UNIVERSITY OF LJUBLJANA
FACULTY OF ECONOMICS

MASTER'S THESIS

DIGITALIZATION IN SPORT

Ljubljana, March 5th, 2019 ENSAR DEMIR

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LIST OF ABBREVIATIONS

AFC – Asian Football Confederation

AR – Augmented Reality

ARPANET –Advanced Research Projects Agency Network

BC – Before Christ

CD – Computer Disk

CONCACAF – Confederation of North, Central American and Caribbean Association Football

CONMEBOL – Confederación Sudamericana de Fútbol

CRM – Customer Relationship Management

DoS – Denial of Service

ENIAC – Electronic Numerical Integrator And Computer

FIBA – Fédération Internationale de Basketball Amateur

FIFA–Fédération Internationale de Football Association

FTP – File Transfer Protocol

GDPR – General Data Protection Regulation

GPS – Global Positioning System

IMAX – Image MAXimum

IoT – Internet of Things

IT – Information Technology

ITF – International Tennis Federation

M2M – Machine-to-machine

NBA – National Basketball Association

NCAA – National Collegiate Athletic Association

NFL – National Football League

OFC – Oceania Football Confederation

PC – Personal Computer

RF – Radio Frequency

RFID – Radio Frequency Identification

SaaS – Software as a Service

SMTP – Simple Mail Transfer Protocol

SQL – Structured Query Language

TCP/IP – Transmission Control Protocol/Internet Protocol

UEFA – Union of European Football Associations

USA – United States of America

UWB – Ultra-Wide Band

VAR – Video Assistant Referees

VPN – Virtual Private Network

VR – Virtual Reality

WWE – World Wrestling Entertainment

WWW – World Wide Web

INTRODUCTION

We are living in the world of rapid changes and technology. Smart devices and digitalized solutions have become a part of everyday life. Companies as well as individuals use a wide range of technologies in order to cope with huge amounts of data. Sport is an industry that develops very fast and attracts a great number of viewers every day. That leads to the fact that players, clubs, federations and other sports organizations have become companies and that sport has turned into much more than scoring goals or baskets, practicing, winning, and losing. As the technology develops from day to day, it has also found its way to become a part of sport. Most of technologies that are used in sport have appeared recently, which leads to the main problem of master's thesis. Field of digitalization in sport is still unexplored and we are relatively unaware how things work in the background.

Sport is a very wide term because there is enormous number of activities that are categorized as a sport. In order to not lose focus in the thesis, it was decided to limit the research to three sports: football, basketball and tennis. This decision was made after the selection procedure. The first reasoning was to go with sports that are played with a ball. Sports played with a ball are usually very dynamic and it would be interesting to see how technology can support huge amount of changes and arising data. After the first step of filtering the selection, it was decided to choose most popular sports. Defining the term "most popular" in sport is very difficult because many factors, such as number of visitors, TV viewership number or number of professional athletes, can influence the selection. On the other hand, majority of lists of the most popular sports contain similar results, no matter which factors were considered. After limiting the selection to the most popular sports and getting a reasonable number of sports in the selection procedure, the last step was to limit the selection to a certain geographical region. Sports, which are popular globally (somewhere more, somewhere less), got an advantage over sports that are extremely popular in some regions, but highly unpopular in others. Some examples are cricket (very popular in England and Australia), hockey (popular in USA, Canada, Russia and northern Europe), American football and baseball (very popular in the USA) (TOTAL SPORTEK, 2018). In the end, football, basketball and tennis appeared as the best solution.

Theoretical background of the thesis starts with the brief history of sports and development of digital technologies. After information about history of football, basketball, tennis and digital technologies, theoretical background continues with current digitalization trends, Internet of Things (hereafter: IoT) and Virtual Reality (hereafter: VR). Internet of Things is a term that is used very often nowadays. It is commonly known as the concept of connecting any device, which has on and off switch, to the Internet (Morgan, 2014). IoT device is basically any physical object than can be connected to the Internet and controlled that way (Ranger, 2018). Usually, some basic knowledge about this topic stops here. Theoretical part of the thesis aims to expand this general knowledge and move forward from basic definitions. What are the benefits and threats of IoT, how to secure IoT, how

IoT works in real life, are among questions answered in this chapter. Theoretical background also includes an explanation how IoT is used in sports and ends with the brief overview of the Virtual Reality.

The following sections of the thesis represent its main part. Technologies used is sports will be classified in three categories: technologies for match regularity, technologies for player/team performance and technologies for fans' experience. The first idea was to divide technologies by each sport in terms of applicability. However, some technologies can be used in more than one sport. Considering that, classification of technologies by sport is not an appropriate solution. The final classification came from an idea to group technologies by something common for each sport. Matches, players or teams and fans represent three main parts of each sport and they are great base for the classification of technologies.

Dynamics of each sport have rapidly increased over the years, which has become a huge problem for referees. Everything happens so fast that it is almost impossible to decide in one moment whether the ball crossed the line or not, whether there was a violation or a personal foul or not, whether the field goal was scored before the time has run out or not, etc. Technologies for match regularity should help referees to resolve this issue and allow players or teams to win fairly, not because of referees' mistakes.

Professional athletes dedicate their lives to practicing, getting better and achieving the best possible results on individual and team level. Technologies for player/team performance should enable them to achieve better results.

Finally yet most importantly, sports are played for fans and their support means everything to athletes and teams. In addition, they represent a big source of revenues for sports organizations. Technologies for fans' experience should make them feel even better and increase their experience.

Another important thing to mention is that prices of the technologies used in sports are rarely published. They are a part of agreements between players, sport organizations and technology providers. So, the technologies' prices and value for money will not be analyzed in the thesis. Similarly, most technologies for game regularity and team performance are not available for public use. That fact will be overcome with getting needed information about them from different sources like providers' web pages and video presentations.

The purpose of the master's thesis is to find out about digitalized solutions and technologies used in sports industry, and contribute to this actual, popular, but also unexplored field.

There are several objectives of the master's thesis. The first objective is gathering information about history of sports, digital technologies, Internet of Things and Virtual

Reality from the relevant sources and explaining the IoT concept as the theoretical background of the thesis. The second objective is analyzing different technologies used in sports industry. During the analysis, the objective is to review available video presentations of technologies, get free trials of some technologies, go over case studies and deeply analyze technology providers' web pages.

The theoretical background of this master's thesis will be based on the literature review. Relevant literature provides all required information for analysis of this concept.

Analysis of the following parts of the thesis require more than one method because this field is very new and unexplored, so literature does not offer much information. The analysis starts with the review of technologies providers' web pages and it continues with getting information from available video materials about technologies used in sports. In addition, the analysis contains a review of available case studies and technology free trials.

1 HISTORY OF SPORTS AND DEVELOPMENT OF DIGITAL TECHNOLOGIES

Sport is a very popular term nowadays and it has become a part of everyday life. Before moving to development of sports throughout the history, it would be interesting to check how sport is defined. Sport can be defined as an activity that involves skill and physical exertion in which a team or an individual competes against others or another for entertainment (English Oxford Living Dictionaries, 2018). This definition misses a very important aspect of sport. Nowadays sport is not played for entertainment only. Professional athletes earn a lot of money from playing sport, which means that sport can be described also as a job than rather only as entertainment. Another definition of sports includes this aspect and says that sport is a game, competition or similar activity that is done as a job or for enjoyment, takes physical effort and skill and needs to be played or done by particular rules (Cambridge Dictionary, 2018).

The history of sports is as old as the history of humankind. Talking about beginnings of sports that are documented or recorded takes us at least 3000 years back in history. The early history of sports involves activities such as throwing stones or spears, fighting or training for hunting or war. First formal sports event recorded in the history of sports are the first Olympic Games held in 776 BC in Ancient Greece. Sports that were part of the first Olympic Games are wrestling, jumping, human and chariot races, disk and javelin throwing and similar (Bellis, 2018).

Throughout the years, different sports have been developing in different regions and continents. Therefore, it is possible to talk about traditional African sports, traditional Asian sports, sports of the ancient Mediterranean world, sports in middle ages, sports in the Renaissance or sports in modern periods. Years and years of sports development brought an incentive for creating an international sports event. Pierre de Coubertin selected the first

members and created the International Olympic Committee in 1894. Conference held at the Sorbonne in Paris resulted with the organization of the first Olympic games of the modern era that took place in Athens in 1896. This event was one of the most important events in the sports history and was the huge step towards the sports that we are witnessing today (Rowe, Maguire, Thompson & Guttmann, 2018).

