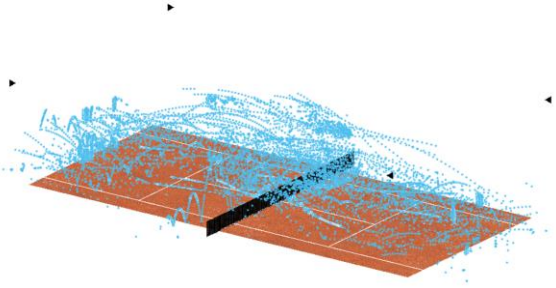

Figure 4 – 3D Simulation of balls' trajectories. Black triangles represent the position of the four cameras. (Reno et al., 2017)

visualizations to coaches and players without the need of technical experts so then they can extract insights about match and play patterns to facilitate them in ad hoc hypothesis generation and evaluation. Also in tennis, Reno et al. (2017) proposes a method to detect and track a tennis ball's trajectories in game in a 3D space, and coaches and players can afterwards examine these routes and add a more conclusive analysis to the video recording in terms of direction of the ball and where it landed, for instance. With the evolution of processors, Internet speed, and technology it is very common to see video recording being used live. Sports in the United States are the leaders of this implementation. Basketball, American football, baseball and ice hockey, all use video recording for live refereeing, live coaching, and post-game analysis by journalists or coaches in practice. Referees are allowed to review some calls during the game and coaches often use footage to show the players what can be improved in tablets right on the bench.

Video recording has been closely associated with inertial sensors like accelerometers and gyroscopes as both complement video analysis about the performance of the athlete. These sensors allow, both at recreation activities and professional activities, to collect data about the location, movements, and speed/velocity of the athlete or any other object, like balls. One can collect data about a stroke in tennis, such as its strength, speed, and arm rotation and ball trajectory allowing to preview the technique and details that can be improved in practices or post-game analysis (Reno et al., 2017). Golf, baseball, and cricket's use of inertial sensors is very similar to tennis. Coaches and athletes can examine each stroke and analyze what is wrong having the outcome to compare, and in Kooyman, James, & Rowlands (2013) a graphical user interface (GUI) is proposed to help players improve motor skills of a golf putt by video analysis, and a gyroscope data extraction and the conclusion of the study is that the players have indeed improved their techniques using the feedback from the interface; detection of illegal actions and arm rotation technique in bowling can also be studied using one inertial sensor, movement sensors (Espinosa, Lee, & James, 2015); conclude for improvements of the use of inertial sensors in race walking in the detection of any illegal technique in practices. In refereeing in an event, judges are asked to scrutinize each athlete's technique and decide whether they are racing according to the rules or there is any foul that can lead to a disqualification. Ballet is also a demanding sport in terms of specific movements, so that inertial sensors helps to monitor it and reveal certain flaws of technique. Thiel, Quandt, Carter, &

Figure 5 - Graphical User Interface for a golf putt video. (Kooyman, James, & Rowlands, 2013)

Moyle (2014) report that inertial sensors in wrists and sacrum (bone at the base of the spine) are good quantifiers of the performance during simple ballet activities.

The use of inertial sensors is a big part of sports analysis and can be used in almost every sport. These sensors can be used indexed into video. Rowlands, McCarthy, & James (2012) demonstrate that data collected from these devices can be synchronized to video records and used to detect certain events in the tapes which are relevant and important for the sporting event under investigation. With the model of a suitable event detection algorithm, this can be applied to any sport that requires analysis and allows the data scientists to skip large amounts of unnecessary video data and focus only on important landmarks for the current analysis.

One can also discuss the potential of inertial sensors use in regular activities of daily living, as done by (James et al. (2012) regarding health concerns in the monitorization of daily movements, such as walking, running, and standing, by successfully classifying and examining the activity intensity and its duration. Many biomedical sensors are already used either in sports or leisure, such as wrist bands and smartwatches, allowing the users to monitor parameters such as heart rate.

Enumerating a few examples of the use of inertial sensors, one can now discuss this use, particularly, in football. Video recording is a long-time use and with the appearance of inertial sensors, allows a complete analysis experience of performance. Football players are not yet allowed to use them in games, but with several cameras placed in the stadium, movements/trajectories and velocity can be tracked without the need of these sensors. Nevertheless, these devices can be used in practices, and coaches and data scientists can monitor and analyze a player's evolution in certain physical tactical aspects such as positioning, stress effort that can lead to injuries, and velocity monitorization and management. This is where analytics enters. Through video cameras and sensors, sports analysts create exact and detailed statistics about a game and can create reports and conclusions that can help the coaching staff make decisions in real game time or during practices, adapting new exercises or practices to certain aspects of the game. There are now people in the coaching staff working specifically in analytics, analyzing past games and practice results, making prediction models about injury risk and evolution of the players physical and performance skills (Stein et al., 2015). In the video analysis, classification approaches are used, creating a classifier trained by past data to distinguish certain situations in a match and then effectively split the game into phases and divide them in similar situations, like free-kicks and corner kicks.

Many studies have been written about Football Analytics, and one can say that in today's game, coaches would rather decide by justified facts and figures and less by intuition. This is where interface analytics show up, a software that can be easily used by coaches to display in a visualization and graphic manner what happened in the game in a more advanced way than the regular raw statistics. We have the example of Janetzko et al. (2014) and Perin, Vuillemot, & Fekete (2013) in which the authors

present a visualization example of single-player analisis of positioning, direction of the movement, speed, distance covered, and distance to the ball, events done by the player (shots, fouls, receptions) and multi-player analysis regarding the team's formation (width and height of the team shape). Analysis also detects potential dangerous game situations like corners, free-kicks (which are a huge relevant part of a football match) and ball positioning breakdown, ball-goal distance, and almost every event including passes, receptions, cards, fouls, goals, assists, and shots on goal. This was presented to a group of coaches and it was mentioned, for instance, the relevancy of this information during games for notifying players about specific aspects during half-time.

Another study focused on players' movement and interaction spaces between them. The field is divided into a grid and the action areas of each player and each zone are analyzed. This allows the picturing of free spaces or more crowded ones helping in a new feature of football matches completing other analyses (Stein et al., 2016).

Technology in football is not only analytics. More and more we constantly hear about new inventions able to impact the sport, like new boots that are lighter and with new designs, communication systems between referees, goal line technology, video-refereeing (both technologies starting to be implemented) and so on. Included are new ways of practice using technology, namely Benfica's 360S Lab. This is a 360-degree simulator made of four LED walls with four ball launchers capable of reproducing speeds up to 100km/h with a variety of arcs, effects, high, medium and low balls which allow a wide variation of numerous combinations in order to measure reaction time, player decisions to achieve maximum precision in passing and shooting. This is an analytics lab with full data from previous football games and previous practices and allows data processing to be made in real time and constantly adapt new exercises to each player. It is a system to develop new skills in young players but also to measure the level at which players are recreating real match situations (Pettit, 2017).

2.4. ARTIFACTS

Having described the main problems and challenges football faces and presented the Internet of Things/Everything concept and how it is fitting into sports and football, it is now time to explain what is the best way to answer those problems and challenges. This will be made through artifacts, which are no more than devices belonging to certain technologies and to the Internet of Things framework. There are four major technology groups. Image Acquisition, Wearables, Video Refereeing and Simulation Technology. Image Acquisition has three artifacts: Video Cameras, Monitorization Tablets and Statistics Analysis Software. Wearables is made up of four artifacts: Movement Sensors,

Performance Monitoring Sensors, Wrist Bands and Vital Sign Sensors. With five artifacts, Video Refereeing has Video Cameras, Goal-Line Technology, Hawk-Eye Technology, Exact Stopwatch and Communication Hardware. Simulation Technology as the name says, has 360° Simulators and Virtual Reality Goggles. Lastly, one has individually a Giant Screen artifact. Additionally, artifacts for the future will also be presented. Devices, techniques, or technologies that might be invented or implemented in football in the future, will be shown as ideas to revolutionize the game of football.

3. METHODOLOGY

With the main topics of this thesis presented and explained, one must delineate what may be done and how it can be done. The methodology used will help to accomplish these requirements in an organized way, helping with the correct research approach approved and used by the scientific community.

A methodology is a set of well-defined principles, practices, and procedures defined so the researcher can standardize his/her work according to a rules format in order to develop a quality design science research characterized by its rigor, consistency and valuable investigation (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007).

3.1. DESIGN SCIENCE RESEARCH (DSR)

The methodology implemented in this thesis is Design Science Research. The increase of interest in this matter started in the 1990's, when Information Systems researchers, concerning previous research work, discussed and agreed on the difference between Design Science Research and other research paradigms. Design Science Research accomplishes three objectives, it is consistent with prior literature, it provides a nominal process model for doing Design Science research and it provides a mental model for presenting and evaluating Design Science research in Information Systems. Therefore, the process consists of six steps: the problem identification and motivation, followed by the definition of the objectives for a solution, then the design and development, demonstrations, evaluation, and lastly communication (Hevner, March, Park, & Ram, 2004).

Having identified organizational problems, Design Science Research manages to create Information Technology artifacts involving a rigorous process to design it, make research contributions, evaluate the designs, and communicate the results to the proper audiences. The artifacts talked about are any designed object with an embedded solution, such as constructs, models, methods, instantiations, or social innovations. The focus of this kind of research is the importance of the artifact for the solution and its creation to best address the unsolved business problem by a search process of existing knowledge and theories. After the creation of the artifact, a meticulous assessment needs to be run to measure and evaluate its utility, quality and accuracy in the current problem definition. Lastly, after the final results drawn from the development of the artifact and its evaluation, the effective communication of the research conclusions to the addressees is crucial (Hevner et al., 2004).

3.2. RESEARCH DESIGN

Design Science Research methodology is implemented in the current thesis. As part of the execution of it, in the previous chapters the identification of the problem and the relevance for the course that this thesis is presented were described. Technology is the main pillar and area of emphasis and, in this case, it is applied in Sports. One must state the justification and a clear objective that the Design Science Research will operate.

With a substantial justification and clear identification of a business problem, one moves to creation of the artifact. In this case, there will be more than one artifact, associated with certain technologies, that is, an artifact will be a physical device used in football related to a technology that can be a term, framework, or overall invention. A technology can have more than one artifact, as there can be more devices in one technology.

In chapter 2, section 2.1.2, certain problems and challenges that football faces were discussed regarding fairness in football games, players' health, players' performance standards, fans' experience. These were the topics evoked and these will be linked to the artifacts and technologies by ways of a matrix. A matrix will be created connecting artifacts (associated with technologies) to problems/challenges, and because not every artifact can answer to a certain problem/challenge there will be blank connections. This is the artifact proposal, and it will be addressed in the next chapter.

After a proposal and artifact designing, an evaluation must be conducted. In the Design Science Research explanation, the importance of an assessment of "its utility, quality and accuracy in the current problem definition" is emphasized and that is the analysis that will be presented in chapter 5. Followed by that are the conclusions drawn from the proposal and the evaluation chapters.

4. RECOMMENDATIONS PROPOSAL

After presenting the topics that this thesis addresses and the methodology that will be implemented, we now show the proposals' matrix, first justifying its construction and design. This matrix is the merger of the list of artifacts presented before and the problems/challenges associated with football, resulting in crossing points where the artifact answers the problem/challenge in a specific way, explained below.

4.1. JUSTIFICATION FOR THE CONSTRUCTION OF THE MATRIX

The first point made by Hevner et al. (2004) tells us about the Problem Identification and Motivation of a Design Science Research project. It starts when the problem definition is considered and well thought and designed, as with a strong clarification of it, the subsequent development of the artifacts will be affected. This is the period to really understand the reasoning of the researcher's work, pursuit of answers and the knowledge of the state of the topic to a future demonstration about what the solutions can accomplish.

Since the start of modern societies, when humans had any problem, obstacle, or challenge, it was thought and attempted to (re)invent any method or procedure by means of creating a new tool, technique and later on, devices, to answer the respective problem. Constant problem facing, and consequent inventions led to today's modern technology, as many curious minds sought to facilitate or fulfill a wish they faced every day. This premise is brought to this work. In football there are a few problems/challenges coaches, players, fans, and staff take notice of and through the years there have been changes and slow implementation of new rules and new technology to answer to these problems/challenges.

Admittedly, and as has been said in previous chapters, technology has been a problem solver and a helper in everyone's tasks. Humans have become more and more dependent on technology since the beginning of its implementation and that is one of the objectives of technology, to make humans use it and replace the old methods that are often less effective and more time consuming.

Refering to Hevner et al.'s (2004) second activity, "Define the objectives for a solution", one must describe the kind of objectives this work will be using, because after the problem identification in the first activity, the objectives must be inferred from it and can be quantitative, in the sense of the measurability of the solutions, and compare them with each other or qualitative. In this work, qualitative objectives are the most fit ones, regarding the artifacts and problems/challenges that were designated.

4.2. CONSTRUCTION OF THE MATRIX

The matrix works as a method to answer the problems/challenges gathered in the respective chapter 2, section 2.1.2. These were aggregated in four categories by the similarities of the influence on football, Fairness, Health, Performance, and Fans Experience as they will probably share the same artifacts answering themselves. The problems/challenges arethe columns and the artifacts – answers to these – will be the rows of the matrix. There are also four categories of artifacts; Image Acquisition, Wearables, Video Refereeing, and Simulation Technology, combined by the same technology they belong to, as the devices as a group form a technology.

The creation of the artifacts is the third activity, named “Design and Development”. These artifacts can be defined as “constructs, models, methods, or instantiations” (Hevner et al., 2004) or “new properties of technical, social, and/or informational resources” (Pertti Järvinen, 2007).

The crossing cells between rows and columns, problems/challenges and artifacts make the justification of its use, meaning, this match only makes sense when the device is, indeed, a solution to the problem/challenge presented. This resulted in 43 matching points, that is, there are 43 combinations of answers to the problems/challenges football faces in the perspectiveof this study, from now on called recommendations. The recommendations were a study itself, since after the study and search of the problems/challenges and artifacts, a search about the crossing of these two (problems/challenges and artifacts) was conducted, resulting in the inclusion of each artifact that could make sense to answer the problems/challenges of football.

Accordingly, in the Fairness subject there is the refereeing/goal topic, which has a match with all the technology from video refereeing since these artifacts were directly invented and implemented in order to specifically answer the fairness side of football based on some other sports technology already used (Jon Garland, 2013).

The subjects of Health and Performance cover the Wearables and Image Acquisition technologies, meaning that these problems/challenges are mostly fulfilled with the artifacts belonging to these groups of technologies. Wearables, officially called electronic performance and tracking systems, are the devices the players use to gather and collect data for further analysis that can be used either for Health concerns or Performance purposes, with more precision in data collection than any other technology or analysis. They are like a smartphone that can detect not only the location of a player at a certain point in time but also which direction he is facing, the velocity at which he is going, the impact of events such as jumps and tackles, and how quickly he accelerates and decelerates. Thus, with the combination of this data extraction, coaches can perform more in-depth analysis regarding the Performance subject and step up conclusions and justifications for practice adaptation, post-game

analysis, youth development and live coaching decisions, all problems/challenges presented (Svetlik, 2017).

Last there is the fans' experience perspective, which faces new challenges regarding the improvement of it with new display technologies, specifically virtual reality. This technology is aggregated in the Simulation Technology along with the 360° simulators that are presented in every problem/challenge except Health. The revolution of virtual reality not only can be seen in video games and movies but also has already arrived in the football world, making this innovation the big factor for the Fans' Experience problem/challenge (Svetlik, 2017).

4.2.1. Recommendations Present Technologies

In this section, we will explain the artifacts best suited to solve each football/challenge. This is the fourth activity, Demonstration of the "use of the artifact to solve one or more instances of the problem". (Hevner et al., 2004) Table 1 shows the matching points of each artifact with the problems/challenges.