1.1 History of football

Modern football was invented in England in the 19th century. A series of meetings organized by clubs from London and its surroundings in 1863 resulted in the first printed rules of football, which prohibited the carrying of the ball. That was the first step of differentiating football from rugby. By 1870, Football Association prohibited all hand contacts with the ball excluding goalkeepers. In 1871, fifteen clubs that were part of Football Association accepted an invitation for first cup competition and participated in purchase of the trophy. In the beginning, football was played by working-class population on Saturday afternoons when they were free from work. As the interest for football rose, some clubs started charging admission for spectators and were able to pay some amount of money to attract better players. Although Football Association was against professionalism in the beginning, they had to accept it because the payment of players became a usual act. Introducing professionalism in football triggered organizing the first official Football League in 1888 (Weil, Joy, Rollin, Giulianotti & Alegi, 2018).

After appearing in England, football rapidly spread to other countries. National leagues decided to follow the structure of the British competition model, with one league championship, lower divisions and one annual cup competition. A league was organized in the Netherlands in 1889 and in Germany in 1903. Interestingly, professionalism in other countries was not introduced as fast as in England. For example, first professional league in France was organized in 1932, while the Netherlands lacked a professional league until 1954 (Weil, Joy, Rollin, Giulianotti & Alegi, 2018).

By the early 20th century, football was played all across Europe, which triggered the need for an international organization. In 1904, representatives of the football associations of Belgium, Denmark, France, the Netherlands, Spain, Sweden and Switzerland created Fédération Internationale de Football Association (hereafter: FIFA). All British countries were accepted by 1911 but resigned twice by 1928. Firstly in 1920, after failing to persuade other members to ban Austria, Germany and Hungary because of the World War I. After returning in 1924, all British countries resigned in 1928 because of disputes with other members about professionalism in Olympic Games. British associations remained outside FIFA until 1946, which meant that they had missed the first three official FIFA World Cups (in 1930, 1934 and 1938). First World Cup took place in Uruguay, which was also the cup winner. FIFA grew steadily through the years, but the World Cup remained as the most important event in the football. In 1961, Guinea became 100th member of FIFA,

which today counts more than 200 members, which means that it has more members than United Nations (Weil, Joy, Rollin, Giulianotti & Alegi, 2018).

In addition, FIFA initiated organizing continental confederations, which are allowed to organize their own club, international and youth tournaments, promote football in their continents and elect FIFA's Executive Committee members. First association of this type was Confederación Sudamericana de Fútbol (CONMEBOL), created in South America in 1916. In 1954, the Asian Football Confederation (AFC) and the Union of European Football Associations (UEFA) were founded. The Confederation of North, Central American and Caribbean Association Football (CONCACAF) was established in 1958, while the Oceania Football Confederation (OFC) appeared in 1966 (Weil, Joy, Rollin, Giulianotti & Alegi, 2018).

1.2 History of basketball

Basketball was invented by James Naismith on or about December 1st, 1891 at Springfield College, where Naismith was a physical education instructor. This puts basketball as the only major sport originating from USA. For the first basketball game, Naismith used two peach baskets as goals, which gave the name to the sport. In the first historic match between Naismith's students, William R. Chase scored the only basket, which was recorded as the first basket in the history of basketball. News about newly invented game spread around, which resulted with the publication of basketball rules in 1892 (Mokray, Donald & Logan, 2018).

In the beginning, the number of players on the court varied depending on the court size. In 1897, number of players was set at five, which has remained ever since. First baskets were frequently attached to the balconies making it easy for spectators to interfere the shots from the balcony. As a suitable solution for the problem, first backboards appeared in the beginning of the 20th century. The first nets with the open bottom appeared in 1912. In the first two years, basketball was played with the ball for football, but in 1896, the first ball for basketball was promoted. The weight and the size of the ball changed through the years (Mokray, Donald & Logan, 2018).

Basketball spread rapidly after its invention. After a couple of years, it was already played in Europe, China, Australia and India. On the other hand, popularity and importance of basketball started to grow steadily after the World War II. Interest in the game was developing hand in hand with the television exposure, which exploded in 1980s with the appearance of cable TV and some phenomenal players, such as Magic Johnson, Larry Bird, Julius Erving, and Michael Jordan. In those years, the popularity of the best basketball league in the world, NBA league rose together with the popularity of the sport. NBA was formed in 1949 and today has a total of 30 teams, divided into Eastern and Western conference and six divisions (Mokray, Donald & Logan, 2018).

Basketball was introduced in the Olympic Games in 1936, while the first World championship was held in 1950. Fédération Internationale de Basketball Amateur (FIBA) is the association regulating international competitions (Mokray, Donald & Logan, 2018).

1.3 History of tennis

The origins of the tennis can be traced to the 12th and 13th century in the French game jeu de paume ("game of the palm"). Modern tennis as it is played today was introduced in 1873 when Walter Clopton Wingfield published the first book of rules. Next year, he took a patent on this game, although some historians have claimed that the similar types of games had been played earlier (Lorge & Bruce, 2018).

The first modern tennis tournament was Wimbledon Championships in 1877. Prior to the tournament, the court size, scoring and serving rules were determined, which remain the part of the modern rules. Spencer Gore won the tournament and cemented his name in the history of tennis as the first champion of the game. In the following years, U.S. National Championship, Australian Championship and French Championship started. Those four tournaments are still the biggest tennis events which are considered the Grand Slam tournaments (Lorge & Bruce, 2018).

Interest for tennis started increasing rapidly in the late 1960s, when the major championships allowed professional players to compete, and continued in 1970s with the appearance of TV broadcasts, some exceptional rivalries and phenomenal players, such as Jimmy Connors, Björn Borg and John McEnroe. The period from the first tournament including professional players until today is called the modern era and it started in 1968. The first open era tournament was British Hard Courts at Bournemouth won by Ken Rosewall. In the same year, the first open Wimbledon and U.S. Open were held. Rod Laver and Arthur Ashe emerged as winners, respectively (Lorge & Bruce, 2018).

Since the begging of the open era, every decade brought some exceptional players and rivalries, which helped popularize the game. In addition to Connors, Borg and McEnroe, other players that put a special mark in 20th century were Boris Becker, Pete Sampras, Martina Navratilova, Steffi Graf, and Monica Seles. The 21st century brought some extraordinary players, which are considered as the best in the history of the game. Roger Federer, Rafael Nadal, Novak Đoković, Serena Williams and Venus Williams are the synonyms for tennis in the first two decades of the 21st century (Lorge & Bruce, 2018).

1.4 From ENIAC to current digitalization trends

Similar to sports, technology has been developing through the years. In 1947, the first digital computer called ENIAC was turned on representing the first appearance of digital technology. Soon in 1951, the first publicly available computer appeared. Other notable

inventions from that period are IBM 305 hard disk, BASIC programming language and Intel 4004 microprocessor (Magic Logix, 2014).

1970s were the years of further development of computers and the appearance of some companies that still are one of the biggest in the IT sector. Microsoft was founded in 1975, while Apple was founded in 1976, which released Apple II computers. Apple II computers appeared in 1977 and were readily available to the public. In the 1980s, IT companies continued to bring new products and services. Microsoft released MS-DOS, IBM released IBM PC and Sony invented the first CD. In this period, Microsoft Word, Apple Macintosh, the first IBM laptop and first worm virus also appeared. The invention that marked the 1990s was the development of the World Wide Web (WWW), Internet application that has been the base for web browsing since then (Magic Logix, 2014).

Although the World Wide Web appeared in 1993, Internet had been developed before. The first host-to-host network connection appeared in 1969, when Advanced Research Projects Agency of the U.S. Department of Defense released ARPANET. ARPANET represented one of the first computer networks with the general purpose. After the creation of ARPANET, new tools and applications, such as the simple mail transfer protocol (SMTP) and the file transfer protocol (FTP), rapidly emerged. SMTP was used for sending short messages, commonly known as e-mails, while FTP was used for longer transmissions. The Internet appeared as a solution for connecting different research networks in USA and Europe. The program called Internetting was developed for investigating the interconnection of heterogeneous networks. In order to work this program needed a new protocol, which resulted with the creation of the Transmission Control Protocol/Internet Protocol (TCP/IP) in 1974. A rapid commercialization of the Internet was influenced by the introduction of personal computers in 1980s and then with the World Wide Web and first Internet browsers in the 1990s (Kahn & Dennis, 2018).