		Fair Game / Refereeing				Health / Injuries			Players' Performance				Fans' Experience	
Technologies	**Artifacts / Problems**	**Refereeing**	**Goal**	**Opportunities**	**Illegal Betting**	**Injuries**	**Resting**	**Vital Signs**	**Practices Adaptation**	**Post-Game Analysis**	**Youth Development**	**Live Coach Decisions**	**Home Watching**	**Live Attendance**
Image Acquisition	Cameras			X					X	X	X		X*	X*
	Monitorization Tablets			X		X	X	X	X	X	X	X		
	Statistics Analysis Software			X					X	X	X		X*	
Wearables	Players' Movement Sensors			X		X	X		X	X	X	X		
	Performance Monitoring Sensors			X					X	X	X	X		
	Wrist Bands on Players			X			X	X						
	Players' Vital Signs Sensors			X		X	X	X						
Video Refereeing	Cameras	X											X	
	Goal-Line Technology		X										X	
	Hawk-Eye Technology	X											X	
	Exact Stopwatch	X											X*	X*
	Communication Hardware	X												
Simmulation Technology	Virtual Reality Goggles			X					X		X		X	
	360º Simulator			X					X		X			
Other	Giant Screen			X										X

Table 1 - Artifact Matrix

Fair Game / Refereeing

Refereeing

Fair Game / Refereeing will be the first problem/challenge to analyze and the artifacts associated with Refereeing sub-problem are:

Video cameras, where the objective was to broadcast football events worldwide through direct transmissions to every country available. Replays have been a tool accessed by the audience, commentators, and reporters, but now we see the potential of cameras and the potential of replays to help a referee in his/her job. This technology is slowly being implemented in football leagues and tournaments and in the current year we saw the use of it in a FIFA world competition (Confederations Cup) and we will see the use of it in national leagues in Europe. The idea is to have a team of referees backstage with full access to replays and cameras in order to better judge questionable plays and then communicate to the on-pitch referee the correct decision. This is a solution talked for many years, as fans and everybody involved in football have always been discussing bad fouls judging and questioning referees' work, and praising the implementation of video refereeing.

Hawk-eye is a technology already used in several sports such as tennis, snooker, gaelic football, cricket, badminton, hurling, rugby, volleyball, and lastly, football. In football, it is already addressed as goal-line technology, but what if we can use it to discover when the ball goes out of bounds in the whole size of the pitch? What if we have a quick-response software capable of alerting the on-field referee if a ball goes out of bounds or if a potential penalty play was indeed inside the goalkeeper area? This adds a new set of possible answers to the doubts arising about these plays that could be crucial to the gameplay. Hawk eye simulates the trajectory of the ball and shows a video replica of its statistically most likely path as a moving object.

Football matches are 90 minutes long, 45 minutes each half. At the end of a half, the referee gives some extra minutes, compensating the minutes spent in substitutions, injuries, foul breaks or any stop the game had. These minutes are given by the referee in a relative way, referees think over the minutes the game was stopped and then give his/her opinion about the extra time. This extra time can always be debatable because the winning team would rather have less time and the losing team more time. In other sports, the time is counted by clock in descending order so a game/half, ends at the 0-minute mark, stopping the clock each time the game stops. Therefore, one can argue that a football game typically does not have 90 minutes of playing time even with the extra time, but one could also state that a football game having stops on the clock would take too long to end, as what occurs in other sports such as basketball, futsal, and American football. A technology concerning this topic is an exact stopwatch. It could be used as a counter to the time of stops in the game, translating to a fairer extra

time compared to today's system, given by the referee's view or in a more extreme way, counting the exact game time so that a football game would actually have a 90-minute playing time.

Nowadays, referees can communicate between each other using microphones and earphones. This has proves to be a successful implementation as the referee's job is now more efficient regarding the communication with other referees in play calls and getting the feedback from the other judges. In many other sports, referees are "mic up", meaning, the sound coming from the referee's microphone is made audible to the audience as the game stops and the referee explains what happened. This works in rugby and American football, as a way to let people know what the referee's decision was in any play call and what was judged. In football, we face a bigger problem, the respect between players and referees. If the fans were able to hear what happens on the field, we would be disappointed as many insults are thrown at referees and players and the real purpose of the technology would be lost. It must be considered if this implementation would add anything substantial to the game and to the audience's experience, because on field sound would not be very pleasant and many measures would have to be applied.

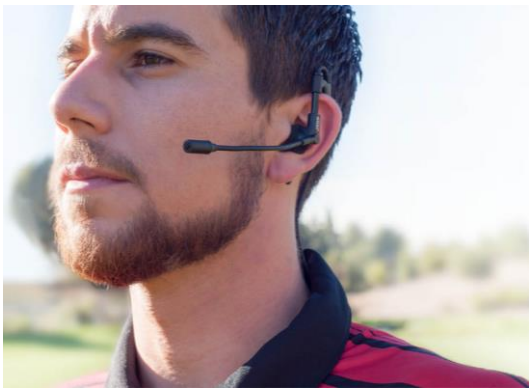

Figure 6 - Communication Hardware for Referees *via proreferee.com*

Goal

For "Goal" sub-problem, video-refereeing brought another associated technology with it. The goal-line technology, as the name states, evaluates if a play was indeed a goal or not. This technology uses multiple cameras, ball sensors, and a signal receiver to the referee indicating if the ball was fully inside the goal line or outside. Before the existence of it, referees had to judge a potential goal play in just a few seconds and with the imperfection of the human being, and referees sometimes made poor calls.

Figure 7 - Goal-Line Technology in use *via NBCSports*

Opportunities

The problem of different opportunities for several clubs is very real. One does not need to compare clubs from different countries or divisions, clubs from the same country and league have unbalanced opportunities regarding money to spend on players, coaching staff, technology departments, infrastructures, and facilities. Money generates money and having money to spend on these artifacts

will only increase the probability of being more successful in results. Clubs with less chance of investing in these will fall behind the richest clubs and the gap between them will only increase through the years, and in some leagues this gap is already indeed evident. Many technology and sport brands are making partnerships with football clubs, but as football is a business, the brands probably only invest in profitable markets and profitable clubs. The solution for this goes for partnerships with every club, even those with poorest technology packages. All organizations should have access to these through less famous brands, less expensive deals, or fewer artifacts compared to higher value clubs.

Health / Injuries

Injuries

Next, one has "Injuries" sub-problem from "Health / Injuries" where:

Monitorization tablets are used as a graphic interface to display data, graphics and useful information about a player through the sensors on his/her body. Data are collected by sensors and displayed in these tablets using a visualization software. It can be used by the doctors, masseurs and physical condition staff as a way to monitor and have access to the physical condition of the player and his/her history in previous games or during the season in order to prevent injuries by analyzing the injury risk of the physical stress the player is undergoing. Through this display of data, specialists use prediction models to estimate or prevent a future injury before it happens and advise the coaching staff about a change in the physical condition of a player. This can even be done in real-time in games, so an in-game substitution can be done.

Another artifact used for this problem are movement sensors placed in a player's boot or equipment so its positioning, movements, velocity, acceleration can be monitored. One has access to these data and with the help of prediction and data analysis models might be able to calculate and predict the injury risk associated with each player. Supervising movement actions, data analysts are able to inform the medical staff of the condition of a player before, during, and after an injury by checking changes in the velocity of movements throughout a game, practice, and the season, the effort the player is putting into his/her body regarding muscle and body physical stress, and risk behaviors in any physical action. During the recovery, in-depth analysis allows coaches to follow the condition of the player and decide the best moment for the inclusion of a player in games, either as a starter or off the bench, monitoring his/her minutes.

Vital sign sensors are higher precision sensors than wrist bands. These devices allow a precise measurement of the part of the body that is being monitored, allowing analysts and medical staff a complete current scanning and medical history through a long period. There are smart leggings with

several sensors strategically placed at the player's knee, ankle, and base of the spine of the clothing, allowing to track the postures and positioning at the pitch while playing, or individual sensors spread in critical areas of the body so one can assess the stress the muscle or bones are being exposed to and as a way to prevent future injuries by using prediction models using these data. It can also be used in case of an injury for faster diagnosis of the problem by accessing past and present data about a body area.

Figure 8 - Vital Sign Sensors by StatSports

Resting

Resting is a huge part of sports and with today's technology and modern sports, players desire to extend their careers as much as possible. Through movement and vital sign sensors displayed by monitorization tablets, one can be warned and advised about a potential high-level fatigue by a player either in game or outside of it and have effective fatiguemanagement by the coaching and physical condition staff. This allows fitting specific after-game recovery practices for each player and managing the best way to extract the best performance from the athletes. Movement sensors can be placed in a player's boot or equipment so its positioning, movements, velocity, and acceleration can be monitored. Resting management uses movement data to design specific resting routines regarding practices and minutes restriction during a game, as coaches want players to perform at a high level without harming their health because the season is long and with many important games. With this kind of data, one can have a clear perception of a player's playing usage and can have a prediction for future games and season ending. Vital sign sensors allow a precise measurement of the part of the body that is being monitored, allowing analysts and medical staff a complete current scanning and medical history through a long period. Using sensors scattered in a player's body, data analysts can observe the stress and effort of a player during a game and season. This is where resting management is so important, having this kind of data many injuries and over-stress situations can be prevented, allowing the players to perform at their highest level and getting the best out of them. Healthcare is also a big part of it, as many diseases and problems can be quickly diagnosed by analyzing this data transformed into medical information for specialists in sports health.

Professional clubs invest much money in transfer of players, and as a way to secure their interest, they use wrist bands to monitor the players' activity outside of football camps, hours of sleep, time they arrive home, what was the daily activity regarding an active or sedentary life, etc. Players need to follow clubs' rules, risking suspensions or decrease of play time. Wrist bands also allow any user to

follow their activity regarding distance of running or walking, how many calories burned, and alerting to get up when the user is sitting for a long-time period and keep track of the sleep cycles.

Vital Signs

We occasionally hear news of players needing to go to the hospital during a game. What if we could be ready and avoid these kinds of situations by monitoring the vital signs of a player, such as heart rate, blood pressure, respiration rate, and body temperature. Using monitorization tablets, vital sign sensors, and wrist bands, we could have access to real time data about the health status of a player and monitor the evolution of it through an exposure to high intensity physical action. We could avoid many dangerous situations and always be prepared for the worst. Now, there are regulations forbidding the use of these sensors in games in the players' bodies, but it is already used in practices or during training camps, where players need to stay at the club facilities. There are a few examples of it, like smart shirts or vests used in practices to measure all vital signs in the chest area, heart rate, accelerometer, respiration cycles, devices very important to a players' good-health and stress management. Life is more important than football and with a few past unfortunate situations regarding life losses in football matches, there are greater reasons to improve these technologies to avoid further incidents. Healthcare is a big part of sports; many heart and lungs diseases and problems can be quickly diagnosed by analyzing this data transformed into medical information for specialists in sports health.

Players' Performance

Practices Adaptation

To design a practice cycle, coaches require the greatest amount of data to build an effective practice. With the recording of games and practices, coaches and sports scientists can have a different perception from what happened, allowing them to pause, rewind and fast-forward the video as they please. Past video analysis can be used to create new routines of practice and new exercises so that a specific technique, strategy, or skill can be developed after the recognition of a weakness or strength either in their own team or analyzing other team's game footages. A common practice to prepare for coming games is to examine past games of an opponent so that a coaching team can prepare a practice cycle specifically to work a new strategy focused on the next game, make a report and transmit some knowledge to their players on how the opponent team plays in terms of formation and style, and which players are most talented and what to beware of. Analyzing their own footage of the games allows for informing the players of an aspect of the game they should work on in practices.

Additionally, players' movement sensors and performance monitoring sensors collect data that is displayed in the monitorization tablets and is analyzed by the coaching staff and physical condition team and can translate to adapting practices according to these analyses. Having identified potential improvements, focused practices are the best way to prepare, individually or even as a team, working on formation fundamentals, special tactics required by the offense and defense playstyle, defense and offense transition, since it takes more than velocity to get back on defense or to quickly change the defensive mentality to an offense one in a play. As the season goes by, these reports in the monitorization tablets prove to be a fact justification for the coaching teams to support the decisions in the adjustment of practice cycles.

Figure 9 - Performance Monitoring Sensors incorporated in the boots *via adidas.com*

With an analysis software that integrates video recordings, statistics, plots, personal information and data about the players and team, dynamic schemes, coaching analysis is facilitated having so much more at their disposal than simple game and practice observation. Once again, the set of all these analysis technologies helps to coordinate with all the coaches, doctors and physical condition staff the better design of practices, either individual technique or team strategy drills, physical workouts or mental exercises. Another application of this analysis software can be through scouting of opponents as having our own personal data, we can have access other teams' reports through scouting of their games. This, of course, also applies to the adaptation of practices, preparing for the next game with a full report of who the team is going to play.

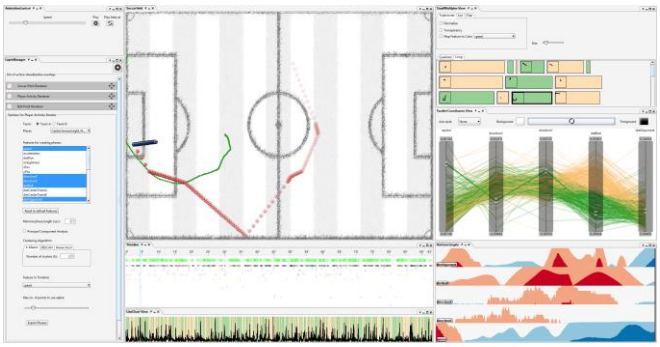

Figure 10 - Example of a Statistics Analysis Software

Practice adaptation can use Virtual Reality Goggles. Coaches know that practices are not the best replication of games, but they try to design it as close as possible and with the use of a virtual reality simulation, this gap can be diminished. Having recognized what the players need to work on, one can simulate a game experience and then have players practice and work these drills and tasks in a more realistic atmosphere. We have the examples of penalty kicks, one player can master the technique of shooting the ball in that distance with a goalkeeper ahead, but then with the intensity, responsibility and tension the real moment in a real match is unmatched by any penalty kicks practice. Imagine if we could simulate a penalty kick session in a virtual reality world so that the players could more closely

feel the moment in a match. In this field, one has 360° simulators, a technology that only a few clubs have at their disposal. This is a big platform with LED panels surrounding a center where the player stands and constantly receives footballs and is required to make different kinds of passes to different targets. Players essentially work on their passing ability with both feet, reaction to where the ball comes from and where to target, and decision-making related to the time reaction, allowing a full monitorization of the results by the analyst's department. Indeed, this works as a practice supplement and a very good one, with an infrastructure capable of varying each exercise with new ball rotations and speed, angles and different targets for the player to aim at it.

Figure 11 - 360° Simulator via *BenficaTV*

Post-Game Analysis

In line with what was said above, using several cameras spread over the field, one can have an individual or team scrutiny as an overall performance. Post-game analysis allows for understanding what went wrong or right on the game after a live view that has not the best angle for the coach (as they are right in the ground) and with so much going on with the crowd, arena atmosphere, and game action, most of the time not the best scenario to examine a game. Having the power to switch cameras and angles, change time periods, and write at the same time in the office is the most effective situation a coaching staff and sports analysts can have to take conclusions and notes about the game. Video footage allows a manual analysis of how the team or individual player played in the eyes of the analyst or coach and can observe technicalities such as team or individual positioning on the field, movements on it, passing, shooting, crossing and tackling quality, pace of the game, identification of key plays and examination of the execution of planned ones. It also allows to extract game statistics and analytics.

Monitorization tablets have a software incorporated capable of organizing a game's footage in categories so that users can have at their disposal whatever and whenever statistics, videos, analysis about the past games, and take quick conclusions instead of going through the whole video footage on a television. With the easy accessibility of a tablet, players can borrow it and coaches can show key plays that players should be aware of and take into mind on practices, next games, etc. Statistics Analysis Software can be displayed on tablets and enables the user to keep up with the evolution of a player regarding his/her performance during the season, and have access to a certain footage and statistics of the past. There are now independent departments inside football clubs focusing on data

analysis and designing prediction models and data analysis models to use post-game data and present a full report to the coaching staff. They use data collected from players' movement and performance monitoring sensors in which deficiencies in a team's or player's movement can be detected, as in positioning on the field, distance to the ball and teammates, execution of strategic plays, running technique, and become recognizable to the coach in an later and quiet environment. Collecting this kind of data allows to evaluate the team's performance through concrete facts, such as ball possession, passing, and shooting accuracy, and time with the ball. Often it is hard to assess a player's or team' performance during a match, but with actual sensors giving us what went wrong on a missed goal, free kick, penalty, pass, one is able to decrease the potential errors in future games or actions.

Youth Development

Youth Development is now different from what it was a few decades ago. Clubs' investment in development academies is higher than ever and technology in young players is almost the same as used in the professional level. Cameras are a big part of that and are used to record games as well as practices. Video footage is often used in scouting, as scouts have access to many players' databases to fully examine the development of young prospects and select the best ones to recruit to their clubs. The commodity of having tapes of several players without leaving the seat, at a young age, and improving technique and skills is even more important, whichis why analysis of past games and practices using not only cameras, but also players' movement and performance monitoring sensors, has such importance in the development of young football players, so weaknesses can be observed and quickly improved in specific directed drills to fill a less advanced skill. In young players' development, feedback from the coaches is essential to correct something wrong about a player's actions. Having these tablets always in hand, this feedback can be even more dynamic and more understandable by players, as facts can support an argument in the form of a video, a statistic, plots, or dynamic scheme. This can be used in games on the bench, during a substitution or in halftime, as well as in practices, video sessions, etc.