Internet has been spreading and developing since its first appearance. Today, there are almost 4,2 billion active Internet users in the world (Statista, 2018). Internet and other digital technologies have become a huge part of the every-day life in all fields including business. The process of moving to digital business is called digitalization. Additionally, digitalization represents the usage of digital technologies in order to change a business model, provide value-producing opportunities and increase revenue (Gartner, 2018a). Besides digitalization, the term that is commonly used in the field is digital transformation. Digital transformation characterizes the process of using digital technologies and supporting capabilities to create a powerful new business model (Gartner, 2018b). The current trends in the digitalization and digital transformation are the most modern technologies of today. Technologies that are currently making the biggest impact and are believed to continue doing so in the near future are Internet of Things, Cloud Computing, Blockchain, Machine Learning, Artificial Intelligence, Augmented Reality and Virtual Reality (Newman, 2018).

2 INTERNET OF THINGS & VIRTUAL REALITY

Nowadays, we are witnessing a highly connected world, which appeared as the result of the phenomena called Internet of Things. IoT is a huge network of physical objects with inserted sensors, microchips and communication capabilities that connect people, machines and entire system through the Internet. The company Cisco Systems, which is credited for creating the term Internet of Things, estimated that 20 billion connected devices would exist by 2020 (Greengard, 2015).

Internet has been available for quite some time, but it was mostly a product of people. Everything available on the Internet, such as data, videos, books or games, was created by people and for people. Internet is considered one of the most important technologies ever invented. It is interwoven into our lives as a digital fabric and has changed the world. The "new" Internet is not just about connecting people but also about connecting things, so it is called the Internet of Things. IoT represents sharing the experience between the things. This is achieved by adding the ability to sense and communicate to things, which enables them to collaborate and interact with other things (Hougland, 2014).

Any physical object, which is connected to the Internet and controlled in that way, is considered as an IoT device. IoT device can be a light bulb that can be switched on by a smartphone app, smart thermostat or driverless truck. Usually, the term IoT device is used for devices that are not expected to have an Internet connection and can communicate with the network without human action. Therefore, devices such as PCs, smartphones or tablets, are rarely counted as the IoT devices. However, a fitness band, a smartwatch or any other wearable device can be considered as an IoT device (Ranger, 2018).

Internet of Things uses wired and wireless protocols, such as Ethernet, Wi-Fi, Near Field Communication (NFC) and Bluetooth. The framework allows people and systems to share content as video, audio or text, interact with others through mobile or other devices, control and monitor events remotely. Typical examples are calling a taxi or making a reservation through an app (Greengard, 2015).

Physical-first and digital-first are two types of connected devices. Physical-first devices are designed for built-in connectivity, such as streaming media players and smartphones. Those devices include a sensor or microchip with communication capabilities. For example, a key chain can contain a chip, which allows a person to track its position. Digital-first devices collect data and communicate with other devices. This type of communication is called machine-to-machine (M2M) communication (Greengard, 2015).

2.1 Benefits of IoT

Benefits of IoT can be divided into two groups: IoT benefits for business and IoT benefits for consumers. The main IoT benefit for business is that IoT enables companies to get

more data about their products and internal systems. This part of IoT is also known as the Industrial IoT. Using Industrial IoT depends on the particular implementation and the field in which the company is operating. For example, manufacturers can add sensors to the components of their products, which will inform them to react in case that component is not working properly. Furthermore, Industrial IoT can be separated into two groups: industry-specific offerings and IoT devices for all industries. Industry-specific offerings can be used only in some specific field, such as real-time location devices for healthcare. On the other hand, IoT devices for all industries can be used everywhere, such as smart air conditioning (Ranger, 2018).

IoT for business offers an opportunity for creating new business models and increasing revenue. IoT enables companies to change their traditional business models and create new services, which will be based on real-time sensor data. Another huge benefit of IoT is that it helps in increasing operational efficiency. Companies can remotely monitor and control operations, automate manufacturing processes and optimize supply chains. Besides that, IoT helps in increasing workforce productivity and job satisfaction. Technology can support employees in decision making, fast-track communication and automate routine tasks (SAP, 2018a).

As well as companies, consumers can benefit from IoT in many ways. IoT makes homes, vehicles and offices smarter, better and chattier. Smart speakers make it easier to play music, get information or set timers. Home security systems help to monitor what is happening inside or outside of home, check visitors and communicate with them. Smart thermostats can adjust the temperature before we come back, while smart light bulbs can turn on or off and make an impression that we are home. There are many more examples of same kind, which all show how IoT can be beneficial in every-day life (Ranger, 2018).

2.2 Threats of IoT

As every phenomenon in the world, IoT also brings some potential threats. IoT threats can be analyzed from two different perspectives. First perspective analyzes IoT threats on each architecture layer, while second perspective analyzes them from application scenarios perspective (Chen et al., 2018).

IoT infrastructure contains several hierarchical layers. Four-layer architecture contains the perception layer, the network layer, the middleware layer and the application layer. The perception layer identifies objects, collects target information and transforms them into digital signals. The main technologies used in this layer are sensors, cameras, RFID tags, etc. The network layer takes responsibility for the IoT infrastructure connectivity. In addition, it collects data from the perception layer and in transfers it to the upper layer. The key technologies used in this layer are technologies for connectivity, such as Wi-Fi, Bluetooth or ZigBee. The middleware layer receives the data from the network layer, links to system to the database and cloud and executes data processing and storage. This layer is

developing continuously and provides more powerful computing and storage capabilities, due to the development of IoT and cloud computing. Finally yet importantly, the application layer processes data from the middleware layer and provides a quality service to the final user (Chen et al., 2018).

The perception layer uses identification technology and large number of sensors. Malicious attacks, which aim at manipulating or destroying data collection and communication, represent the IoT threat on the perception layer. Examples of malicious attacks on this layer are Unauthorized Access to Tags, Tag Cloning, Eavesdropping, RF Jamming, Spoofing Attack and Sleep Deprivation Attack. The network layer is responsible for the IoT connectivity, so the threat on this level are attacks that aim to exhaust network resources, affect the availability of network, gain control of network or destroy network communication. Some examples of attack on the network layer are DoS attack, Sybil attack, Sinkhole attack, Sniffing attack, Traffic Analysis, and Replay attack. The middleware layer executes data processing and storage, which means that on this layer attackers aim to affect the quality of service and users' privacy. Attacks can also negatively influence operation and information security. Attack of this type are Flooding Attack in Cloud, Cloud Malware Injection, Signature Wrapping Attack, Web Browser Attack and SQL Injection Attack. The application layer is intended for final users, so the attacks mainly target to gain users' sensitive data. Counterfeiting identity in order to get the same permissions as the legitimate user is also considered as a threat on this level. Besides the attacks on this level, such as Code Injection, Buffer Overflow and Phishing Attack, the application layer is also endangered by viruses, Trojans, worms and other malicious programs (Chen et al., 2018).

Application scenarios for IoT cover four different domains: Industry domain, Smart environment domain, Urban infrastructure domain and Healthcare domain. Threats and attacks in domains are diverse and cover all IoT architecture layers. Attacks in industry domain are specific for every industry that uses IoT, such as automobile industry. Today's cars have an enormous number of electronic systems and sensors. Attackers can use relay attacks in order to steal a car by relaying messages between the car and the smart key. Attackers can also inject malicious components into the cars' networks and launch further attacks, which can be a big threat to the drivers' life. Smart environment domain covers the field of smart-home devices, smartphones and wearable devices. Attacks in this domain aim to users' security and privacy. The main goal of the attackers is obtaining the users' sensitive data. Urban infrastructure domain covers smart grid, transportation and logistics. Threats in this domain are attacks, which aims to affect the operation of smart grid and obtain traffic emergency information. Similarly to the smart environment domain, threats in healthcare domain are attacks for obtaining patients' personal information. In addition, the big threat are attacks aiming on different medical devices, which represent an enormous threat on patient's life (Chen et al., 2018).