Two technologies that can be used to develop young prospects are virtual reality goggles and 360° simulators. Young players are not often experienced in high tension moments when the responsibility of it really weighs on any decision made. That is why virtual reality can help them by simulating a real game atmosphere. Young prospects can feel the tension of an important game and work in an intensity environment, fostering better decision making in a football match, thus in real matches these players will be more comfortable performing, decreasing the pressure on their shoulders. Starting at such a young age, these players will feel less nervous in future matches in their future careers as they already experienced a simulation of what it feels like to be on a professional football field. The simulators allow

the player to work on a platform that helps develop their skills and have a full history and growth in these types of skills. This becomes a more intensive passing and reaction practice than having two players making passes at each other, as in this case, we have a flawless machine making new passes each time the ball is thrown with diverse ball rotations and speed, angles and different targets for the player to respond to. The software has different difficulty levels and aims to instill a challenging attitude toward adversity at a higher scale than a regular practice.

Analysis software can improve scouting processes, as these departments need to work with so many players that this software will only make these procedures easier by designing full reports on young prospects allowing comparisons with actual data and videos. As used by professional players and teams, analysis software can also be used to save relevant data about past games and practices in order to develop a historic profile of the player and constantly take conclusions to give feedback and improve some part of the game that data show as a weakness or strength.

Live Coach Decisions

In live games coaches must be very meticulous with the formation changes, substitutions, position changes, and they only trust in their experience and hope they are going to be successful in these actions. With the help of monitorization tablets, coaches can have a reliable source of data to support these actions and decide from a range of possible options to act in the perfect timing with the best possible solution, as these play an important role in a live game. We now see the classic coaching staff helping the main coach, but also sports scientists and analysts in the stands with laptops and tablets monitoring the game and communicating this knowledge to the field through the coaches. Decision-making by the coaches often relies on what they observe and sometimes are biased from previous thoughts or the live environment, but by the use of sensors and a software capable of analyzing this in short time periods, coaches would have a wider range of sources to act on substitutions and feedback given to the players. This is mentioned as a future possibility, as at the moment it is not permitted to use this kind of technology in football equipment.

Fans' Experience

Home Watching

Video broadcasting plays a central role in the success of football. Television broadcasting is a very competitive market regarding transmission rights of matches and competitions and must ensure good service quality, keeping people entertained. Therefore, to reach it, new innovations should be made in recording technology, like video and sound quality, graphical elements added to the transmission like statistics and the actual score and game time and overall good video editing of the broadcasting

by the producers. New inventions were recently added, including drone segments, spidercam, slow-motion cameras, inside goal cameras, all implemented to innovate and improve the fans' experience, giving new ways of involvement in the game.

One example of a recent innovation is the goal-line technology, which adds another contribution to the audience because the public already had access to replays but not always the best to make a final conclusion of a goal play. But now there will be no indecisions, which adds a sense of justice and stability to the fans' watching. Hawk-eye could also be a technology added to attract viewership at home since it can present an out of bounds play, clarifying the fans about how the play was, since the fans in the television audience do not often have the best view of it. It is an addition to the fans' experience and a replay that can be displayed when the game stops for some reason (fouls, substitutions, out of bounds, injuries) as fans generally like a plays' replay just to make sure that what they saw was right and matches what the referee decided.

Virtual Reality in the last few years has been one of the hottest technologies in the market and technology investigation. By way of using a headset, it allows a user to simulate presence in a virtual reality through more realistic images and sounds. These headsets are goggles with a screen close to the user's eyes, allowing to "look-around" and behold a new world. Virtual Reality Goggles are often used in gaming to add a more introspective presence into games, and this works exactly the same in sports. Many broadcasting platforms, specifically on the internet, are now creating virtual reality transmissions of sports allowing fans to watch their favorite games on virtual reality goggles. These platforms film the live events in a privileged stand point of view and then make it available to improve and enhance the experience of a sporting event, as many users do not have the opportunity to attend it.

Live Attendance

Giant screens are a technology used for over 10 years, but they should not get stuck in the past, as it is the artifact most suited to solve the live attendance problem/challenge. The number of attendees at a football game makes the stadium screens a huge opportunity to interact with the people not only with commercials but also with things related to the match. One could have access to even more statistics than we have, half time

Figure 12 - Example of a Giant Screen in a Stadium by adi.tv

analysis with dynamic plots and elements, entertainment interactions with the audience, and much more.

4.2.2. Recommendations Future Technologies

Presented with a matrix of the time period we live in about the existing technologies and existing football problems/challenges, one must aim to the future of this topic. Mankind has always wondered and tried to predict what the future of the world and society will be, for instance, how is technology going to be, is the world going to be the same, what and how will be the next generation of technology devices. The sports world slightly crosses the predictions of society in the future in the sense that many ideas and inventions might also be applicable in sports. We have the example of Artificial Intelligence, a topic such discussed in recent years, mainly due to its ethical problems or the threats to humans, since many Hollywood movies have portrayed a futuristic scenario where Artificial Intelligence is in use (Garland, 2015) (Proyas, 2004). Artificial Intelligence could also have its application in sports, in health, helping diagnose injuries through data collected directly from the players' body through sensors and microchips; in the broadcast of games, having an intelligent software to choose the best cameras for the television audience, or in virtual reality broadcasting, also choosing the best cameras to better follow the game or in live refereeing, where some calls might be made by a software such as offside, goal confirmation, out of bounds or hand violation. Artificial Intelligence works as a background to all artifacts one might introduce, such as the body microchips, virtual reality goggles for the fans to follow the game, or the technology that allows to watch what the players are observing.

Wearables and monitoring devices are slowly being introduced in football and one can only imagine what the future will be, when all the potential meets up with the expectations since "according to analysts IHS Technology, global revenues for sports, fitness and activity monitors will grow from $1.9 billion in 2013 to $2.8 billion in 2019." (Svetlik, 2017). Will all the problems/challenges be solved with the current technology, or only with the next generation and new advances of the today's technology? That is why, a new matrix will be presented in. Table 2, a matrix with future assumptions that one could only imagine being used in football years from now. Even if today's technology might not even have the answers for the "how?", the type of ideas suggested just by imagination or based in science fiction culture are included.

		Fair Game / Refereeing				Health / Injuries			Players' Performance				Fans' Experience	
Technologies	**Artifacts / Problems**	**Refereeing**	**Opportunities**	**Goal**	**Illegal Betting**	**Injuries**	**Resting**	**Vital Signs**	**Post-Game Analysis**	**Practices Adaptation**	**Youth Development**	**Live Coach Decisions**	**Home Watching**	**Live Attendance**
Wearables	Microchips Inside/Outside Skin					X	X	X	X	X				
	Eye Recording Chip								X*	X*			X	X
	Aerodynamic Equipment								X	X	X	X		
	Reduced Fatigue Equipment					X	X		X	X	X	X		
Video Refereeing	Multiple Cameras creating 3D simulation	X							X				X*	
	No referee, only Video-Referee	X												
	Artificial Intelligence in Refereeing	X												
	VR Glasses to the Video-Referee/Referee	X												
Simulation Technology	Artificial Intelligence for Coaches		X		X				X			X		X
	Virtual Reality Goggles													X

Table 2 - Future Artifact Matrix

Fair Game / Refereeing

Refereeing

The development of technology might make the camera placement in football events cheaper and more convenient than nowadays. Having cameras placed in all different angles and having a full coverage of the field can open opportunities to the creation of 3D simulations that can be used for live refereeing. This technology would be available to referees working in a room close to the field and communicate to the on-field referee the correct decisions, just like video refereeing is starting to be used nowadays. These simulations, as the name says, could simulate the previous plays in a 3D environment allowing the user to scroll the image in different angles and have the power that todays' cameras do not have, as they have the disadvantage to be still. Better calls can be made regarding when the ball comes out of the field, whose is it, any foul or free kick, or offside plays.

As a result of the implementation increase of technology, specifically in refereeing, the actual referees on field might become useless. Video referees in the stands might do the job of the whole judging of calls, only missing someone to actually whistle on field, giving the information about any occurrence, like fouls, offside, and goals to the players and coaches. So, the video referees will use all the technology at their disposal and replace the on-field referee because the results from the technology are far more reliable and accurate than an on-field referee judging the game with the flaws that referees are accused of, since they are humans and far from perfect.

A new step forward in refereeing, after the video referee, might be Artificial Intelligence. This might be a little hard to imagine today, but one can envision an algorithm capable of keeping up with the images of a football game and analyzing it in real time with a velocity that only a machine could do. Through the constant perception of several angles of the video recording, the software could analyze every play of the game from every angle available and make the right call of a violation of the football rules without any indecision. This would only be possible if several video angles are available, so that the software could analyze them at the same time and waste no time with the call.

Virtual Reality Goggles for refereeing requires further technology here expressed such as multiple cameras recording the game or even the eye recording chip used by the players. This would be required because the goggles used by the referees need different angles of the game, so that the referees could change the images according to the best angles to keep up with the game and make the right calls. This technology would be used by referees in the stands and would be a major improvement to the monitors of the regular video-referees because the referee would have the power to switch visions using only his/her head and eyes and be way more into the game with no surrounding distractions.

Opportunities and Illegal Betting

The opportunities problem/challenge football faces might have a solution in a "present" future. To better explain this, one must consider the movie "Moneyball", because an analogy can be made using the same techniques used and developed by the baseball coaches in the Major League of Baseball team, Oakland Athletics. The movie is based on a true story focused on a team struggling to form a competitive and good team after years of using the same methods of wisdom and experience of baseball recruiting insiders, such as coaches, players, scouts and general management. The Oakland Athletics were a small market team, meaning they did not have the same budget to spend on attracting new and better players as larger market teams such as the New York Yankees. As a result, a new approach was followed, having statistics and analytics reports and analysis as the main player selection criteria. This turned out to be very successful, as the Athletics reached the playoffs in consecutive years (2002 and 2003).

Artificial Intelligence can be one of the answers for the small market football teams, the ones with lower budgets to spend, as a simple software and a team of data scientists can improve and be active in the recruiting processes of new players, and with less money, teams can scout for less-known players with high potential to develop using their personal data and performance statistics. Nowadays, this kind of software is still expensive, but in the future with higher use of Artificial Intelligence in almost every aspect and area of our society and with so many companies developing it, its price will only decrease as time goes by.

Artificial Intelligence can be one tool to face Illegal Betting in Sports and in Football. In order to spot possible result manipulation and unusual concentrated amounts of bets, betting websites can always have an Artificial Intelligence algorithm capable of having on one hand, the stats of a game and its development, and on the other hand the history and development of bets on the game, allowing to look for uncommon behaviors by the bettors. Maybe betting websites are not interested in facing illegal betting because they are a business and the main focus is increased profits, but national or international sports organizations can handle this, creating special departments specialized in the monitorization of Artificial Intelligence algorithms in sports betting.

Health / Injuries

Injuries

Microchips placed on core spots of the body could be an important improvement in injury diagnosis because through the sensors' signals, a computer could have faster results and diagnosis than the typical x-rays or other medical exams done to discover an injury in bones, muscles, or tendons.

These microchips could be placed under the skin closer to the muscles, bones or tendons or outside of it on the skin's surface, depending on the level of accuracy it takes, the technology progress or even if it is feasible to have an invasive chip inside the body. One imagines a faster acknowledgment of an occurrence of an injury, with faster results that translate into faster actions in order to start right away the assistance, basically in critical body spots like ankle, knee, head, shoulder, leg muscles, or even in the chest for organs monitoring. With constantly updated data, prediction models can also be performed to predict and anticipate an injury before it occurs, managing the stress and fatigue of the athlete in games, practices or during the season.

In 2017, reduced fatigue equipment might be hard to imagine, but the probability of the use of it is higher as we develop today's technology. Any invention with the goal of reducing the injuries of the players, and in this case the fatigue, is very well received by any intervenient in the football world, as injuries and rest are one of the problems of football that no one wants to be a part of. One can only wonder how this is going to be done, perhaps by inventing new sport clothes that increases aerodynamics and so then reduces the effort of the players' movements, new clothes that help the skin sweat and reduces it, helping the players not to have the discomfort of transpiration and therefore endure even more on the field, clothes accessories designed to reduce the most frequent injuries like ankles and knee sprains or leg muscles, bones and tendons, decreasing the probability of these injuries or even preventing further effort so players can resist more minutes and games throughout the season. This has a high probability of happening, as it already happened in the past, because we see today new techniques that have never been used in the past to reduce and prevent injuries, like muscle bands (colored bands attached to the skin of the players designed for muscles not to have big extensions of its movement).

Resting

Resting management is a key part in long and intense football seasons, so with the help of any data collector from the players that helps to better understand and manage the players' minutes is well received and usable. Microchips inside or outside the skin can gather accurate data regarding muscles, bones, tendons and vital organs of the players' bodies and transform it to knowledge about each performance detail and the current status of the players' bodies. With this, coaching and medical staff can design specific and individual resting programs according to the season phases, more important games and competitions, helping make better decisions in a roster management. Reduced fatigue equipment, mentioned above, might also be an artifact to answer the Resting problem/challenge.

Vital Signs

Vital sign microchips have a high importance in the players' health concerning critical situations where there is a dangerous threat to the athletes' health. Many accidents could be avoided because doctors and coaching staff can be more informed of a hazardous situation and prevent unfortunate events. Having in account less-severity situations, vital signs are also an indicator of body fatigue, which can be used to measure performance levels in live games where this can affect coaching decisions, practice levels of intensity, or resting.

Players' Performance

Post-game analysis can also be an application through microchips placed outside or inside a player's body closer to muscle, bones, or tendons. Medical staff could use these microchips to make better post-game analysis regarding the health of players, as these devices are directly connected to a computer software capable of receiving data and producing an immediate report of the status of a player in terms of muscle fatigue, injury occurrence probability, or an actual injury done during the game. The precision of these results can increase with these microchips compared to the software and hardware used at present, and the start of a treatment can be made faster, being an advantage so the injury does not get worse.

After the post-game analysis of health data from the players, the next practices can also be adapted according to it, adding another variable in the practices adaptation design along with the data from the last game's performance. Players have different levels of fatigue and injury probability in each body element and with the use of this data, individual practice programs can be planned more rationally with data that supports it, preventing errors; for instance, physical overload in a player that should do a softer practice cycle. The medical department is decreasing the distance to the coaching staff, meaning, the medical department is working more and more with the coaching staff regarding game decisions, practice adaptation, and post-game analysis, as coaches need data to justify much of their work.

Artificial Intelligence could also be used in live coach decisions. With the extraction of the data from players' movements, players' performance, and physical indexes and overall game statistics, a software could analyze and scrutinize it and make conclusions about it. Then the coaching staff would have at their disposal final conclusions from the data collected. Thus, conclusions would be more precise and faster than the same analysis made by a human. Coaches can have continuous and endless knowledge about the game beyond their visualization of the game, having a second opinion with real facts supporting it. Artificial Intelligence in data processing can be used to facilitate post-match analysis made by data scientists and/or coaches. The software would only require the data collected from the

game and then automatically make its analysis and create data models available to the coaching staff. The end-users would not be required to be experts in data science since the results would come as graphical and be easy to access and use. Artificial Intelligence would raise the data quality and provide more precise results than humans making their own analysis.

Aerodynamic Equipment will improve the Players' Performance, but one does not have the specific problem in this problem/challenge, instead it is all a Players' Performance problem/challenge. This new generation of technology can go along with the advances made in football boots and balls, where minimum weight and special designs are the main concerns for better results by the athlete. New equipment will prevent the shorts, socks, and shirts to be any kind of distraction in a match, allowing the player to move faster, be more agile, jump higher, and have better ball control.

Reduced Fatigue Equipment goes in line with the same procedure as Aerodynamic Equipment. Players' equipment is a part of the game, pulling a player by his shirt or shorts or a heavier equipment when wet. With this kind of advanced equipment, it would no longer be a distraction or a intervenient on the game since it had no effect on the players' performance. In a game, equipment can be a cause for more fatigue either by warm, cold or humid weather and having specific equipment for each of these weathers conditions with smart and specific technology allowing the fatigue of the player to be reduced, the player would feel freer and more focused on the game.

Multiple Cameras creating a 3D simulation are almost the same as the recording of the game, but now there is the possibility to navigate in every angle of a play with the one that best fits the display needs. This will transform the post-game analysis and the showing of it to, for instance players, as with these many angles and perspectives, better conclusions and insights can be drawn. A player's individual analysis can be performed as the simulation can be focused on one player's vision and environment, and then it can be made available to the player, so he/she can watch from another perspective how the game went, adding the insight from a coach to have another opinion of the performance. Not only in post-game analysis by coaches, but also from television analysists where they can manipulate the simulation and show crucial viewpoints of a play, from the referee or from any other intervenient in the game and extract better analysis and conclusions about the reasons of a final result and player performance discussions, and better show it to the audience, having visual justifications for what is stated.

Fans' Experience

Home Spectatorship

Currently, virtual reality goggles are starting to be used in many football application subjects and, the eye recording chip is an upgrade technology of it. In a near future, virtual reality is predicted to be a very present technology in football and what one proposes is a continuation of this technology but a more advanced one in which players could have microchips in their eyes, recording what they see during the game so the fans can have their perspective and watch it through the virtual reality goggles. The fans at home already have a general broadcasting image of the whole field and different cameras across the stadium, but now they could scroll through different players' perspectives of the match and follow their idols and watch exactly what they see. This will give an even more introspective intrusion of the fan in the game and close the gap between fans and the game as they can almost feel the same atmosphere as the players and fans at the game. Not only will home attendance have access to virtual reality broadcasting, but also the live attendance at the stadium, as the watching of the game will have options, regular viewing of the game with no accessories or viewing of the game with the virtual reality goggles, just like the home watching experience, where the fan can control what perspective he/she wants to play, regular stadium cameras or individual player perspective. The advantage of the live attendance to the home watching is to really be a part of the show, as the atmosphere, the sounds, the tension, the smells are yet to be recreated for the television audience.

5. DESIGN OF THE ANALYSIS AND EVALUATION OF THE PROPOSALS

5.1. METHODOLOGY

Design Science Research tells us that after the construction of the artifact matrix, an assessment should be run. This is activity five, "Evaluation", in which the recommendations are evaluated by the adaptability of the artifact to the solution of the problem. Depending on the nature of the problem, it can be demonstrated by several techniques such as comparison of the artifact's functionality with the solution objectives from activity two (mentioned above) or any objective quantitative performance measure, such as budgets or items produced, the results of satisfaction surveys, client feedback, or simulations. Specifically in this work, we implement a questionnaire focusing on the validation of the recommendations proposal made above in order to determine if each matching point between the artifacts and problems/challenges also makes sense for the football intervenient. (Hevner, March, Park, & Ram, 2004)

Therefore, after the Recommendations Proposal, a questionnaire is directed to Football actors such as referees, former referees, professional players, former players, coaches, former coaches, and academic persons. The questionnaire is developed to test the two matrixes regarding the representation of the artifacts in each problem/challenge, for the present and future matrix. With the knowledge from people working in the field, we hope to gain specific insights about the opinions and ideas of the repliers on technology in football.

5.2. TARGET AUDIENCE

The artifacts presented throughout this work pertain to certain aspects of the football world, as one has artifacts about players' performance, live refereeing, coaching decisions, and fans' experience. The target audience must be persons with football experience either as an element of the game or involved in some other way. For this, the answers will be by:

- Referees or former referees as a crucial intervener of a football match with insights essentially in refereeing work, but also as a fan;
- Coaches or former coaches, also with an important role in the game as coaches seeking success for their work and team results;
- Players or former players, because many of these artifacts and technologies discussed will affect the players' work and performance;
- Academic or football officials, people with experience in sports and specifically football organizations, who probably had any of the roles presented above or studied sports as a career or technology or both.

5.3. SAMPLE

As explained in the previous topic, the target audience will be composed of football actors who have had any relationship with the sport. Due to the limitation associated with this research, the target audience is a bit strict, as the distribution of the questionnaire is limited to the people that the researcher knows or is in touch with online. The answers will all be from people above 18 years old and with the interactions with football mentioned previously. A probable limitation will arise, since for a more accurate and precise research, the target audience groups should be equal regarding the number of observations for a more representative group of answers. This works the same for age groups as the ideal scenario would be each age group with the same representation in each target audience group.

5.4. QUESTIONNAIRE

The questionnaire was designed to validate the recommendations' proposal, and hence, the artifacts are the main focus. The questionnaire starts by asking personal information about the respondent: gender, age and what kind of relationship the person has with football and how many years it is/was. Then, the next questionnaire presents the whole list of artifacts, asking the person answering to select if he/she knows or uses the artifact. Having in mind the previous answers and introducing the four problems/challenges of this work, "Health/Injuries", "Fair game / Refereeing", "Players' Performance", and "Fans' Experience", respondents are asked to mark the problems/challenges the respondent most believes the artifacts fulfill and answers to. Then, a same table is shown and, once again, having in mind the previous answers, the respondent must grade with a degree of importance, from 1 to 3, the resolution of the problem/challenge by that artifact, in which degree 1 means the artifact will bring little improvement to the problem/challenge, degree 2, the artifact will bring some improvements to the problem/challenge, and 3, the artifact will solve the problem/challenge. This grade system was created with the intention to bring very few indecisions and abstraction to the respondent, as a larger scale would not only complicate the process of answering but also, tire the respondent by requiring additional effort. With three degrees, the abstraction is reduced and if the respondent is already giving a grade it is because he/she already confirms what the artifact would contribute, even if little, to the solution of the problem. Thus, the respondent is allowed to express an opinion ranging from the artifact adds little to the solution, a more neutral answer with degree two, and a stronger opinion with degree three in which the respondent expresses strong belief.

Lastly, the set of artifacts from the future technologies matrix is revealed and the respondents are asked to match to the four problems/challenges that in his/her opinion the artifact might be successful in resolving.

These problems/challenges are briefly explained in each question, that is, the respondents have access to the explanation and description of each problem/challenge for a better understanding of what the problems/challenges mean. The questionnaire was distributed in two ways: a printed version to which the respondents had to manually answer and online, in which the respondents filled in a file.

Section	Description
Personal Data	The respondents fill this section with their own details, gender, age and relationship with football and for how many years.
Recognizing the Artifacts	The respondents are asked to fill a table if they know and/or use any artifact from the list presented.
Matching Present Artifacts with Problems/Challenges	Using only the previous questions' answers, the respondents must check the boxes with football's problems/challenges that in their opinion might be solved by the artifacts they know and/or use.
Grading each Problem/Challenges for each Artifact	This section presents the grade system used to score the ability of the artifact to contribute to the solution of the football's problems/challenges that the respondent chose previously.
Matching Future Artifacts with Problems/Challenges	Presented with a list of future artifacts, respondents again match the set of artifacts to the football's problems/challenges.

Table 3 - Summary Explanation of the Questionnaire's Questions

An observation should be made regarding sections three and four. These two could be aggregated into just one, where the respondent could in only one question, match the artifacts with the problems/challenges and at the same time, score it. This was a decision made thinking from the user's perspective, as respondents usually do not really read the questions and advices carefully and could make mistakes. If it were just one question, the respondents would feel the need to fill the whole

matrix with the grades in the cells matching the artifacts (rows) with the problems/challenges (columns). This would not be correct, because they would most certainly also answer to cells for which they do not agree, meaning, the respondents would give a score to an artifact they do not believe that would fulfill the problem/challenge just because they are in a rush or do not have the time to read the instructions carefully. Of course, a point might arise regarding the time needed to respond, as creating two questions instead of one would add more time, but once the respondent checks the boxes in section three, section four would almost be automatic to answer. On the other hand, it is more effective for the data analysis to analyze only the real matches from the artifacts to the problems/challenges, as the rest of the cells would probably be filled with grade 1. This also works as a control of the answers; the researcher can observe if there is any incoherence in the respondents' answers.

6. ANALYSIS AND DISCUSSION

After the design of the questionnaire and its distribution throughout the football community, the data collected were aggregated with the intention to better analyze then and take conclusions about the Internet of Things technologies in Football. The questionnaire was distributed in person or via online in social networks where the researcher approached with potential target audience as coaches, players or ex-players, referees and academic personas working on the field. Table 4 shows the first part of the questionnaire with the personal information questions.

Variables for Table 4:

- **Observation:** ID of the Observation
- **Feminine:** 1 if the gender of the respondent is feminine, 0 if masculine
- **Age:** Age of the respondent
- **Referee:** Number of years as a Referee in Football
- **Player:** If the respondent is a current professional player, how many years has he/she been
- **Coach:** Number of years as a Coach in Football
- **Ex-Player:** Number of years the respondent has been as a football player
- **Academic:** Number of years the respondent has been an academic in the field

Observation	Feminine	Age	Referee	Player	Coach	Ex-Player	Academic
1	1	18	1				
2	0	40			21	15	
3	0	67			33	20	
4	0	25			5		
5	0	47					4
6	0	36	9				
7	0	24			4	3	
8	0	33			11		
9	0	24			6		
10	0	23			3	4	
11	0	39			16		
12	0	26			1		
13	0	24				7	
14	0	24				17	
15	0	30			12		
16	0	18	2			10	
17	0	23			4		
18	0	22			4	10	
19	0	33			9		
20	0	41			4		
21	1	30	10				
22	0	20			3		
23	0	45			23		
24	0	31			10		
25	0	46			15		
26	0	36					9
27	0	22	5				
28	0	36			7	15	
29	0	44			10		
30	0	57					35
31	0	22		17			
32	0	19	1				
33	0	30			3		
34	0	33			10		
35	0	32				25	
36	0	30			5		
37	1	26	8		8		
38	0	25			6	16	
39	0	35			9		
40	0	24			7	7	
41	0	43			15		
42	0	25			1	14	
43	0	39			17		

Table 4 - Responses for the Personal Details Question

6.1. PERSONAL QUESTIONS

The first section of the questionnaire works as an identification of our respondents' universe, as one can take conclusions about personal details of the people who answered the questionnaire.

The questionnaire was answered by 43 individuals with some kind of relationship with the researcher or were addressed via social network due to their potential relationship with the sport of football.

6.1.1. Gender

Men in football outnumber women in players, referees, coaches or football officials but feminine football is on the rise. There are now professional feminine national leagues and international competitions for national teams involving women in football. This is expected on the questionnaire's universe, a more representation of men than women. The answers' universe of the questionnaire was composed of 40 men and 3 women.

6.1.2. Relationship with Football

This question was implemented to know the relationship the respondent has with football. One can segment and group the answers made and observe if the relationship with football works as a differentiator of the answers.

The respondents might have multiple relationships with football, and therefore, we have 7 referees (5 being solely referees, 1 being also a coach and the other an ex-player), 1 professional player, 3 academic sports persons, 21 exclusively coaches, 3 ex-players, and 9 individuals both coaches and ex-players.

Analyzing the years of each position facing football, the lowest average of tenure is, as expected, from the referees, five years; since there is a minimum limit of age to start judging matches and since the age range of respondents' universe is also young, there are not many experienced referees among the questionnaire's respondents. The maximum years of experience of the respondent's referees is ten years with frequency one and the minimum is one year with frequency two. The rest of the answers are one-time frequency for two, five, eight and nine years.

Relation	Years	Frequency
Referee	1	2
	2	1
	5	1
	8	1
	9	1
	10	1

Table 5 - Frequency of Referees' Observations

The following years average is from coaches, nine years, and with a standard deviation of seven years, the highest (except academic, which has only three observations) between these categories. The range of experience of the respondents can be observed from the ones just starting, nine with equal to or less than four years of practice to the ones with more experience, seven with 15 or more years. The maximum is an observation with 33 years of experience as a football coach.

Relation	Years	Frequency
Coach	1	2
	3	3
	4	4
	5	2
	6	2
	7	2
	8	1
	9	2
	10	2
	11	1
	12	1
	15	2
	16	2
	17	1
	21	1
	23	1
	33	1

Table 6 - Frequency of Coaches' Observations

There is only one observation from a professional player and it is for 17 years, contrasting with 13 ex-players with an average of experience of 13 years and with a standard deviation of six years. This is the second highest standard-deviation, and one of the reasons for this is the long range of years an ex-player can have, from only playing in youth leagues to being professional and be able to play for many years, as with the observation with the most years of experience, 25 years.

Relation	Years	Frequency
Player	17	1

Table 7 - Frequency of Players' Observations

Relation	Years	Frequency
Ex-Player	3	1
	4	1
	7	2
	10	2
	14	1
	15	2
	16	1
	17	1
	20	1
	25	1

Table 8 - Frequency of Ex-Players' Observations

In the academic relationship with football, the years of experience range from three, nine and 35 years for the three observations, having an observation with little experience, one with a little more, and one a professor for most of the career.

Relation	Years	Frequency
Academic	4	1
	9	1
	35	1

Table 9 - Frequency of Academics' Observations

6.1.3. Age

Age will also work as a probable segmentation of the answers, since having different age groups can work as an observation of the different opinions of the respondents. The average age of the 43 observations is 32 years old, with 22 for the only player observation, 24 for the referees, 30 for the ex-players, 33 for the coaches, and 47 for the academics. Regarding the standard deviation of the age, the highest belongs to the academic observations with 14 years, following ex-players, with 12 years, coaches, with 10 years, and referees with 6 years.

Age	Frequency
18	2
19	1
20	1
22	3
23	2
24	5
25	3
26	2
30	4
31	1
32	1
33	3
35	1
36	3
39	2
40	1
41	1
43	1
44	1
45	1
46	1
47	1
57	1
67	1

Table 10 - Frequency of Observations' age

6.2. Presentation of the Present Artifacts

6.2.1. Recognition of the Artifacts

The list of artifacts grouped by technologies is presented and the respondents are asked if he/she knows the artifact or uses it. If the respondent does not know the artifact, the cell may be left empty. If the respondent does use the artifact in his/her football activity, one assumes the user knows it, obviously.

		Only Knows	Uses	Does Not Know
Image Acquisition	Cameras	20	22	1
	Monitorization Tablets	34	2	7
	Statistics Analysis Software	26	13	4
Wearables	Players' Movement Sensors	33	2	8
	Performance Monitoring Sensors	36	1	6
	Wrist Bands on Players	27	2	14
	Players' Vital Signs Sensors	32	5	6
Video-Referee	Cameras	41	2	0
	Goal-Line Technology	43	0	0
	Hawk-Eye Technology	34	0	9
	Exact Stopwatch	28	3	12
	Communication Hardware	31	6	6
Virtual Simulation	Virtual Reality Goggles	31	0	12
	360º Simulator	32	0	11
Other	Giant Screen	38	2	3

Table 11 - Frequency of Recognition of Present Artifacts

Analyzing the table above, one can observe the distribution of the knowledge and use of each artifact by the respondents. First, the artifacts most known among the universe of answers are the goal-line technology (43) and cameras (43) in refereeing and cameras (42) in image acquisition. This does not come as a surprise of results, since in the last months and years these were the most spoken technologies by the media and general public, introducing debates and discussions about their implementation's benefits and reluctance, largely because it is about the match's refereeing, which has a high impact on the game. The cameras in image acquisition is also one of the most known technologies and the reason for this result is about the public responding to the questionnaire. This is probably the artifact longest used in football and since the respondents, one way or another,

interacted with football, the probability of having used cameras in their games and/or practices is high, which justifies the result.

The artifact with the next highest score is giant screen (40). Giant screens happen to be in almost every stadium of the world's main leagues and are the interaction bridge between the public with the game itself, and are very popular in general audience.

The less known artifacts presented in the table are the wrist bands on players (29), exact stopwatch (31) and the virtual reality goggles (31). Wrist bands and virtual reality goggles outside of professional sports is a trendy technology that started to be commercialized recently and their use in competitive sports is slowly being implemented, being this, one of the probable reasons of the low result. The reason why the exact stopwatch artifact had such a low score might be related with the fact that the respondents did not quite understand what it was.

Regarding the use of the artifacts by the respondents, there are two artifacts that stand out from the rest, cameras from image acquisition (22) and the statistics analysis software (13). This result might be biased with the high percentage of respondents being football coaches because both technologies are used mainly by them in pre-game and post-game analysis. The runner-up artifacts are communication hardware from the referees (6) and players' vital sign sensors (5). We had seven answers from referees, and six of the seven use communication hardware in their matches' judging. Vital sign sensors do not have a pattern to be diagnosed, since the respondents that use it are two coaches only, one referee, one academic person, and one both coach and ex-player. One thing that could justify this, which is about the use of any smartwatch or wrist band that makes this kind of analysis and with the question's subjectivity about in what occasions the artifacts are used, the respondents could answer both in their football activity or outside of it in any daily activity.

There are four artifacts that are not used by any of the respondents, goal-line technology, hawk-eye technology, virtual reality goggles, and 360º simulator. These are the most advanced artifacts with restricted use, meaning that only highly qualified people in great organizations, such as, first division clubs and referees, have access to them. This is a limitation of this research work as almost any respondent is amateur in their football relationship and works in a regional environment.