2.3 IoT security

IoT brings great benefits, but a number of IoT attacks leaves an impression that IoT is highly insecure. However, many of these attacks originate from the failure of implementing basic protections. Nowadays IoT devices are everywhere around us, which means that they are usually physically accessible by everyone – employees, contractors, final users, etc. As more people have access to IoT, the risk of potential threats rises. Besides ensuring physical protection of IoT devices, it is crucial to know how to implement and apply security measures in order to keep IoT operating safely (van Velzen, 2017).

There are some main recommendations for securing IoT for business. Recommendations are following (van Velzen, 2017):

- Manage risk – assessing risk from the perspective of ease of an attack and potential consequences gives a strong indicator of amount of needed security. For example, IoT solution for optimizing, monitoring and managing operations in a chemical factory requires much tighter security protocols then the solution for turning off the lights in a conference room when nobody is inside.
- Limit device-to-device communication – definition of IoT which indicates that many devices are connected to many other devices can be misunderstood. Number of IoT devices connected to each other should be reduced by removing connections without any purpose. That will increase IoT security and limit any potential damage that might occur.
- Retain control over IoT structure – it is very important to maintain the control of IoT devices. This is achieved by selecting appropriate devices, updating devices in secure way and controlling that process.
- Use end-to-end encryption – the communication between devices should be encrypted, so that attackers cannot listen, gain sensitive data or impersonate devices. Encryption should also be tied to the device identity, which ensures that data actually comes from that particular device.
- Leverage existing expertise – only proven technologies, tools and best practices should be used. In case of applying new techniques, existing concepts and principles should be followed. There are not many established standards yet due to the IoT adoption still being in early days. In order to overcome this, adopters have to plan and build-in IoT security from the start and evaluate any IoT equipment brought to the company.

In addition to those main recommendations, there are some additional tips that can help companies improve their IoT security. The tips are as follows (Le, 2017):

- Prioritize IoT security – boards and senior leaders should be highly involved in the topic of IoT security.

- Define responsibilities – a policy describing everyone's role in IoT security should be developed. All employees should be aware of potential risks and required precautions.
- Revise security policies – as the technology is rapidly changing, all security policies need to be revised and up to date.
- Include outside devices – as many employees use their own connected devices to work, these devices should also be controlled and secured.
- Create separate networks – networks on which IoT is operating should have additional monitoring and restricted access, while business partners and guests can log on different Wi-Fi network.

In addition to the mentioned recommendations and tips, it is crucial for companies to have intelligent security systems that can operate without human supervision and are able to take proactive and defensive actions when needed. As the number of connected devices increases, it is almost impossible for security teams to manually identify all risky activities and react properly. IoT security system has to be intelligent enough to recognize all vulnerabilities of connected devices, approve access to networks and be more effective over time by learning from constantly evolving conditions. After identifying suspicious activity, an intelligent system can immediately stop the device, which is the target of malicious attack and take appropriate actions for avoiding or limiting the damage (Dibrov, 2017).

Besides companies, unsecured final users are also in danger of cyberattacks aiming to gain their sensitive data. Strategies for final users' protection from IoT cyberattacks are as follows (Dinha, 2018):

- Secure devices – keep the software updated, avoid phishing scams, use proper filters and firewalls, practice good Internet habits and use a second-layer password protection.
- Buy smart devices from reputable vendors – although the price might be higher, reputable vendors offer more secured devices.
- Upgrade the security of home network – keep passwords protected and configure the network to not send out any data without a permission.
- Think about using the public or the private cloud – consider what level of privacy is needed for each device.
- Use virtual private network (hereafter: VPN) – add a firewall to incoming traffic by using VPN on the router.

2.4 IoT in sports

As the digital world is increasing, IoT started to spread in the sports field. Today, IoT is present in sports through player development, player safety and fan engagement. Using advanced analytics, sensors and game videos, coaches can obtain metrics on player

performance, player efficiency and opponent weakness. This information can be used fatherly for developing training regimes and game strategies. In addition, by using embedded devices, such as smart insoles, team doctors and physiotherapists can reduce players' injuries and help them heal faster. Another very important aspect of sports are fans. IoT can also help in increasing their engagement (Giorgio, Marzin, Lee & Vonderhaar, 2018).

One of the newest trends in this field is using sensors and IoT in technologies for reducing referees' mistakes. For example, sensors, which are connected to an IoT platform, collect the data. IoT platform processes the data in real time and notify referee when event of interested occurred, such as the ball crossing the goal line. The entire process occurs without any interruptions of the game (Mudric, 2018).

IoT and smart technologies help sports organizations decrease expenses, increase revenues and get possibilities to capture new revenue. By implementing smart technologies and IoT, sports organizations get more possibilities for ad sales and sponsorship rights. Additionally, sports organizations can increase sales of tickets, merchandise and food during the games. New technologies can also help in reducing expenses and minimizing costs (Giorgio, Marzin, Lee & Vonderhaar, 2018).

Using IoT in sports is a relatively new trend, so sports organizations have to be aware of potential problems they can face in case of wrong implementation of IoT. When implementing IoT capabilities and new technologies, they have to be connected in order to achieve their full IoT potential. Independent solutions that are not working together hinder sports organizations from leveraging IoT benefits. Another very important aspect for sports organizations are league regulations about the technology. As already mentioned, IoT in sports is just starting to spread; so many leagues still do not have defined rules and regulations about its usage. That leads to conclusion that all sports organizations have to be familiar with the regulations of leagues that they are competing in (Giorgio, Marzin, Lee & Vonderhaar, 2018).

2.5 Virtual Reality

Virtual Reality represents using computer simulation and modeling for enabling people to interact with an artificial three-dimensional visual or any other sensory environment. VR applications put the user in a computer-generated environment, which simulates reality by using interactive devices that can send and receive information. Those devices can be worn as headsets, goggles, gloves or body suits. In a usual VR format, a user wears a helmet with a stereoscopic screen which previews animated images of the simulated environment. Motion sensors that adjust the view on the screen in real time according to user's movements create the illusion of telepresence. In other words, the user can experience different perspectives and viewpoints that arise from own head turnings and steps. The objects that are part of the virtual environment can be even picked up and manipulated by

using data gloves equipped with force-feedback devices that deliver the sensation of touch (Lowood, 2018).

The term Virtual Reality was created by Jaron Lanier in 1987. His research and work have made a huge contribution to the VR industry. Inspiration for VR came from performers, artists and entertainers who have always been interested in setting narratives in fictional spaces, imaginative worlds and deceiving the senses. Panoramas of the 18th and 19th centuries can be considered as the first forerunner of the VR technology. They blurred the visual boundaries of the two-dimensional images and three-dimensional spaces from which they were viewed. This image tradition inspired further innovations, which represent the steps forward to the Virtual Reality. Stereopticons, 3-D movies and IMAX movie theaters are some typical examples of the technologies that brought us to the Virtual Reality phenomena (Lowood, 2018).

Nowadays, Virtual Reality can be used for different purposes in many industries. Primarily, VR is used in the gaming and entertainment industry. Users can experience playing games, watching movies and visiting concerts in virtual reality. VR can also be used in health care for diagnosis, creating models or practicing difficult procedures, in automotive manufacturing for creating prototypes of interior and exterior and in education for improving cognitive learning. VR users can also virtually visit some museums, go shopping in shops that provide virtual tour or relax in their happy places (Sheikh, 2016).

Virtual Reality has also found its way into the sports industry. Fans now can enjoy in VR broadcast of some games that are offered in this technology. By capturing matches with 360-degree cameras, fans can see what they want and focus on their favorite players or watch the game from the angle they like. Although this way of watching games is in the developing phase, it can soon become a habit (OmniVirt, 2018).

In the near future, it is expected that VR devices will become more sophisticated and powerful, which will bring about higher quality visuals. Human understanding of the technology will also evolve, which will result with the more natural ways of exploring and interacting in virtual space. Future can also bring a significant increase of VR usage in training and teaching. Virtual environments offer the possibility for students to practice anything, such as surgeries or flights, without any risks that appear in real-life trainings. This VR feature is expected to be exploited considerably more. Another interesting VR feature that might appear in the near future is interacting and meeting our friends and families in virtual environments. VR communication can become an addition to mobile messaging systems and social medias. Virtual conference calls or virtual meetings with friends can become a part of our everyday life very soon (Marr, 2019).