Having an overview of the answers, one can now have a segmented insight about the answers of each football relationship, coaches, referees and ex-players, since the rest of the categories are too low-numbered to have a good overall analysis. This will be a relative analysis made with percentages since the categories have different numbers of answers.

Starting with the coaches and observing Table 12, one can emphasize the high percentage of artifact knowledge the respondents have. The artifacts with the lowest percentage of respondents knowing it are the wrist bands (73%) and exact stopwatch (73%), which can be concluded as a high number since the rest of the artifacts are well-known for the coaches' answers, which have a universe

of 30 answers. Eight artifacts have 90%-plus knowledge from the coaches, all image acquisition artifacts (100%, 90%, 100%), performance monitoring sensors (90%), players' vital sign sensors (93%), cameras in refereeing (100%), goal-line technology (100%), and giant screens (97%). The artifacts usage goes in line with the overview analysis, the image acquisition cameras (50%) and statistics software (40%) are the artifacts with the highest percentage of respondents using it, mostly because these are coach oriented technologies.

Universe = 30 Observations		Only Knows	Uses	Does Not Know
Image Acquisition	**Cameras**	15	15	0
	Monitorization Tablets	25	2	3
	Statistics Analysis Software	18	12	0
Devices	**Players' Movement Sensors**	24	2	4
	Performance Monitoring Sensors	26	1	3
	Wrist Bands on Players	22	0	8
	Players' Vital Signs Sensors	25	3	2
Video-Referee	**Cameras**	30	0	0
	Goal-Line Technology	30	0	0
	Hawk-Eye Technology	25	0	5
	Exact Stopwatch	21	1	8
	Communication Hardware	24	0	6
Virtual Simulation	**Virtual Reality Glasses**	23	0	7
	360º Simulator	26	0	4
Other	**Giant Screen**	29	0	1
Image Acquisition	**Cameras**	50%	50%	0%
	Monitorization Tablets	83%	7%	10%
	Statistics Analysis Software	60%	40%	0%
Devices	**Players' Movement Sensors**	80%	7%	13%
	Performance Monitoring Sensors	87%	3%	10%
	Wrist Bands on Players	73%	0%	27%
	Players' Vital Signs Sensors	83%	10%	7%
Video-Referee	**Cameras**	100%	0%	0%
	Goal-Line Technology	100%	0%	0%
	Hawk-Eye Technology	83%	0%	17%
	Exact Stopwatch	70%	3%	27%
	Communication Hardware	80%	0%	20%
Virtual Simulation	**Virtual Reality Glasses**	77%	0%	23%
	360º Simulator	87%	0%	13%
Other	**Giant Screen**	97%	0%	3%

Table 12 - Frequency of Recognition of Present Artifacts (Coaches)

Ex-football players, in Table 13, have a good overall knowledge of the artifacts, not as much as coaches but also high in some artifacts. Seven artifacts have 90%-plus knowledge rate, cameras in image acquisition (100%), statistics analysis software (92%), performance monitoring sensors (92%), players' vital sign sensors (92%), cameras in refereeing (100%), goal-line technology (100%) and giant

screens (100%). In this list, a few artifacts mostly used by players do not have a good score in knowledge or usage in the ex-players answers, but this might be affected by the time passed since these players abandoned football, a few years where there was no technology implemented or there was no possibility of using it since it was in regional divisions with low budget clubs. The lowest knowledge percentage artifacts are wrist bands (54%) and virtual reality goggles (69%).

Universe = 13 Observations		Only Knows	Uses	Does Not Know
Image Acquisition	**Cameras**	6	7	0
	Monitorization Tablets	10	0	3
	Statistics Analysis Software	10	2	1
Devices	**Players' Movement Sensors**	9	1	3
	Performance Monitoring Sensors	12	0	1
	Wrist Bands on Players	7	0	6
	Players' Vital Signs Sensors	11	1	1
Video-Referee	**Cameras**	13	0	0
	Goal-Line Technology	13	0	0
	Hawk-Eye Technology	10	0	3
	Exact Stopwatch	8	1	4
	Communication Hardware	9	1	3
Virtual Simulation	**Virtual Reality Glasses**	9	0	4
	360º Simulator	10	0	3
Other	**Giant Screen**	13	0	0
Image Acquisition	**Cameras**	46%	54%	0%
	Monitorization Tablets	77%	0%	23%
	Statistics Analysis Software	77%	15%	8%
Devices	**Players' Movement Sensors**	69%	8%	23%
	Performance Monitoring Sensors	92%	0%	8%
	Wrist Bands on Players	54%	0%	46%
	Players' Vital Signs Sensors	85%	8%	8%
Video-Referee	**Cameras**	100%	0%	0%
	Goal-Line Technology	100%	0%	0%
	Hawk-Eye Technology	77%	0%	23%
	Exact Stopwatch	62%	8%	31%
	Communication Hardware	69%	8%	23%
Virtual Simulation	**Virtual Reality Glasses**	69%	0%	31%
	360º Simulator	77%	0%	23%
Other	**Giant Screen**	100%	0%	0%

Table 13 - Frequency of Recognition of Present Artifacts (Ex-Players)

In Table 14, Referees present results that can be concluded as the lowest regarding overall knowledge of the artifacts' list. The percentages of not knowing the artifacts are highest among the referees, as eight of the 15 artifacts have a percentage of knowing below 60%, 360º simulator (29%), statistics analysis software (43%), players' movement sensors (43%), players' vital sign sensors (43%), monitorization tablets (57%), performance monitoring sensors (57%), hawk-eye technology (57% is

very low for a judging technology), and virtual reality goggles (57%). The artifacts' highest knowing percentages are all from the refereeing category, 100% for cameras, goal-line technology and communication hardware, meaning that all referees asked do know these artifacts.

	Universe = 7 Observations	Only Knows	Uses	Does Not Know
Image Acquisition	Cameras	1	5	1
	Monitorization Tablets	4	0	3
	Statistics Analysis Software	2	1	4
Devices	Players' Movement Sensors	3	0	4
	Performance Monitoring Sensors	4	0	3
	Wrist Bands on Players	5	1	0
	Players' Vital Signs Sensors	2	1	0
Video-Referee	Cameras	5	2	0
	Goal-Line Technology	7	0	0
	Hawk-Eye Technology	4	0	3
	Exact Stopwatch	3	2	2
	Communication Hardware	1	6	0
Virtual Simulation	Virtual Reality Goggles	4	0	3
	360º Simulator	2	0	5
Other	Giant Screen	5	0	2
Image Acquisition	Cameras	14%	71%	14%
	Monitorization Tablets	57%	0%	43%
	Statistics Analysis Software	29%	14%	57%
Devices	Players' Movement Sensors	43%	0%	57%
	Performance Monitoring Sensors	57%	0%	43%
	Wrist Bands on Players	71%	14%	0%
	Players' Vital Signs Sensors	29%	14%	0%
Video-Referee	Cameras	71%	29%	0%
	Goal-Line Technology	100%	0%	0%
	Hawk-Eye Technology	57%	0%	43%
	Exact Stopwatch	43%	29%	29%
	Communication Hardware	14%	86%	0%
Virtual Simulation	Virtual Reality Goggles	57%	0%	43%
	360º Simulator	29%	0%	71%
Other	Giant Screen	71%	0%	29%

Table 14 - Frequency of Recognition of Present Artifacts (Referees)

6.2.2. Associating the Artifacts with Football's Problems/Challenges

Using the answers given above, the respondent is presented with the same list of artifacts in the rows and the football's problems/challenges, that were explained, in the columns. The respondent might fill in more than one problem/challenge for each artifact and leave empty if the previous question was also left blank for the artifact.

Table 15 represents the distribution of the answers by the respondents in each crossing between artifact and football problem/challenge. The results are presented in a relative way due to the different number of answers given in each artifact because it was allowed to choose more than one problem/challenge for each artifact. Each row has a total of 100% representing the distribution of the answers for each problem/challenge. The color scheme is a visual support in order to recognize the higher values between each row, in which green is the highest value, orange the second highest, and yellow the third highest.

		Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	Cameras	18%	3%	51%	28%
	Monitorization Tablets	21%	15%	58%	6%
	Statistics Analysis Software	16%	12%	56%	16%
Wearables	Players' Movement Sensors	39%	8%	48%	5%
	Performance Monitoring Sensors	37%	2%	58%	5%
	Wrist Bands on Players	42%	0%	53%	5%
	Players' Vital Signs Sensors	54%	0%	46%	0%
Video-Referee	Cameras	0%	86%	2%	12%
	Goal-Line Technology	0%	79%	0%	21%
	Hawk-Eye Technology	0%	77%	2%	20%
	Exact Stopwatch	0%	71%	7%	21%
	Communication Hardware	0%	90%	0%	10%
Virtual Simulation	Virtual Reality Goggles	2%	12%	26%	60%
	360º Simulator	7%	11%	44%	38%
Other	Giant Screen	0%	15%	8%	77%

Table 15 - Distribution of the Overall Answers for each Problem/Challenge

The overall answers of the whole universe of respondents go in line with each category of technology, meaning that the artifacts of the same category of technology have a similar distribution of answers in each problem/challenge. Starting in the Image Acquisition category, one can detect a pattern in the distribution; in all three artifacts the most dominant problem/challenge is "Players' Performance" with more than 50%, in the second place, the artifacts: cameras and statistics analysis software, have "Fans' Experience" with balanced distribution, and monitorization tablets have "Health/Injuries" balanced with "Fair Game /Refereeing". These results can be concluded as expected, since these artifacts have the ability to fulfill a few tasks both in Players' Performance and

"Health/injuries". It can also respond to the other two problems/challenges due to the kind of data it generates, which help referees in their task and enrich the fans' experience with football.

In Wearables category a pattern can also be seen, as "Players' Performance" gets the highest results in all first three artifacts and "Health/Injuries" the second highest results. In the artifact players' vital sign sensors, the roles are reversed, as "Health/injuries" has a higher distribution (54%) (even if balanced) than "Players' Performance", which obtains the second most distribution (46%). This role reversal makes sense, vital sign sensors do have more application in health and injuries concerns due to the kind of data generated, but also can be applied in players' performance tasks.

All Video-Referee artifacts answers have the same logic, as expected. The main problem/challenge indicated by the respondents is "Fair Game/Refereeing", with "Fans' Experience" the second. This does not come as a surprise since the name of the technology category might bias the results and the artifacts are almost self-answered.

For the opinion of the respondents regarding the problem/challenge, Virtual Reality Goggles might have the best application in "Fans Experience" (60%), followed by "Players' Performance" (26%) and "Fair Game/Refereeing" (12%). Although Virtual Reality Goggles have a high impact in Players' Performance in practices, it is still not what it is best known for in the audience. Virtual Reality in recent years has been sold as a substitute of the regular televisions and monitors, enhancing the intrusion of the user to the virtual environment. The simulator 360º holds a balanced result with "Players' Performance" (44%) and "Fans Experience" (38%). The order of the results is expected but 360º simulator is built with the purpose of helping the development and improvement of players' technique and skills with the ball, so "Players' Performance" could have a better highlight regarding the results of the answers.

Lastly, giant screens, according to the respondents and as expected, are more attributed to answer the "Fans' Experience" problems/challenges (77%) and then "Fair Game/Refereeing" (15%).

Having in mind the same segmentation as in the previous section, individual results for coaches, ex-players, and referees, one can analyze the answers given by each group of respondents, specifically in Tables 16, 17, and 18. The patterns for each artifact and problem/challenge follow almost the same as the overall view; there are no changes regarding the relationship with football. One thing worth noticing is in the coaches' answers and Image Acquisition category. The results are more balanced between the problems/challenges and this might be a result of the fact that these artifacts are related to the coaches' work, meaning, coaches are usually the ones using these kinds of devices and technology. By that one can conclude that coaches have more insight about the problem and might see the potential of these artifacts for every problem/challenge presented in this work, resulting in more distributed values but following the general view and analysis. 360º Simulator gets a 50% balance between "Players' Performance" and "Fans' Experience", instead of a more unbalanced result of the

overall view. Ex-Players respondents might better know this kind of technology than the rest because this technology is used only by players, but due to the small number of answers and not having a representative sample for each group, this conclusion might not be secure.

Universe = 30 Observations		Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	**Cameras**	17%	4%	53%	26%
	Monitorization Tablets	17%	15%	62%	6%
	Statistics Analysis Software	13%	12%	58%	17%
Devices	**Players' Movement Sensors**	42%	6%	46%	6%
	Performance Monitoring Sensors	38%	2%	56%	4%
	Wrist Bands on Players	42%	0%	53%	5%
	Players' Vital Signs Sensors	55%	0%	45%	0%
Video-Referee	**Cameras**	0%	88%	0%	12%
	Goal-Line Technology	0%	81%	0%	19%
	Hawk-Eye Technology	0%	79%	3%	18%
	Exact Stopwatch	0%	78%	4%	19%
	Communication Hardware	0%	89%	0%	11%
Virtual Simulation	**Virtual Reality Goggles**	3%	7%	27%	63%
	360º Simulator	6%	9%	41%	44%
Other	**Giant Screen**	0%	17%	11%	72%

Table 16 - Distribution of Answers for each Problem/Challenge (Coaches)

Universe = 13 Observations		Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	**Cameras**	14%	0%	55%	32%
	Monitorization Tablets	19%	19%	63%	0%
	Statistics Analysis Software	18%	9%	55%	18%
Devices	**Players' Movement Sensors**	39%	11%	44%	6%
	Performance Monitoring Sensors	37%	5%	58%	0%
	Wrist Bands on Players	43%	0%	50%	7%
	Players' Vital Signs Sensors	55%	0%	45%	0%
Video-Referee	**Cameras**	0%	72%	0%	28%
	Goal-Line Technology	0%	72%	0%	28%
	Hawk-Eye Technology	0%	77%	0%	23%
	Exact Stopwatch	0%	67%	0%	33%
	Communication Hardware	0%	83%	0%	17%
Virtual Simulation	**Virtual Reality Goggles**	0%	0%	33%	67%
	360º Simulator	0%	0%	50%	50%
Other	**Giant Screen**	0%	15%	0%	85%

Table 17 - Distribution of Answers for each Problem/Challenge (Ex-Players)

Universe = 7 Observations		Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	**Cameras**	0%	0%	50%	50%
	Monitorization Tablets	40%	0%	60%	0%
	Statistics Analysis Software	25%	25%	50%	0%
Devices	**Players' Movement Sensors**	33%	17%	33%	17%
	Performance Monitoring Sensors	50%	0%	50%	0%
	Wrist Bands on Players	50%	0%	50%	0%
	Players' Vital Signs Sensors	50%	0%	50%	0%
Video-Referee	**Cameras**	0%	86%	0%	14%
	Goal-Line Technology	0%	86%	0%	14%
	Hawk-Eye Technology	0%	75%	0%	25%
	Exact Stopwatch	0%	75%	0%	25%
	Communication Hardware	0%	100%	0%	0%
Virtual Simulation	**Virtual Reality Goggles**	0%	20%	20%	60%
	360º Simulator	0%	0%	50%	50%
Other	**Giant Screen**	0%	0%	0%	100%

Table 18 - Distribution of Answers for each Problem/Challenge (Referees)

6.2.3. Grading the Artifacts in each of Football's Problems/Challenges

For each match of the artifacts with the problems/challenges a grade must have been given from 1 to 3 to previous given matches between artifacts and problems/challenges.

The following table shows the average score given by the respondents, only in the colored matches of Table 15, the ones that matter because they had the highest frequency of choosing.

		Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	Cameras	1.92		2.18	2.10
	Monitorization Tablets	1.92	2.11	2.31	
	Statistics Analysis Software	2.09		2.37	2.10
Devices	Players' Movement Sensors	2.12		2.26	
	Performance Monitoring Sensors	2.04		2.25	
	Wrist Bands on Players	1.96		2.14	
	Players' Vital Signs Sensors	2.40		2.27	
Video-Referee	Cameras		2.21		2.40
	Goal-Line Technology		2.67		2.70
	Hawk-Eye Technology		2.41		2.13
	Exact Stopwatch		2.00		2.14
	Communication Hardware		2.32		1.33
Virtual Simulation	Virtual Reality Goggles		1.60	1.73	2.00
	360º Simulator			1.95	2.18
Other	Giant Screen		2.29		2.17

Table 19 - Scoring for each match between Artifact and Problem/Challenge

One expectation of these results is that the green cell is expected to have the highest scoring, since it was the most frequent problem/challenge chosen to that artifact, but as we see, this is not what is really happening. Five of the 15 artifacts have the orange match having the highest scoring, meaning, the second most frequent chosen match in the respondents' opinion has the best fit to answer the problem/challenge of that artifact. This happens to Cameras in Refereeing, Goal-Line Technology, Exact Stopwatch, 360º Simulator, and Giant Screens. There is one thing in common for the first four artifacts mentioned, the orange cell is the problem/challenge "Fans' Experience", which means that even though it was only the second most frequent problem/challenge in those artifacts, it received a higher amount of "score 3" than the most frequent problem/challenge. The fifth artifact was Giant Screens, with the green cell (Fans' Experience) having a lower score than the orange cell (Fair Game/Refereeing). This kind of giant screens currently do not help referees in their task, so this might have happened due to misunderstanding of the artifact.

The rest of the artifacts' average score in the green cells is placed in the score 2, which is "the artifact will bring some improvements to the problem/challenge". This is a medium score in which the

respondents have their opinions not too high in the implementation of technology in football but not being too skeptical and against the use of technology in football. The artifacts with the highest score are Goal-Line Technology (2.67), Hawk-Eye Technology (2.41), and Statistics Analysis Software (2.37). The lowest average scoring artifacts are the 360º Simulator (1.95), Virtual Reality Goggles (2) and Exact Stopwatch (2). Discussing the orange cells (the second most frequent matches between artifacts and problems/challenges), the average score is also 2, except for Virtual Reality Goggles with a score of 1.73 for "Players' Performance".

Analyzing coaches' answers in Table 20, there is also the observation of the orange cells (second most frequent problem/challenge in that artifact) having a higher score than the green cells (most frequent match between problem/challenge and artifact). One can detect this for five of the 15 artifacts: Monitorization Tablets (2.43 over 2.41), Cameras in Refereeing (2.33 over 2.27), Goal-Line Technology (2.83 over 2.73), Exact Stopwatch (2.25 over 2.05) and Giant Screen (2.50 over 2.24). The same reasons pointed to before can be suggested for the last four artifacts, but to the Monitorization Tablets the difference is negligible. The highest scoring artifacts for the most frequent problems/challenges selected by the coaches are: Goal-Line Technology with 2.73, Hawk-Eye Technology with 2.58, Statistics Analysis Software with 2.43, and Monitorization Tablets with 2.41. In this top four there are two artifacts from the refereeing and two from the image acquisition; this last is more coach-focused.

	Universe = 30 Observations	Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	**Cameras**	2.00		2.29	2.21
	Monitorization Tablets	2.13	2.43	2.41	
	Statistics Analysis Software	2.29	2.00	2.43	2.00
Devices	**Players' Movement Sensors**	2.16		2.29	
	Performance Monitoring Sensors	2.07		2.29	
	Wrist Bands on Players	2.06		2.21	
	Players' Vital Signs Sensors	2.44		2.36	
Video-Referee	**Cameras**		2.27		2.33
	Goal-Line Technology		2.73		2.83
	Hawk-Eye Technology		2.58		2.40
	Exact Stopwatch		2.05		2.25
	Communication Hardware		2.52		1.50
Virtual Simulation	**Virtual Reality Goggles**			1.75	2.11
	360º Simulator			2.07	2.27
Other	**Giant Screen**		2.50	2.00	2.24

Table 20 - Scoring of each match between Artifact and Problem/Challenge (Coaches)

In the ex-players analysis in Table 21, once again there are five artifacts with the most frequent problem/challenge having a lower score than the rest of the problem/challenge in that artifact: Cameras in Image Acquisition (2.14 to 2.08), Statistics Analysis Software (2.50 to 2.33, yellow to green cell), Cameras in Refereeing (2.50 to 2.15), Goal-Line Technology (2.75 to 2.69), and Exact Stopwatch (2.50 to 2.25). The only new artifact having this kind of result is the cameras in image acquisition, with "Fans' Experience" with a higher score than "Players' Performance". Although "Players' Performance" seems to be the most suitable problem/challenge to be solved by the Cameras artifact, "Fans' Experience" has a higher score, not by much, but as this a recurring event for the "Fans' Experience", one can say that the overall respondents like the idea of these artifacts to fulfill the fans' experience challenges in football with a higher probability. The artifact Statistics Analysis Software has a peculiar observation, the yellow cell (third most frequent problem/challenge chosen by the respondents to be solved by the artifact) presents a higher grade than the rest. This can be justified as an outlier, since the few ex-players who chose this problem/challenge gave it a higher grade than the rest.

	Universe = 13 Observations	Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	**Cameras**			2.08	2.14
	Monitorization Tablets		2.00	2.30	
	Statistics Analysis Software	2.00	2.50	2.33	2.00
Devices	**Players' Movement Sensors**	2.00	1.50	2.13	
	Performance Monitoring Sensors	2.14		2.18	
	Wrist Bands on Players	1.67		2.14	
	Players' Vital Signs Sensors	2.25		2.10	
Video-Referee	**Cameras**		2.15		2.50
	Goal-Line Technology		2.69		2.75
	Hawk-Eye Technology		2.20		2.00
	Exact Stopwatch		2.25		2.50
	Communication Hardware		2.30		1.00
Virtual Simulation	**Virtual Reality Goggles**			2.00	2.00
	360º Simulator			2.20	1.80
Other	**Giant Screen**		1.50		1.91

Table 21 - Scoring of each match between Artifact and Problem/Challenge (Ex-Players)

Referees, with only seven respondents in Table 22, will be harder to take conclusions from because from the seven answers, only a few knew the most part of the artifacts. The refereeing category will be the only category to be analyzed due to this limitation and it is where almost all of the respondents had input. Goal-Line Technology has a score associated with the orange cell of 3 and to the green cell 2.67. After going through the answer, the reason for this is because only one referee associated the "Fans' Experience" with the Goal-Line Technology and gave it a 3 score and the rest of the answers (including the same referee) gave 2s and 3s to the "Fair Game/Refereeing" problem/challenge. The rest of the refereeing artifacts had a score in the category 2 for the most frequent problem/challenge, which is "Fair Game/Refereeing".

Universe = 7 Observations		Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Image Acquisition	**Cameras**			2.33	2.00
	Monitorization Tablets	2.00		2.33	
	Statistics Analysis Software	2.00	1.00	3.00	
Devices	**Players' Movement Sensors**	3.00	2.00	3.00	3.00
	Performance Monitoring Sensors	2.33		2.33	
	Wrist Bands on Players	2.50		3.00	
	Players' Vital Signs Sensors	3.00		2.00	
Video-Referee	**Cameras**		2.33		2.00
	Goal-Line Technology		2.67		3.00
	Hawk-Eye Technology		2.33		2.00
	Exact Stopwatch		2.00		2.00
	Communication Hardware		2.14		
Virtual Simulation	**Virtual Reality Goggles**		1.00	1.00	2.33
	360º Simulator			2.00	3.00
Other	**Giant Screen**				2.40

Table 22 - Scoring of each match between Artifact and Problem/Challenge (Referees)

Now for each problem/challenge and using Table 19, one will demonstrate which artifacts were the best suited to solve it. Vital Sign Sensors in Health/Injuries is the artifact with the highest score, with 2.40, also this problem/challenge is the most frequent choice to this artifact, as we can see by its green cell. In Fair Game/Refereeing with a score of 2.67, Goal-Line Technology is the artifact with the highest score, Hawk-Eye Technology with 2.41 the second highest, and Communication Hardware the third with 2.32. In Players' Performance, 2.37 is the highest score, belonging to Statistics Analysis Software and 2.31 the second highest score, Monitorization Tablets. In Fans' Experience there is a specific analysis to be made. The highest scoring artifact has an orange cell (it is not the most frequent

problem/challenge chosen), 2.70 by Goal-Line Technology, meaning this is not the best suited problem/challenge of this artifact. Therefore, one will look for green cells in the Fans' Experience problem/challenge because these are the artifacts, according to the questionnaires' results, more suited to solve this problem. Giant Screen and Virtual Reality Goggles are the only ones with this behavior, with Giant Screen having the highest score, with 2.17, and 2.00 for Virtual Reality Goggles.

6.3. Presentation of the Future Artifacts

Having in mind the same procedure of the present artifacts' question, the cells for each problem/challenge and future artifact may be filled in, in which it is allowed to choose more than one problem/challenge. After presenting a new list of artifacts for the future, this is Table 23 of the frequency of the answers, with absolute (top side) and relative (bottom side).

	Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Microchips Inside/Outside Skin	31	2	22	1
Recording Chip in Players' Eyes	4	4	19	12
Aerodynamic Equipment	9	4	25	5
Equipment for the Reduction of Physical Fatigue	26	4	35	1
Multiple Cameras allowing a 3D Game Simulation	0	13	13	31
Non-Existence of Referee, only Video-Referee	0	16	0	5
Artificial Intelligence in Refereeing	0	23	1	4
Virtual Reality Goggles for Stadium's Audience	0	1	1	26
Artificial Intelligence for Coaches	1	2	23	1
Virtual Reality Goggles for Video-Referees	0	20	1	4
Microchips Inside/Outside Skin	55%	4%	39%	2%
Recording Chip in Players' Eyes	10%	10%	49%	31%
Aerodynamic Equipment	21%	9%	58%	12%
Equipment for the Reduction of Physical Fatigue	39%	6%	53%	2%
Multiple Cameras allowing a 3D Game Simulation	0%	23%	23%	54%
Non-Existence of Referee, only Video-Referee	0%	76%	0%	24%
Artificial Intelligence in Refereeing	0%	82%	4%	14%
Virtual Reality Goggles for Stadium's Audience	0%	4%	4%	93%
Artificial Intelligence for Coaches	4%	7%	85%	4%
Virtual Reality Goggles for Video-Referees	0%	80%	4%	16%

Table 23 - Frequency of Recognition of Future Artifacts (Absolute and Relative)

On the top side of the table, an absolute counting of the answers given by all respondents is presented, whereas on the bottom there is a relative counting made by row, making each row sum 100%. In some artifacts, one can easily detect one major problem/challenge selected by the respondents, as the distribution is not balanced between problems/challenges, as is the case of "Non-Existence of Referee" with 76% of the respondents choosing Fair Game/Refereeing; Artificial

Intelligence in Refereeing with 82% choosing Fair Game/Refereeing; Virtual Reality Goggles for Stadium's Audience with 93% of the answers to Fans' Experience; Artificial Intelligence for Coaches with 85% to Players' Performance and Virtual Reality Goggles for Video-Referees with 80% to Fair Game/Refereeing.

The remaining artifacts have a distribution of its problems/challenges more balanced, where one can be chosen as the most frequent, but the others might be worth mentioning. Microchips Inside/Outside Skin is distributed between Health/Injuries (55%) and Players' Performance (39%); Recording Chips with a stake of 49% on Players' Performance and 31% on Fans' Experience; Aerodynamic Equipment has its frequency on Players' Performance with 58% and Health/Injuries with 21%; Reduction Fatigue Equipment with 53% on Players' Performance and 39% on Health/Injuries; Multiple Cameras has three problems/challenges worth mentioning, being Fans' Experience the most frequent with 54% and 23% for Fair Game/Refereeing and Players' Performance.

After building of the same frequency tables but for coaches, ex-players and referees (following tables 24, 25, and 26), one arrives at almost the same conclusions as in the overall view. For every football relationship category (coach, ex-player, and referee) the distribution is the same for every artifact, that is, the problems/challenges most frequently chosen are the same for each category as in the overall view. There are two exceptions worth noting, one from Recording Chip in Players' Eyes from ex-players answers and the other from the same artifact but from referees. The first diverges from the overview because the problem/challenge "Players' Performance" gets a higher percentage (49% the overall to 64%) and remaining 36% gets split into "Health/injuries" and "Fans' Experience". The second has a well-balanced distribution with 33% to "Health/Injuries" and "Players' Performance" and 17% to "Fair Game/Refereeing" and "Fans' Experience".

Universe = 30 Observations	Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Microchips Inside/Outside Skin	24	2	18	1
Recording Chip in Players' Eyes	2	2	15	10
Aerodynamic Equipment	7	4	19	5
Equipment for the Reduction of Physical Fatigue	18	2	24	1
Multiple Cameras allowing a 3D Game Simulation	0	11	10	22
Non-Existence of Referee, only Video-Referee	0	14	0	5
Artificial Intelligence in Refereeing	0	18	0	3
Virtual Reality Goggles for Stadium's Audience	0	0	1	20
Artificial Intelligence for Coaches	1	2	19	1
Virtual Reality Goggles for Video-Referees	0	17	0	3
Microchips Inside/Outside Skin	53%	4%	40%	2%
Recording Chip in Players' Eyes	7%	7%	52%	34%
Aerodynamic Equipment	20%	11%	54%	14%
Equipment for the Reduction of Physical Fatigue	40%	4%	53%	2%
Multiple Cameras allowing a 3D Game Simulation	0%	26%	23%	51%
Non-Existence of Referee, only Video-Referee	0%	74%	0%	26%
Artificial Intelligence in Refereeing	0%	86%	0%	14%
Virtual Reality Goggles for Stadium's Audience	0%	0%	5%	95%
Artificial Intelligence for Coaches	4%	9%	83%	4%
Virtual Reality Goggles for Video-Referees	0%	85%	0%	15%

Table 24 - Frequency of Recognition of Future Artifacts (Coaches)

Universe = 13 Observations	Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Microchips Inside/Outside Skin	10	0	7	0
Recording Chip in Players' Eyes	2	0	7	2
Aerodynamic Equipment	2	1	10	1
Equipment for the Reduction of Physical Fatigue	9	1	11	0
Multiple Cameras allowing a 3D Game Simulation	0	5	3	9
Non-Existence of Referee, only Video-Referee	0	6	0	2
Artificial Intelligence in Refereeing	0	9	0	3
Virtual Reality Goggles for Stadium's Audience	0	0	1	7
Artificial Intelligence for Coaches	0	1	9	0
Virtual Reality Goggles for Video-Referees	0	7	0	0
Microchips Inside/Outside Skin	59%	0%	41%	0%
Recording Chip in Players' Eyes	18%	0%	64%	18%
Aerodynamic Equipment	14%	7%	71%	7%
Equipment for the Reduction of Physical Fatigue	43%	5%	52%	0%
Multiple Cameras allowing a 3D Game Simulation	0%	29%	18%	53%
Non-Existence of Referee, only Video-Referee	0%	75%	0%	25%
Artificial Intelligence in Refereeing	0%	75%	0%	25%
Virtual Reality Goggles for Stadium's Audience	0%	0%	13%	88%
Artificial Intelligence for Coaches	0%	10%	90%	0%
Virtual Reality Goggles for Video-Referees	0%	100%	0%	0%

Table 25 - Frequency of Recognition of Future Artifacts (Ex-Players)

Universe = 7 Observations	Health / Injuries	Fair Game / Refereeing	Players' Performance	Fans' Experience
Microchips Inside/Outside Skin	3	0	1	0
Recording Chip in Players' Eyes	2	1	2	1
Aerodynamic Equipment	1	0	3	0
Equipment for the Reduction of Physical Fatigue	2	2	5	0
Multiple Cameras allowing a 3D Game Simulation	0	0	1	4
Non-Existence of Referee, only Video-Referee	0	0	0	0
Artificial Intelligence in Refereeing	0	2	0	0
Virtual Reality Goggles for Stadium's Audience	0	1	0	4
Artificial Intelligence for Coaches	0	0	2	0
Virtual Reality Goggles for Video-Referees	0	2	0	1
Microchips Inside/Outside Skin	75%	0%	25%	0%
Recording Chip in Players' Eyes	33%	17%	33%	17%
Aerodynamic Equipment	25%	0%	75%	0%
Equipment for the Reduction of Physical Fatigue	22%	22%	56%	0%
Multiple Cameras allowing a 3D Game Simulation	0%	0%	20%	80%
Non-Existence of Referee, only Video-Referee				
Artificial Intelligence in Refereeing	0%	100%	0%	0%
Virtual Reality Goggles for Stadium's Audience	0%	20%	0%	80%
Artificial Intelligence for Coaches	0%	0%	100%	0%
Virtual Reality Goggles for Video-Referees	0%	67%	0%	33%

Table 26 - Frequency of Recognition of Future Artifacts (Referees)

One will now do the cross match between the Recommendations Proposal from chapter 4 and the Results from the Questionnaire from chapter 6, finding out if the analysis followed the proposal presented by the researcher. After that, a final summary of the whole work will be introduced, summarizing what was done throughout this investigation work and, lastly what its limitations were, as well as recommendations for future work.

6.4. Validation of the Questionnaire's Results

6.4.1. Validation of the Present Artifacts' Matrix

This validation will be a comparison of the results from the recommendations proposal matrix to the results of the questionnaire, more specifically, the association of the artifacts to the problems/challenges and its grading, Tables 1 and 19, respectively.