In conclusion, it is very important to emphasize that Virtual Reality is not the synonym for Augmented Reality (hereafter: AR). Augmented Reality begins with a camera-equipped device, such as a tablet, smartphone or smart glasses, loaded with AR software. AR

transforms data and analytics into animations that are overlapped with the real world around us. Some basic examples are Snapchat filters and Pokémon Go game. On the other hand, VR replaces real-life world with a computer-generated environment (Porter & Heppelmann, 2017). In the other words, it transfers users to a digital world and immerse them completely in a software environment (Wessel, 2014).

3 TECHNOLOGIES FOR MATCH REGULARITY

Sports dynamics has rapidly increased over the years, which has become an enormous problem for referees. Everything happens so fast that sometimes is almost impossible to make the right call. Although it might sound unimportant, but those little things can decide the winner of the game, the tournament or the league.

Technologies for match regularity support referees and help them make the right calls. The most important reason, which caused the appearance of these technologies in sports, is injustices caused by referees' bad calls. Although some believe that the technologies are killing the sport charm, the referees' mistakes are even more harmful (Mudric, 2018).

This chapter contains four key technologies for match regularity used in the sports that are covered in the thesis. Chapter starts with the two technologies used in football, Goal-line technology and VAR technology. Goal-line technology aims to help referees in situations in which is not clear whether the ball has crossed the goal line or not. VAR technology is one of the newest technologies used in sports. It represents using video footage for checking and supporting referees' decisions. It is used in four different situations: scored goal situations, penalty situations, direct red card situations and mistaken identity situations. The chapter continues with the Instant Replay technology used in basketball. Due to the differences in technology in NBA league and EuroLeague, this technology is analyzed separately for both leagues. The chapter concludes with the Electronic Line Calling technology by Hawk-Eye, which has been available in tennis for quite some time. This technology checks whether a ball has bounced inside or outside the tennis court. All those four technologies have been created to support the referees' decisions and making the game fairer.

3.1 Goal-line technology

3.1.1 About Goal-line technology

In order to score a goal in football, the whole ball has to cross the goal line. In most cases, a ball hits the net and it is obvious that the goal has been scored. However, it can happen that a goalkeeper or some of the players kick out the ball, which is very close to the goal line, or even across it. In those cases, it is very difficult for referees to determine whether the goal was scored or not, so they can easily make mistakes.

Typical example of a referee's mistake of this kind was Frank Lampard's disallowed goal versus Germany in World Cup 2010 in the round of sixteen. At 2:1 for Germany, Lampard kicked the ball from about 18 meters out and hit the crossbar. After hitting the crossbar, the ball went into the goal, as shown in Figure 1, but because of its rotation immediately bounced out after touching the ground. Referee did not see that the ball crossed the goal line, so Germany did not concede the goal. At the end, England lost 4:1 and was eliminated from the World Cup 2010 (Chula, 2010).

Figure 1: Frank Lampard's disallowed goal at World Cup 2010 vs Germany

Source: Chula (2010).

In order to overcome this issue, FIFA came up with a Goal-line technology. Goal-line is a technology which instantly determines whether the ball has crossed the goal line or not. Requirements of the International Football Association Board is that Goal-line technology should not obstruct a game itself. To fulfill this requirement, as shown in Figure 2, only referees receive a signal on their watches indicating whether the ball crossed the line or not. This signal is transferred within one second, which means that referees do not have to stop the game or interfere it in any other way. Besides telling whether the ball crossed the line or not, the system is able to show an animation of the ball crossing the line, which can be shown on TV broadcast and even on big screens at stadiums. The match organizer is allowed to decide whether the animation is to be shown on the big screen or not. If not, the animation is available only to people watching TV broadcast of the game (FIFA, 2018a).

Figure 2: Goal-line technology watch

Source: Ran (2016).

3.1.2 Goal-line technology licensees and systems

Goal-line technology does not work on a single system. Goal-line technology is offered by FIFA Quality Programme licensees. In order to become a licensee, a provider has to demonstrate a fully accurate and functional system. The first part of the procedure is submitting the application form with all required documents. After documentation is approved, a Goal-line technology test institute starts with the system testing. In case of positive test report, the provider is awarded a license agreement. This FIFA license allows providers to install Goal-line system anywhere in the world. Providers must ensure a two-year warranty and properly inform end costumers about the technology. After each installation, the system has to be tested again by a FIFA-accredited test institute or a test institute that is certified to ISO 17025 for goal-line technology tests. Subsequently, the end customer (stadium owner, club or competition organizer) shall approve the installation (FIFA, 2018b).

All approved systems can be divided in three groups according to the technology they use. Camera-based systems rely on cameras that are able to detect the ball and software for evaluating the footage from all cameras. Current requirements for this type of systems is seven cameras per goal (fourteen in total) placed as high up as possible considering stadium structure (FIFA, 2018a).

Magnetic fields systems are based on cables that are placed underground around the goal and the elements of technology inside of the ball. The interaction between magnetic fields created by underground cables and receptors in the ball allow the software to precisely

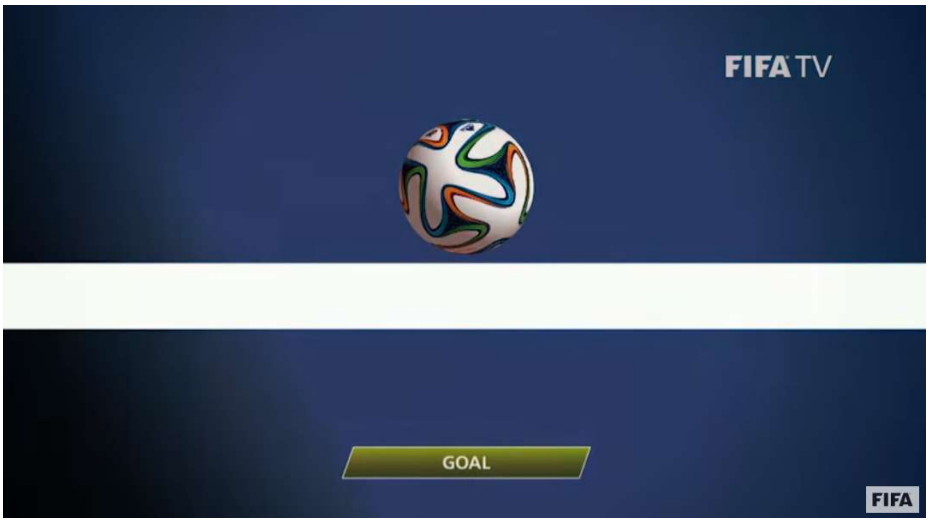
calculate the ball's position and determine whether the ball crossed the line or not (FIFA, 2018a).

Incidents are systems used for analyzing goal line situations that had happened in the past. An example is the analysis of the disallowed goal by Frank Lampard's mentioned above (FIFA, 2018a).

3.1.3 First Goal-line technology goal in World Cup 2014 Brazil

Goal-line technology was officially used for the first time at FIFA Club World Cup Japan 2012 and since then the number of matches played with this technology has risen sharply (FIFA, 2013). In 2014, FIFA World Cup Brazil Goal-line technology was used for the first time at the World Cup. Karim Benzema's kick considered the first Goal-line technology application in the history of World Cups. After hitting the post, the ball hit the Honduras's goalkeeper and crossed the line. As shown in Figure 3, the fans were able to see the goal animation on TV broadcast (FIFA, 2014).

Figure 3: First use of Goal-line technology in World Cup



Source: FIFATV (2014).

3.2 Video Assistant Referees (VAR)

3.2.1 About VAR

Video Assistant Referees (hereafter: VAR) is the technology used to check three main incidents in football (goals, penalties and direct red card) and one administrative incident (mistaken identity). In goals, VAR assists referees to determine whether there were any fouls committed or if the goal was scored offside, which means that the goal should be disallowed. In penalty decision, VAR ensures that right decision is made respecting award

or non-award of a penalty kick. In direct red card incidents, VAR helps referees decide whether to show a red card or not. Lastly, VAR helps in situations when referees are unsure which player should be disciplined. VAR informs referees which player has to be sanctioned (FIFA, 2018c).

VAR works in three steps (FIFA, 2018c):

1. Incident occurs
2. Review and advice by the VAR
3. Decision or action is taken

In step one, when an incident occurs, the main referee can inform the VAR to check the incident. It is also possible that the VAR recommends to the referee to review the incident. In step two, the video footage is checked by the VAR who explains the referee via headset what the replays show. In step three, the referee can review the video footage by himself/herself on the screen on the side of the field or he/she can accept VAR instructions and take appropriate decision (FIFA, 2018c).