Starting by the Image Acquisition artifacts and in the matrix, Cameras were attributed mostly to Players' Performance and a little to Fair Game/Refereeing. Checking Table 19, respondents mostly

chose Players' Performance, with 51% and a score of 2.18, with 28% and 2.10 choosing Fans' Experience and 18% and 1.92 Health/Injuries. Cameras for Fans' Experience was not included in the matrix, mostly because it is not a recent innovation and more a granted technology, but it is, obviously, used for television broadcasting and visualization on stadium's giant screens. For this reason and with a relatively high score of 2.10, two new matches in the matrix will be added for Fans' Experience Home Watching and Live Attendance.

Monitorization tablets had the majority of answers attributed to Players' Performance with 58% and a score of 2.31, 21% to Health/injuries with score 2.11, and 15% to Fair Game/Refereeing with 1.92. In the matrix we had exactly the same matches, Monitorization Tablets were matched with Players' Performance, Health/injuries, and Fair Game/Refereeing and with this score order expectancy.

Statistics Analysis Software had a distribution of 56% of the answers to Players' Performance with 2.37 and 16% to both Health/Injuries (2.09) and Fans' Experience (2.10). In the matrix, one has Players' Performance and Fair Game/Refereeing. In fact, television football coverage presents statistics to the viewer, not as developed as coaching staff uses, but as complementary information for the fans watching at home. For this purpose and with a relatively score of 2.10, a new match will be created for Fans' Experience Home Watching. As for Health/Injuries, statistics software using image acquisition is not the best technology for health and injuries in football nor the more viable and reliable.

Changing to Wearables, Players' Performance with 48% and 2.26 is the most frequent problem for Players' Movement Sensors and Health/injuries the runner-up with 39% and 2.12. In the matrix these are exactly the problems associated with Players' Movement Sensors, plus Fair Game/Refereeing. The score order goes in line with what was expected, Players' Performance with a higher score.

Performance Monitoring Sensors in the matrix are filled in by Players' Performance and a little to Fair Game/Refereeing. In the questionnaire, the results gave us 58% to Players' Performance with a score of 2.25 and 37% to Health/Injuries with 2.04 score. Since the exact name of the artifact is "Performance" a little bias might be influencing the results, but even so, the goal of this artifact is measuring and monitoring the performance of the athlete because for health concerns there are the previous artifact and the next two. The score of 2.25 is the fourth highest amongartifacts for the solution of Players' Performance problem/challenge, which means it is not the best artifact but still has a good score.

In the matrix, Wrist Bands were attributed to Health/Injuries and slightly Fair Game/Refereeing. In the results of the questionnaire one has 53% to Players' Performance with 2.14 and 42% to Health/injuries with 1.96. Wrist Bands do not have the ability to calculate the performance measures, such as passes and shooting, instead, it calculates heart rate, distance, sleep quality, and calories burned. For the goal of performance there are other sensors specifically for this regard. The score for Health/Injuries is lower than expected since the main goal of Wrist Bands is to help the user with Health

issues. The same goes to Vital Sign Sensors, where the only problem/challenge in the matrix is Health/Injuries (and Fair Game/Refereeing) and in the results both Health/Injuries (54% with 2.40) and Players' Performance (46% with 2.27) are chosen. The score for Health/Injuries for this artifact is the highest among artifacts, and is the best solution for this problem/challenge.

In the Video-Refereeing Technology, all artifacts were chosen by the respondents to solve both Fair Game/Refereeing and Fans' Experience problems/challenges, but with different distributions. Fair Game/Refereeing was always the top problem/challenge (From 71% to 90% and 2.00 to 2.67) and Fans' Experience with little distribution (From 10% to 21% and 1.33 to 2.70). In the matrix, all artifacts were selected to Fair Game/Refereeing and, except for Exact Stopwatch and Communication Hardware, to Fans' Experience. Exact Stopwatch might also be used by the whole audience watching the game for checking how much time is left in the match and with a score of 2.14 it is necessary to add a new number (47) for Fans' Experience Home Watching and Live Attendance. Communication Hardware between referees to Fans' Experience was chosen by only 10% with a score of 1.33, which means there is little importance of this artifact for this problem/challenge.

Simulation Technology includes Virtual Reality Goggles and the 360º Simulator. Virtual Reality Goggles was chosen for Fans' Experience with 60% and 2.00, Players' Performance 26% with 1.73 and Fair Game/Refereeing with 12% and 1.60. In the matrix, one also has these problems/challenges but with a higher importance for Players' Performance than the results given, since a higher score than 1.73 was expected. The score for Fans' Experience was 2.00, which is a good result, meaning that this would improve the experience of watching a football game.

The 360º Simulator has 44% for Players' Performance with 1.95, 38% for Fans' Experience with 2.18, and 11% for Fair Game/Refereeing. In the matrix, there are only Players' Performance and Fair Game/Refereeing. Even though the score for Fans' Experience is higher than Players' Performance, this artifact is built "merely" to improve the players' skills and technique, so fans' experience is not really a problem/challenge to be solved by it. The score of 1.95 was lower than expected because it is a very expensive technology with high potential for players' development.

Giant Screen had a distribution of 77% to Fans' Experience and 2.17 score and 15% to Fair Game/Refereeing with 2.29. These are the problems mentioned in the matrix, even though this artifact giant screen is more suitable for Fans' Experience than Fair Game/Refereeing.

In the end, the analysis of the artifacts resulted in:

- Eight of the 15 artifacts with an exact match of the results of the questionnaire and the proposal matrix (Monitorization Tablets, Players' Movement Sensors, Cameras in Refereeing, Goal-Line Technology, Hawk-Eye Technology, Communication Hardware, Virtual Reality Goggles, and Giant Screen);

- Three artifacts that resulted in the addition of a match between the artifact and Fans' Experience problem/challenge that was not being considered in the proposal's matrix, and (Cameras in Image Acquisition, Statistics Analysis Software, and Exact Stopwatch);
- Four artifacts for which the questionnaire gave us more problems/challenges than the matrix and the researcher agreed (Performance Monitoring Sensors, Wrist Bands, Vital Signs Sensors, and 360º Simulator).

New topics added to the present artifacts matrix:

Cameras in Home Viewing and Live Attendance

Since the beginning of television broadcasting, cameras have been the number one tool to transmit what is happening in the stadium to wherever the audience is tuning in, homes, bars, cafés, and many more. Cameras have been evolving from the vintage black and white image to 4K resolution or even 3D. New types of cameras have been added for multiple goals and different shots, as is the case of spider-cam, the camera hanging above the field getting a top view of the field and being able to cover the whole field with its movement. A camera inside the goal is also an innovation from recent years, a tiny camera allowing the audience to get a view inside the goal where the goalkeeper operates. Cameras are also used inside the stadiums to feed the giant screens with special content from the game. Usually these cameras tape special moments from the crowd, bench, outside view of the stadium, locker room, and access tunnel images and replays of the game. These add even more to the special experience of the fans, improving not only the lived atmosphere but also whatever is happening around the football game, because football is not only made up of those 90 minutes of competition.

Statistics Analysis Software in Home Viewing

At first, statistics analysis software was mentioned only as a coaching staff focused technology, but this is also used in television transmissions. Many television stations have their own graphics, frequently showing statistics of the game's occurrences as a bottom note on the screen. Half time is usually a time when a more complete report is presented with many statistics about the players and teams involved. Therefore, the fan can get more insightful opinion and perspective of the age, having actual data corroborating an abstract judgement of the game. Statistics does not display everything of the game, but it is an initial analysis that can be made with the observation of it.

Exact Stopwatch in Fans' Experience

The artifact exact stopwatch is an evolution of today's stopwatch. This can be used and controlled by the referee as a way to have a fair notion of the duration of the game, instead of the abstract use of extra time. Fans are also a consumer of this information as it is crucial evidence of the experience and, indeed, the problem/challenge "Home Watching" and "Live Attendance" can be solved by this artifact.

6.4.2. Validation of the Future Artifacts' Matrix

For a validation of the Future Artifacts' Matrix the comparison will be between the future artifacts matrix and the results of the last questionnaire answer, more specifically Table 2 (Chapter 4 Section 4.2.1) and Table 23 (Chapter 6 Section 6.3).

First, the artifact Microchips Inside/Outside the Skin in the matrix was attributed to Health/Injuries and Players' Performance problems/challenges. In the questionnaire, the respondents distributed their answers 55% to Health/Injuries and 39% to Players' Performance, meaning this confirms the solution of this artifact. Recording Chip in the Players' Eyes has 49% of the answers associated with Players' Performance and 31% to Fans' Experience. On the other hand, the matrix has this artifact only as a potential solution to Fans' Experience problem/challenge. Video recorded by the vision of the players' might be useful to a post-match analysis in which the coaches having the perspective of the player could apply insights regarding certain aspects of the game. A cross match will be added to this artifact with number 20 to Post-Game Analysis and Practices Adaption. Aerodynamic Equipment, in the matrix, was associated with Players' Performance and in the respondents' opinion 58% of the answers agree with the Players' Performance and 21% also chose Health/Injuries. Aerodynamic Equipment might have an impact on the players' health, maybe reducing his/her fatigue, but the real impact will be on the players' performance. Fatigue Reduction Equipment has 53% of the answers to Players' Performance and 21% to Health/Injuries. The matrix had the same results with the artifact associated with both Health/Injuries and Players' Performance. Multiple Cameras creating a 3D Simulation has 54% of the answers to Fans' Experience problem/challenge, 23% to both Fair Game/Refereeing and Players' Performance. The matrix does not hold a cross match to Fans' Experience, but agrees with the Fair Game/Refereeing and Players' Performance. It does make sense for 3D simulations to be used by fans in television broadcasting, enhancing the perspective of certain replays improving the understanding of the match at home. A new match will be added for this intersection between 3D simulation and Fans' Experience Home Watching. Non-existence of Referee answers mainly chose Fair Game/Refereeing with 76% and 24% to Fans' Experience. The matrix contemplates only the Fair Game/Refereeing for this artifact because the non-existence of referee

would have little impact on the fans' experience. Artificial Intelligence in Refereeing has 82% of the answers attributed to Fair Game/Refereeing and 14% to Fans' Experience. The matrix appointed Fair Game/Refereeing as the only possible problem/challenge to be solved by this artifact and as the same as the previous artifact, this would not have an impact on the fans' experience. Virtual Reality Goggles for live audiences has a big majority (93%) of the answers to Fans' Experience problem/challenge and in the matrix, one can observe the same as the only problem/challenge to be solved by this artifact. Artificial Intelligence, this time, for coaches, has 85% of the answers to Players' Performance. In the matrix, in addition to Players' Performance, it was also chosen to Fair Game/Refereeing as Same Opportunities and Illegal Betting perspective. Virtual Reality Goggles for Video-Refereeing had 80% of the answers to Fair Game/Refereeing and 16% to Fans' Experience. The Fans' Experience is not in the matrix, but Fair Game/Refereeing is.

As a result, one can say:

- Four artifacts have the same problems/challenges associated both in the matrix and in the table results of the questionnaire (Microchips; Fatigue Reduction Equipment; Virtual Reality Goggles for Audience, and Artificial Intelligence for Coaches);
- Two artifacts had more problems/challenges in the questionnaire than the matrix, these were added to the matrix (Players' Performance in Eye Recording Chip and Fans' Experience in 3D Simulation);
- Four artifacts had more problems/challenges in the questionnaire results than the matrix but were not added because the artifacts would not have any impact on the chosen problems/challenges (Aerodynamic Equipment, Non-Existence of Referee, Artificial Intelligence for Refereeing, and Virtual Reality Goggles for Video-Referee).

New topics added to the future artifacts matrix:

Eye Recording Chip in Practices Adaptation and Post-Game Analysis

As a regular camera, the eye recording chip attempts to tape the events that occur in a game but from a player's perspective. As explained above, the chip would be in the player's eye, allowing a personalized footage from the player's point of view. This is an artifact that could be used in a post-match analysis and practices adaptation, using the videos to give feedback to the players, showing them what was correct, wrong, and could be better. A new standing point would add more insight to coaches and would allow them to place themselves in the players' spot for a better understanding of a specific play of the match. With this insight given by the footage, new drills, specific work, and practices speeches could be designed specifically to attack the flaws observed and improve the players'

decision-making ability. A player's recording could be also be used to record other players' behavior in the game; although the principal focus of a player is the ball, the player also looks at his/her own teammates.

Multiple Cameras creating 3D simulation for Home Viewing

Football's home viewing is always trying to reinvent itself; new cameras, better quality of video and commentary, innovative design of the graphics and statistics, and much more. Creating a 3D simulation of the game that could be used to review plays and watch replays would be much more appealing than what is used nowadays. This simulation would replace the high number of cameras necessary to cover multiple angles of the field, and instead would be steady cameras without human control, necessary for the creation of the simulation. The simulation would be like a virtual reality environment in which the user gets to choose which angle to watch, in television this would require the television broadcasting team to control it.

7. SUMMARY OF THE WORK

After the Analysis, it is time to summarize and reflect on the work done herein, as well as mention its limitations and future recommendations.

7.1. SUMMARY

The two main pillars of this work are Technology and Sports. Technology that we discuss has a concept behind it, Internet of Things, where all technological physical objects are a part. These devices are used by humans to extend the connectivity to the world anywhere, anytime, and with anything. We use them to collect data from the environment, access infinite data from the internet, monitor ourselves, and connect with each other. Each device has its use and goal but with the online interactivity, we can have a web of data with all these devices linked with each other and with the internet, improve the user experience, monitor our daily routines, and easily access knowledge and of data. With all this interactivity between devices, people, machines and environment, Internet of Things evolved to Internet of Everything, where this "Everything" represents every single intervenient in this web connected to each other and the ability to have access to everything.

Football is one of the most famous, if not the most famous, sport in the world. The people, companies, associations and money involved are innumerable in a sport that is a simple two team competition for scoring more goals than the opponent and whoever scores more goals wins. Obviously, this is a simple explanation, football involves many competitions either nationally or internationally and clubs or countries with many formats, leagues, tournaments, cups and many others. Football comprises players, coaches, fans, referees, club officials, media reporters, and these people have elevated football to what it is today, a world phenomenon. Football can be played without technology, but as technology has evolved, so has football. Many technologies are now implemented in the football environment, for example, to improve fans' experience, broadcasting, to develop players' ability to be better at what they do, and help coaches and referees in their job and tasks. This is where Internet of Everything meets Football.

As of our daily routines, Football has also started to use the interactivity of devices and technology in their special environment. Nowadays, technology holds a highly important role in sports, and is usually the difference maker in final results and sports success, enhancing competitive advantages able to help players achieve success at what they do.

This research used Design Science Research for studying the impact of Internet of Everything devices in Football. We built a Recommendations Proposal matrix with artifacts being the devices used in football, based on a prior search for present technologies used in football today. This matrix had a list of artifacts used in football matched with football's problems/challenges also recognized in a

previous search. The recommendation proposal was to explain which artifact would solve each problem/challenge and in what way possible. This was also done for future artifacts known by a research of possible and future implementations prone in football. A list of future artifacts was also matched with football problems/challenges in order to recognize which would be a fit and solution to these problems/challenges.

After the recommendations proposal, we validated it with an audience opinion using a questionnaire. This questionnaire was designed to validate the results of both matrices, questioning the target audience about the list of artifacts and the problems/challenges. This target audience was composed of academic person involved in technology and/or football, football coaches, football players and ex-players, football referees, and football officials. They were asked personal information details, to recognize the list of artifacts, to match each artifact with any problem/challenge, to give it a score and, lastly, to match the future artifacts list to the same problems/challenges.

As a result, a data analysis was run on the 43 observations' answers and results are presented in chapter 6.

7.2. CONCLUSIONS

In this research we explained the importance of technology in football. In light of the questionnaire's results, there is much to be done in the implementation of it, as it is slowly being used and received by the football community. The competitive advantages are clear and in all the processes of football, refereeing, coaching, health, and fans the benefits were clarified, as technology is a huge facilitator and difference-maker. Nowadays, technology is still not cheap but as years go by more businesses will rise based on technology in football and the prices should drop, making the artifacts discussed more common in all departments of a football team, not only in professional ones, but also in youth development and regional leagues. The knowledge of the technology artifacts will also be more common, and people related to football will get used to technological concepts applied in football. People in football's world will benefit as football will grow as an even more outstanding entertainment and competitive show.