3.2.2 The VAR Team and the VAR room

The VAR team is made of one video assistant referee (VAR) and his three assistants called video assistant referees (AVAR1, AVAR2 and AVAR3). All VAR team members are top FIFA match officials. As shown in Figure 4, all members of the VAR team are located in the VAR room together with four replay operators, who choose and provide best camera angles (FIFA, 2018d).

Figure 4: The VAR room during the match

Source: FIFA (2018d).

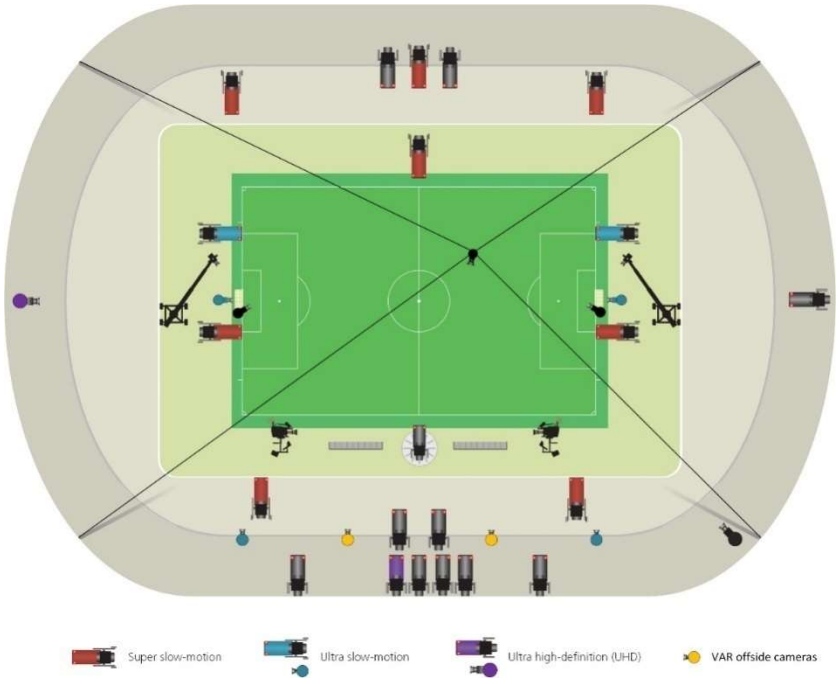
In the VAR team all referees have they own tasks. VAR has to watch the main camera on the upper monitor and check incidents on the quad-split monitor. VAR is also responsible for communicating with the referee on the field and leading the VAR team. AVAR1 concentrates on the main camera and informs VAR about the live play in case of some incident is being reviewed. AVAR2 is responsible for offside situations. He or she has to anticipate and check any potential offside situation in order to speed up the review process. AVAR3 has to focus on whole TV program feed, assist VAR in checking incidents and ensure good communication between VAR and AVAR2. In the Figure 4 VAR is sitting on the right side, AVAR1 is sitting in the middle, AVAR2 is sitting on the left side and AVAR3 is standing (FIFATV, 2018a).

It is very important to emphasize that the VAR team does not make any calls. Their role is to support the referee on the field in the decision-making process, who is the only person that can take the final decision (FIFA, 2018d).

3.2.3 Cameras and VAR Information System

During the World Cup 2018 in Russia, the VAR team had and access to 33 broadcast cameras, including eight super slow-motion and four ultra slow-motion cameras. In addition to this, they had and access to two offside cameras, which were not available for TV broadcast. In the knockout phase, two additional ultra slow-motion cameras were installed behind goals (one on each side) (FIFA, 2018d). Figure 5 shows the position of cameras in stadiums.

Figure 5: VAR cameras



Source: FIFA (2018d).

The VAR team had access to all FIFA host broadcaster camera feeds. Only exception were cameras that did not cover the game, but mostly focused on fans, stands or scoreboard, like helicopter cameras (FIFA, 2018d).

VAR Information System is a system for broadcasters, commentators and infotainment developed by FIFA. The aim of the system is to inform all football fans that are in the stadium or watching a broadcast on TV about a review process. The FIFA staff member, who is located in the VAR room behind the VAR team and replay operators, as shown in Figure 6, can inform broadcasters, commentators and infotainment about the steps of the review process via a networked tablet. The person operating the tablet has the camera angles that the VAR team is checking as well as the audio from referee communication system. The VAR Information System can also automatically create VAR graphic templates for big screens in stadiums and TV broadcast (FIFATV, 2018b).

Figure 6: Position of the FIFA staff member in the VAR room

Source: FIFATV (2018b).

3.2.4 First VAR goal in World Cup 2018 Russia

First use of the VAR technology in World Cup 2018 Russia was seen in the group stage match between France and Australia. At the result 0:0 in second half, Paul Pogba passed a through ball to Antoine Griezmann who was fouled by Josh Risdon in the penalty area. The main referee of the match didn't see that and showed that game should be continued. After couple of moments, VAR team informed the referee to check the incident. Referee accepted the advice from the VAR team, signaled outlines of TV screen with his hands, which is the official sign for using VAR and then checked the incident by himself on the

screen on the side of the field, as shown in Figure 7. After watching the video footage, referee changed his opinion, awarded a penalty to France and showed a yellow card to Risdon, who had committed a foul. Antoine Griezmann scored from the penalty kick, which will be remembered as the first VAR goal in World Cup history. At the end, France won the game 2:1 (FIFATV, 2018c).

Figure 7: Referee reviewing the incident

Source: FIFATV (2018c).

3.3 Instant replay

3.3.1 NBA Replay Center

NBA launched NBA Replay Center at the beginning of the 2014/2015 season. The NBA replay center is fueled by high-speed arena network in order to accelerate the review process and improve performance of NBA referees. It is equipped with 20 workstations, including 17 Replay Operator stations and 3 Replay Manager stations. Altogether, it contains 94 HD monitors. Some of them can be seen in Figure 8. In addition to this, every NBA arena is connected directly to the NBA Replay Center, so that every NBA game can be supported by this technology (NBA Official, 2018).

The main goal of the Replay Center is to provide referees with the exact angle they need when they come to replay. The most important aspect of the Replay Center technology is a 10-gigabit network. The network enables Replay Center to work with super quality HD broadcasts. In the end, it means that referees have access to the best video material. As soon as a referee calls for the replay, Replay Center makes an analysis, doing split screens, zooming in and trying to get to the truth quickly. The aim is to quickly isolate the best

possible angles of the play and provide them to referees. Besides increasing the accuracy of calls, Replay Center increases the speed with which they are made. Replay Center has also a capability to send multiple angles at once to referees. In addition, replays showed to referees are also shown on TV broadcast, so that fans can also see why referees made such calls. It is very important to emphasize that referees make their final decision on all reviewable calls. Replay Center only supports referees with appropriate video footage and does not make any calls (NBA, 2014).

Figure 8: NBA Replay Center

Source: Moynihan (2014).

Referees turn to NBA Replay Center based on 15 different situations, so called instant replay triggers (NBA, 2016):

1. Review of Last Second Field Goals – referees use video footage to confirm whether the ball left shooter's hand before game clock expired or not. Referees can also check whether the shot was a two- or three-point attempt or whether the ball or some of players where out-of-bounds area during the play.
2. Review of Last Second Fouls – referees use video footage to determine whether the game clock expired before the foul occurred. If the foul was made, referees can also check whether the shooter was attempting 2-point or 3-point shot or whether a player was out-of-bounds prior the foul.
3. Review of Flagrant Fouls – referees review all situations where Flagrant Foul was called. There are two types of flagrant fouls. Flagrant Foul 1 is called for unnecessary contact committed by a player against an opponent. Flagrant Foul 2 is called for

unnecessary and excessive contact. Referees review the whole situation and analyze the severity of contact, potential injuries and the outcome of the contact. In case of Flagrant Foul 1, the team, that was fouled, gets two free throws and retains ball possession. In case of Flagrant Foul 2, besides the free throws and retaining the possession, player that made the foul is ejected from the game.