7.3. LIMITATIONS AND FUTURE WORK RECOMMENDATIONS

Being an academic work, this research had its limitations and the one doing it should develop a critical review, pointing out what could have gone better and improving aspects. Therefore, one limitation concerns the dissemination of the questionnaire to the target audience. Since we had five observation categories - coaches, players, ex-players, referees, and academic personas – there should

be a balanced representability of these groups regarding the number of people answering the questionnaire, to have equal analysis of each group and, consequently, better conclusions about the opinion of each category.

The questionnaire was disseminated personally or via online through a word document and the data integration and analysis in Excel. This was viable due to the relatively modest amount of observations but having even more observations, it would not be possible to aggregate too many answers and do the data processing manually in Excel. This questionnaire should be made available online on a questionnaire platform for most of the people with access to internet, but not excluding the people with no access, who should have a questionnaire delivered personally, decreasing the representation bias. Another observation balance that should be considered is about the age range. With the same procedure of the categories, one should have a balanced representability of the age ranges of the observations.

The answers of the questionnaire were not always perfect. There were observations missing crucial data, for example one artifact was used by respondent, and attributed a problem/challenge but forgot to score it. In these cases, a score was manually attributed, in the data processing, with the average of the rest of the answers for that artifact and problem/challenge.

A possible bias reason was discovered in the questionnaire when presenting the list of the artifacts, with each one of them being aggregated in technologies (Image Acquisition, Wearables, Video-Referee, Virtual Simulation, and Other). Admittedly these, more specifically “Video-Referee”, could induce and influence the behavior of the respondents when answering the questionnaire, as they are asked to choose a problem/challenge to the artifact and in the “Video-Referee” artifacts and with this technology label, the respondents might feel the need to choose the problem “Fair Game/Refereeing”. Another problem regarding the artifacts is the lack of an explanation of each artifact, letting the respondent have their own idea of it. An explanation would end any doubt of the respondents but would make the questionnaire even longer, which should be a concern in the design of a questionnaire. It could also have asked to score the future artifacts in the problems/challenges, but then again, the questionnaire would be exhausting.

The respondents always had the opportunity to suggest an artifact that was not talked about in the questionnaire. There was only one suggestion (by a referee respondent) about a device used by the flag of the assistant referees. This device is a button in the assistant referee' flag that warns the referee about a decision of the assistant and it is an artifact that should be inserted in the present artifacts list.

With a critical review of the work made, a researcher has the ability to improve future works by recognizing the limitations of past ones. If this research continues, these limitations should be take into account for a more meticulous analysis and better results.

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ANNEXES

	Image Acquisition						Wearables								Refereeing										Simulation Technology				Other	
	Cameras		Monitorization Tablets		Statistics Analysis Software		Players' Movement Sensors		Performance Monitoring Sensors		Wrist Bands		Players' Vital Signs Sensors		Cameras		Goal-Line Technology		Hawk-Eye Technology		Exact Stopwatch		Communication Hardware		Virtual Reality Goggles		360º Simulator		Giant Screen	
Observation	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it	Knows	Uses it
1		x													x		x				x			x	x				x	
2	x		x		x				x		x			x	x		x		x										x	
3	x		x		x		x		x				x		x		x		x		x		x				x		x	
4	x		x			x	x		x		x		x		x		x		x		x				x		x		x	
5	x		x		x		x		x			x		x	x		x		x		x						x			x
6															x		x						x							
7		x	x			x		x	x		x		x		x		x				x				x		x		x	
8		x	x			x	x		x		x			x	x		x		x		x			x		x		x		
9	x		x			x	x		x		x		x		x		x				x				x		x		x	
10		x	x		x		x		x				x		x		x								x		x		x	
11		x	x		x		x		x		x		x		x		x		x		x								x	
12	x				x		x				x		x		x		x				x								x	
13		x	x		x		x		x				x		x		x						x		x		x		x	
14	x				x		x		x				x		x						x		x						x	
15		x	x			x	x		x						x		x		x		x		x		x		x		x	
16		x	x												x		x		x		x			x					x	
17		x	x			x	x		x				x		x		x		x		x		x		x		x		x	
18		x	x			x	x		x		x		x		x		x		x		x				x		x		x	
19		x		x		x		x		x		x	x		x		x		x						x		x		x	
20		x	x		x						x		x		x		x		x		x				x		x		x	
21		x							x						x		x						x		x				x	
22	x		x		x		x		x				x		x		x										x			
23	x		x		x										x		x						x						x	
24		x		x		x	x		x		x			x	x		x		x		x				x		x		x	
25	x		x		x		x		x		x		x		x		x		x		x				x		x		x	
26	x		x			x	x		x		x		x		x		x				x				x		x		x	
27		x	x		x		x		x			x		x		x	x		x			x		x	x		x		x	
28		x			x		x		x		x		x		x		x		x		x		x		x		x		x	
29		x	x			x	x		x		x		x		x		x		x		x				x		x		x	
30		x	x		x		x		x		x		x		x		x		x		x				x		x		x	
31		x	x		x		x		x		x		x		x		x		x		x									x
32	x		x		x		x		x		x		x		x		x			x		x								
33		x	x			x	x		x		x		x		x		x		x		x				x		x		x	
34	x		x		x		x		x		x		x		x		x				x						x		x	
35	x		x		x		x		x		x		x		x		x		x		x				x		x		x	
36	x		x		x		x		x		x		x		x				x						x		x		x	
37		x	x			x	x		x		x		x		x		x		x		x				x		x		x	
38	x		x		x				x				x		x		x								x		x		x	
39	x		x		x		x		x				x		x		x		x		x				x		x		x	
40	x		x		x		x		x		x		x		x		x		x		x				x		x		x	
41	x		x		x		x		x		x		x		x		x		x		x				x		x		x	
42		x			x		x		x		x		x		x		x		x		x						x		x	
43	x		x		x		x		x		x		x		x		x		x		x				x		x		x	

Table 27 - Answers for the Present Artifacts Recognition Question

For the next tables, the rows will continue to be observations and the columns will be the match between artifacts and problems/challenges, where:

1: Health/Injuries
2: Fair Game/Refereeing
3: Players' Performance
4: Fans' Experience

In the cells, it is the score given by the respondents to that specific match between artifact and problem/challenge, i.e., observation 1 gave a 3 score to Cameras in Players' Performance (3) problem/challenge.

	Image Acquisition												Wearables																Refereeing																Simulation Technology								Other			
	Cameras				Monitorization Tablets				Statistics Analysis Software				Players' Movement Sensors				Performance Monitoring Sensors				Wrist Bands				Players' Vital Signs Sensors				Cameras				Goal_Line Technology				Hawk-Eye Technology				Exact Stopwatch				Communication Hardware				Virtual Reality Goggles				360º Simulator				Giant Screen			
Observation	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1			x																											x				x					x				x												x
2				x	x		x				x						x		x			x			x		x			x		x			x																			x
3			x			x	x				x		x		x				x						x				x				x																			x
4		x	x			x	x				x		x		x		x		x						x				x				x																			x
5	x		x	x	x		x		x		x		x	x	x										x				x				x																			x
6																										x				x																						
7			x				x				x				x				x		x		x		x				x																							x
8	x		x	x			x				x		x		x		x		x		x		x		x				x																						x		x
9			x				x				x		x		x				x		x		x		x				x																						x		x
10			x	x			x				x	x	x				x						x		x		x		x				x																	x		
11	x		x				x				x		x		x								x		x				x																								
12		x	x	x	x		x				x		x		x				x		x		x		x		x		x				x																	x		x
13			x	x		x	x		x		x				x								x		x				x																						x		x
14	x		x	x					x		x	x			x								x		x		x		x				x																	x		x
15			x	x			x		x		x		x				x		x						x				x																						x		x
16			x				x																		x		x				x																					x		x
17			x				x				x				x		x		x		x		x		x				x																					x		x
18			x				x				x		x						x		x		x		x				x				x																	x		x
19	x		x	x	x	x	x	x	x		x	x	x		x		x		x		x		x		x				x		x		x													x	x	x	x		x		x
20			x				x				x										x		x		x		x		x				x																	x		x
21			x	x													x		x						x				x																					x	x	x				x
22			x				x				x				x								x		x																													
23	x		x	x		x	x	x		x	x	x													x				x		x																			x	x	x
24			x		x	x	x	x	x		x	x	x		x				x	x	x		x		x				x																						x		x
25			x				x				x		x		x				x		x		x		x				x																						x		x
26	x		x	x	x	x	x	x			x	x	x		x		x		x	x	x	x	x		x	x			x																			x	x	x	x		x		x
27				x	x		x		x		x		x		x		x		x		x		x		x				x		x		x																	x		x
28	x		x	x	x	x	x		x		x		x		x		x	x	x		x		x		x				x				x																	x		x
29	x		x	x	x		x		x		x		x		x		x		x		x		x		x				x		x		x																	x		x
30	x		x	x	x		x				x				x				x		x		x		x				x		x		x																	x		x
31			x				x				x				x		x		x				x		x				x		x		x																	x		x
32																																						x															
33	x		x		x		x				x		x		x								x		x				x																							x		x
34			x	x		x	x			x	x				x				x				x		x				x																						x		x
35			x		x						x		x		x								x		x				x																						x		x
36			x				x				x		x		x		x						x		x				x																						x		x
37				x	x		x				x				x	x	x						x		x				x																						x		x
38			x				x				x				x		x						x		x				x																						x		x
39	x		x	x			x				x	x	x				x						x		x				x																						x		x
40			x	x			x		x	x	x	x	x	x	x	x	x						x		x				x		x		x																	x		x
41			x				x		x		x				x		x						x		x				x																						x		x
42	x		x	x							x	x	x		x		x						x		x				x		x		x																	x		x
43			x				x				x		x		x		x						x		x				x				x																	x		

Table 28 - Answers for the match between Present Artifacts and Problems/Challenges

	Image Acquisition												Wearables																Refereeing																Simulation Technology				Other			
	Cameras				Monitorization Tablets				Statistics Analysis Software				Players' Movement Sensors				Performance Monitoring Sensors				Wrist Bands				Players' Vital Signs Sensors				Cameras				Goal-Line Technology				Hawk-Eye Technology				Exact Stopwatch				Communication Harware				Virtual Reality Goggles				360º Simulator				Giant Screen			
Observation	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1			3																										2					3				2					2													3
2				1	2		2				2						2		2		2		2		2		2		2		2		3		3		2		2																			2
3			2			2	2				2		2		2		2		2						2		2		2				2				2				2								2							2
4		2	2			2	2				2		3		3		3		3		3		3		3		3		2				2				2				2								2	3			2	3
5	2		2	2	2		2		2		2		2	1	2		2		2		2		2		2		2		1				1				1				1								2	2		2				2
6																													3				2								3				1							
7			2				2				2				1				1		1	1	1		1				2				2				3				3				2				2					2		3
8	2		3	1			3				3		3		3		3		3		3	3	3		3		3		3				3				3				3				3					3			1	3
9			2				3				3		2		2		2		2		2	2	2		2				2				3				3				2								2					2		2
10			2	3			3				3	1	2				2								3				3	3			3		3												3					2		
11	3		2				2				2		2		2				2		2		2		2				3				3				3																			
12		3	2	2	1		2				2		1		2				2		1	2	3		2				2		2		2				3				1				2				1	1		1		1		2
13			2	1		1	2		1		2				2				2				2		2				2				3				2								2					2					2
14	2		2	3					2		2	3			2				3				3		3				3		3		3		3		2		1																	3
15			2	2			2		2		2		2				2		2						3				3				3				2				3								1				1			3
16			2				2																		2		2		2				2				2				2															2
17			2				2				2				2		2		2		2	2	2		2				3				3				3				3								1				1			3
18			2				3				3		2						2			2	3						1				2				1				2								2				3			2
19	3		2	2	2	2	2	2	3		2	3	2		2		2		3		2	1	3		3				3	3			3		3		3		3		3				2	2	2	2	2				2		3	2	3
20			3				3				3										3	3	3		3				3				3				2				1								2					2
21			2	2													2		2						2				2				3								2									1	1				2
22			3				3				3				2				2						3				2				3																				3			
23	1		3	3		3	3	3		1	3	3																	3				3		3						3												3	3	3
24			3		3	3	3	3	2	2	3	1	3		3				3	2	2		2		3				2				2				3				2								2							1
25			2				2				2		2		2				2				2		2				3				3				3				3								2				2			2
26	1		1	1	1	1	1	1		1	2	2	1		1		1		1	2	1	1	2		2		2		2	1			2				2				2					1			2		1	1	2			2
27				2	2		3		2	1	3		3	2	3		3		3		2	3	3		2				2		3	3			2		1		1		3						2				2			2
28	2		3	2	3	3	3		3	3	3		3	2	3		3	2	3		3	3	3		3				3				3				2				3								3					2		
29	2		2	2	2		2		2	2	2	2	2		2	2	2		2	2	2	2	2		2		2		1				3		3		2	2	3		1	1	1		2		3	2	2	2	3		2		3
30	2		2	2	2		2				3				3				2		2		2		2				3		3		2		2				3				2		2		2				2	2			2
31			2				1				1				2		1		2			1	2		1				2		1		2				2	2	2		2								1				1			1
32																																									2				2							
33	2		3		2		3				3		3		3				2			2	2		2				2				3				2				2								2				2			2
34			3	3		2	3			2	2			2	2				3			2	3				2				3				3				3									3			3		3		3
35			1		1						2		1		2				2		1	2	1		2				2				3				2				1								1				1	1		1
36			2				2				2		1		2		1		2		1	2	1		2				2				2				2				2								2					2		2
37				2	2		2				3		3		3	3	2		3		3	3	3		3				3				3				3				2		3		3								3			3
38			2				2				2						2		2		2		2		1				3																				2				2			1
39	2		2	3			3				3	2	2		2				2		3		2		2				2				3		2		1				3		2						1				2			1
40			3	3			2		2	2	3	2	3	1	3	2	3		3		2	3	3		3				3		2		3		2		2				3								1				2			1
41			2				2		2		2				2		2		2		2	2	2		2				3				2				2				2								2					2	2	2
42	1		2	2							2	2	1		2		1		2		2	2	2		1				3				3				3				3								2				1			2
43			1				2				2		2		3		2		3		3		3			1			3				2				1				3								3			2		

Table 29 - Answers for the score between Present Artifacts and Problems/Challenges

	Microchips IO/OU Skin				Recording Chip Eye				Aerodynamic Equipment				Fatigue Reduction Equipment				Mult Camera 3D				VAR Only				Artificial Intelligence in Refereeing				Virtual Reality Audience				Artificial Intelligent Coaches				Virtual Reality VAR			
Observation	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	x							x																								x			x						
2									x		x				x																				x						
3	x		x		x		x				x		x		x					x		x				x					x				x				x		
4	x		x	x			x	x			x	x	x		x	x			x	x		x		x		x		x			x			x		x			x	
5													x		x					x						x														
6														x																											
7	x									x		x			x					x						x														
8							x						x						x	x															x					
9	x		x					x	x		x				x				x	x		x				x					x				x				x	
10	x		x				x	x					x					x		x		x				x					x				x					
11	x		x						x		x							x																						
12	x						x	x				x		x	x			x	x	x											x									
13	x						x		x		x		x		x			x	x	x						x		x												
14											x		x		x																										
15	x				x		x		x		x		x		x				x	x																				
16	x		x		x		x				x		x	x	x					x											x				x					
17	x		x				x					x	x		x					x											x									
18	x						x				x		x					x				x				x					x				x					
19			x								x				x			x		x		x				x					x				x					
20	x		x			x	x	x	x		x		x		x			x		x		x				x					x				x					
21															x											x															
22	x							x		x					x					x		x				x					x				x					
23	x	x	x						x	x	x		x	x	x			x		x		x		x							x				x					
24							x				x		x																		x									
25	x		x				x				x		x		x				x			x				x					x				x					
26									x		x		x		x					x											x									
27						x	x						x		x					x											x				x					x
28													x		x																										
29	x	x	x				x	x											x	x											x									
30	x		x										x		x				x	x																				
31	x		x		x	x	x						x		x			x	x	x		x				x	x				x					x	x		
32	x										x				x					x																				
33	x										x				x					x																				
34	x		x			x		x		x		x	x		x			x		x		x				x					x	x			x					
35	x		x					x			x				x					x		x				x					x				x					
36	x		x												x																									
37									x		x				x				x	x						x					x									
38	x		x				x				x		x		x					x		x				x					x		x	x			x			
39	x		x				x						x		x					x						x											x			
40	x		x				x				x		x		x			x	x	x				x		x		x									x			
41	x		x					x			x		x		x			x		x		x				x					x						x			
42	x		x								x				x			x	x	x		x		x		x		x									x			
43	x							x			x		x		x									x		x					x							x			x

Table 30 - Answers for the match between Future Artifacts and Problems/Challenges