4. Review of Player Altercations – referees review all the situations, where two or more players are engaged in a fight or any physical interaction that is not a part of a normal basketball behavior. Referees have to analyze the whole situations and appropriately penalize all the players involved in the altercation.
5. Review of Clock Malfunctions – referees use video footage to determine the right time that should be left on the game clock.
6. Review of Two-Point/Three-Point Field Goal Attempts or Fouls – referees review the situation to check whether a successful shot was 2-point or 3-point attempt or whether a foul was on 2-point or 3-point shot attempt.
7. Review of Out-of-Bounds Plays – in last 2 minutes of the 4th quarter and in overtimes, referees check which player had the last touch with the ball before it went out-of-bounds.
8. Review of Shot-Clock Violations – referees check whether a 24-second violation was made prior to a made shot or foul.
9. Review of Clear-Path-To-The Basket-Fouls – referees review whether all criteria for clear-path-to-the-basket-foul was fulfilled. Attacking player has to be in a clear opportunity to score without any defenders ahead of him. In other words, there should be no defenders between the ball and the basket. In case of foul from the back by defender, it is considered as a clear-path-to-the-basket-foul. The penalty for this type of foul is two free throws and possession.
10. Review of Correct Free Throw Shooter – referees check which player was fouled, so that right player can shoot free throws.
11. Review of 24-Second Shot Clock Reset – referees check whether the ball touched the rim after the miss. In case of an offensive rebound, if the ball touched the rim, offensive team gets a new 24 seconds for the possession. Otherwise, they have the remaining time from the first possession. With the new rules valid from season 2018/2019, after the offensive rebound when the ball touched the rim, offensive team will get 14 seconds for the new possession (NBA, 2018a).
12. Restricted Area Block/Charge Review – this trigger refers to the review of the position of a defender, when making a foul. Restricted area is the space below the basket limited by the arc that is drawn in the paint. In that space, offensive player cannot make an offensive foul, so called charge or charging foul. Charge can be called in case of legal guarding position, when a defender is outside the restricted area. Otherwise, referees call defensive foul, so called blocking foul.
13. Goaltending/Basket Interference Review – referees check whether any of players interfere the basket in any ways. It is not allowed the touch the rim, net or backboard, while the ball has a reasonable chance to go in the basket. In addition to this, ball

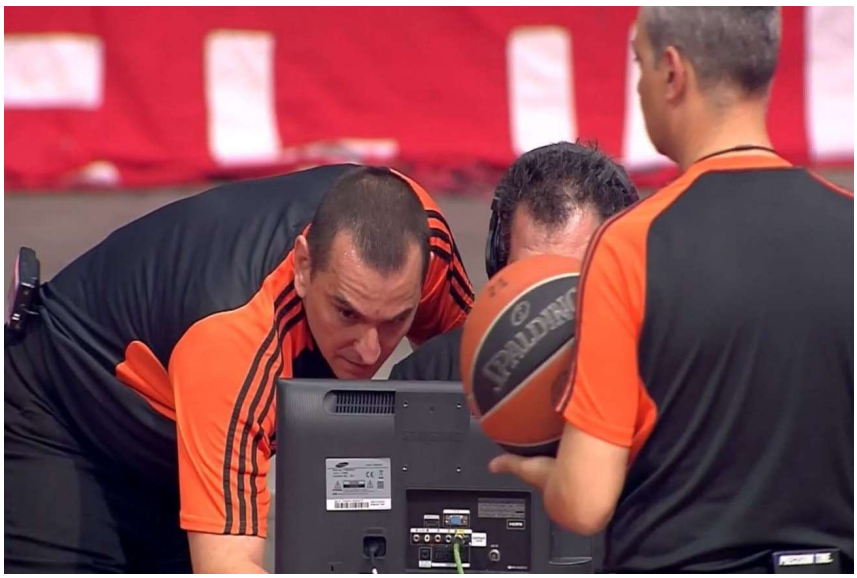
cannot be touched on its downward flight. In case of interference by defender, basket counts, even if the ball didn't go through the net. If offensive player interferes the basket, made shot is disallowed.

14. Off-Ball Foul Timing Review – referees check whether a player without the ball was fouled prior to his teammate beginning the shooting motion. If the foul was made before the beginning of the shooting motion, basket is disallowed.
15. Delay of Game – in those situations referees check whether a player's or team's behavior causes postponement of the game. Typical examples of this behavior are: touching the ball after a made field goal or free throw, entering the game with a untucked jersey, preventing the ball being put into play, not giving the ball to the closest referee, when a foul or any other violation is called, etc. When the delay-of-game violation is committed for the first time, the player or the team gets a warning. If the violation repeats, then technical foul is given.

3.3.2 EuroLeague Instant Replay

Starting in the 2016/2017 season, the Turkish Airlines EuroLeague has been using an elite instant replay technology, which is available to referees during EuroLeague games. Technology is also available for unified scorers and broadcasters. Technology has been developed in collaboration with Hawk-Eye Innovations, globally recognized sports technology company that became famous by their technology used in tennis. Instant Replay allows referees to check video footage captured by eight different camera angles on the monitor placed on the scorer's table, as shown in Figure 9. The main goal of the technology is to help referees make the right calls in a very short amount of time (EuroLeague, 2016).

Figure 9: Referees using Instant Replay



Source: EuroLeague (2016).

Before each EuroLeague game, Instant Replay System operator has to test the Instant Replay system together with referees and verify that the Instant Replay system is working properly. In case of any problems, Company's IT and Statistics department has to be informed about incidents that occurred during the set-up by Skype. During the game, only the referees and Instant System operator are allowed in the area where the system is installed. Any other unauthorized person should leave the area at the referee's order (EuroLeague, 2017a).

Use of Instant Replay technology is divided into three categories according to the time left on the game clock. The categories are 00:00 Game Clock, Fourth or Extra Periods 02:00 or Less Game Clock and Any Time (EuroLeague, 2017a).

In the 00:00 Game Clock situations, referees use Instant Replay for following (EuroLeague, 2017a):

1. Made field goal – in the case that basket was made with no time remaining, referees can check variety of issues. Referees can review whether the ball was released on time, was the shot 2-point or 3-point attempt, whether out-of-bounds violation was made, whether a shot clock violation was made, whether an eight-second violation was made or whether the foul on shooter was made. In case of some violation, basket is disallowed, and referees check how much time should be left on the game clock.
2. Called foul – in the case the foul was called, referees check whether the foul was committed before the end of playing time. If it was, referees check how much time should be left on the game clock.

In the Fourth or Extra Periods 02:00 or Less Game Clock situations, referees use Instant Replay for following (EuroLeague, 2017a):

1. Out-of-bounds situations – referees review the situation to identify the player, who touched the ball last prior to out-of-bounds violation.
2. Goaltending/basket interference violation – after a goaltending or basket interference violation was called, referees review the situation, if they are unsure about the call.

Referees can use Instant Replay at Any Time for following situations(EuroLeague, 2017a):

1. An error in the game clock – in case that game clock does not stop after the referee stops the game or it starts running before the ball is in play, referees check Instant Replay to determine the right time on the game clock.
2. An error in the shot clock – in case that shot clock does not stop after the referee stops the game or it starts running before the ball is in play, referees check Instant Replay to determine the right time on the shot clock.
3. Fight – referees use Instant Replay to check the identity of all players engaged in a fight and decide the appropriate penalty for each of them.

4. Shooting foul – Instant Replay helps referees to check whether the shooting foul was on a two-point or three-point field goal attempt.
5. Field goal made – referees can check whether the successful shot was a two-point or three-point field goal attempt.
6. Shot clock violation in made field goal situations – referees can check whether the shot clock violation occurred prior to a made shot.
7. Shot clock violation in called foul situations - referees can check whether the shot clock violation occurred prior to a called foul.
8. Off the ball foul on the team without control off the ball – referees can check whether an off the ball foul was made on the team without control off the ball prior to a field goal made. If the foul was made before the ball left the shooter's hand, basket would be disallowed.
9. Off the ball foul on the team with control off the ball – referees can check whether an off the ball foul was made on the team with control off the ball prior to a field goal made. If the foul was made before the ball left the shooter's hand, basket would be disallowed.
10. Correct free throw shooter – referees use video footage to check the identity of the correct free throw shooter.
11. Unsportsmanlike or disqualifying foul – referees can check whether the strong foul meets requirements for and unsportsmanlike foul or disqualifying foul.

3.4 Electronic Line Calling by Hawk-Eye

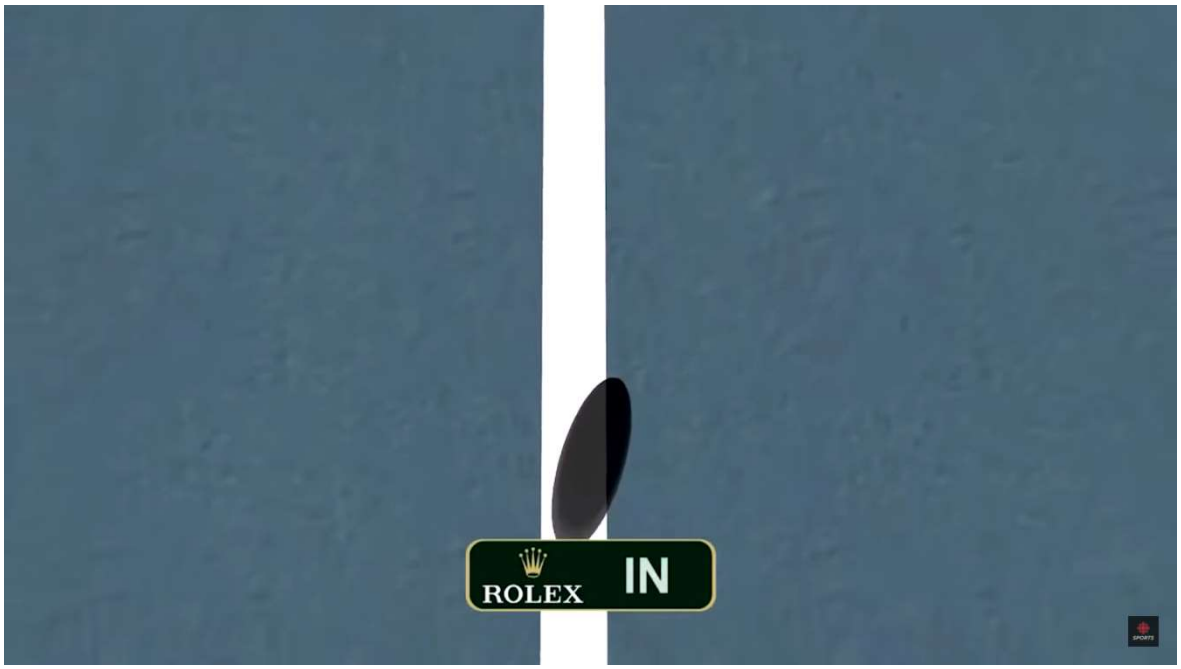
Hawk-Eye is part of Sony Corporation and it is a leading innovator in sports technology. They started with a broadcast tool for analyzing decisions in cricket and now they are an integral part of over 20 sports. Each year their technology is used in 20,000 games or events across 500+ stadiums in over 90 countries. They have developed the most sophisticated vision processing technology which allows tracking of balls, players, and cars. The vision processing technology in combination with an intelligent IT based video replay, creative graphics platform and distribution software results with a number of products and services that are modernizing sports (Hawk-Eye, 2018a).

Electronic Line Calling is a technology used in tennis for checking whether a ball has bounced inside or outside the tennis court. This technology provided by Hawk-Eye has been in use since 2006 when it was officially accredited by ITF. Nowadays, Electronic Line Calling is used by over 80 tournaments every year with the main goal to make the game fairer. During the testing prior to official accreditation back in 2006, results showed that the technology has a mean error of only 2,6 mm in comparison with a high-speed camera placed on the playing surface. Since then, testing of Electronic Line Calling is an on-going process, which is obligatory at all tournaments. The testing has to cover different factors that can influence the system, like wind, bright sunlight, shadows covering some parts of the court, darkness and artificial floodlights (Hawk-Eye, 2018b).

Electronic Line Calling is a camera technology, which works in following six steps (Hawk-Eye, 2018b):

1. Camera Set Up – maximum 10 cameras are set up around the court in order to capture live images.
2. 2D (x, y) – in this step vision processing is used to recognize the center of the ball.
3. 3D (x, y, z) – the system combines information from each calibrated camera and provides a 3D position of the ball.
4. 4D (x, y, z, t) – step 3 is repeated for each frame, so that 3D positions of the ball show a single trajectory of ball's flight.
5. Bounce Mark – the trajectory is used to calculate the exact area on the court that the ball touched during the bounce phase.
6. Virtual Reality – in the last phase, the data is quickly shown as an animation via intelligent virtual reality software, as shown in Figure 10.

Figure 10: Electronic Line Calling animation



Source: CBS Sports (2017).

Players are the ones who call review and challenge a referee's decision. Reviews shall be allowed only on a point-ending shot or when a player stops playing during the rally. Referees are allowed to refuse the review, if they believe that a player is making an unreasonable request or that the challenge was not made in a timely manner. Each player gets three unsuccessful challenges per set and one additional in tiebreak. On the other hand, each player has an unlimited number of successful challenges. Challenges cannot be transferred in the next set (ITF, 2017).

Electronic review is not used on clay courts. In this type of courts, as the ball marks are visible and in cases of uncertainty, referees have to come down from the chair and find the right ball mark. Should the right ball mark not be identified, the original call stands. If a player erases the ball mark, it is a signal that he or she accepts the original call (ITF, 2017).

4 TECHNOLOGIES FOR PLAYER/TEAM PERFORMANCE

Becoming a professional athlete means dedicating whole life to practicing, getting better and achieving the best possible results on individual and team level. Good results and good performance open new possibilities in players' careers, while good results for clubs bring more fans, partners and sponsors. Consequently, clubs increase their revenues and invest in further development.

Technologies for player/team performance supports athletes and teams in achieving better results. Some technologies support whole sports operation of sports organizations, while other technologies focus on one particular part. Technologies can focus on getting data about players' physical performance and preparing training regimes and tactics or put an emphasis on improving players' skills.

This chapter contains four very different technologies for monitoring and improving player/team performance. The selection was based on the idea to show what different aspects of player/team preparation these technologies can cover in all three sports that are part of the thesis. The chapter starts with the SAP Sports One, team management software which supports whole sports operation of one sports organization. The chapter continues with the STATSports technology which aims to get data about players' physical performance and help in preparing training regimes and tactics. STATSports offers two different technologies for professional and amateur athletes, which are both covered in this chapter. The chapter ends with two technologies aiming to improve players' skills. Wilson X Connected Basketball is used in basketball for improving shooting, while Babolat Play smart racket is used in tennis for analyzing and improving tennis skills.

4.1 SAP Sports One

4.1.1 About SAP Sports One

SAP Sports One is a team management software solution which helps clubs and organizations digitalize sports performance management and coordinate all team management, training, scouting, administrative and medical processes. It is a cloud solution with integrated platform for all sports data. Besides football and basketball, SAP Sports One can be also used in ice hockey, handball, rugby and skiing (SAP, 2018b).

In addition to being a cloud solution, SAP Sports One is available as software as a service (SaaS), which means that the software can be accessed from any device. SAP Sports One is optimized and offers role-based interfaces, which is very empowering for all users. Solution can be configured and adjusted for every club or sports organization, allows integrating data from various sources and provides insights about players and teams with real-time analytics. SAP guarantees that all data is protected in their cloud-based environment following the new GDPR security standards (SAP, 2018b).

SAP Sports One was announced in 2015 at SAP Sports and Entertainment Forum held at the Allianz Arena in Munich. At the time, the solution was first sports-specific solution working on cloud. It was developed as an evolution of SAP Match Insights solution, that was used by German Soccer Association for preparation for World Cup 2014 in Brazil. SAP wanted to develop the solution that will help teams and sports organizations make better decisions, achieve better results and bring the best out from players. SAP Sports One from the beginning was planned as a solution for all sports organization members, from players and coaches to scouts, medical stuff, video analysts and directors. The first release of the solution was designed for football with the plan to adapt it for other sports, too (SAP, 2015).

4.1.2 SAP Sport One free trial and key capabilities

SAP offers a 15-day free trial of the SAP Sports One on their web page. All you need to do to get an access is to register. Free trial is based on a real-life sample data of football club TSG 1899 Hoffenheim. There is an option for guided tours, which help users to get familiar with the solution by following systematic instructions provided by SAP. On the other hand, users can explore the solution on their own (SAP, 2018c).

SAP Sports One has 5 key capabilities (SAP, 2018b):

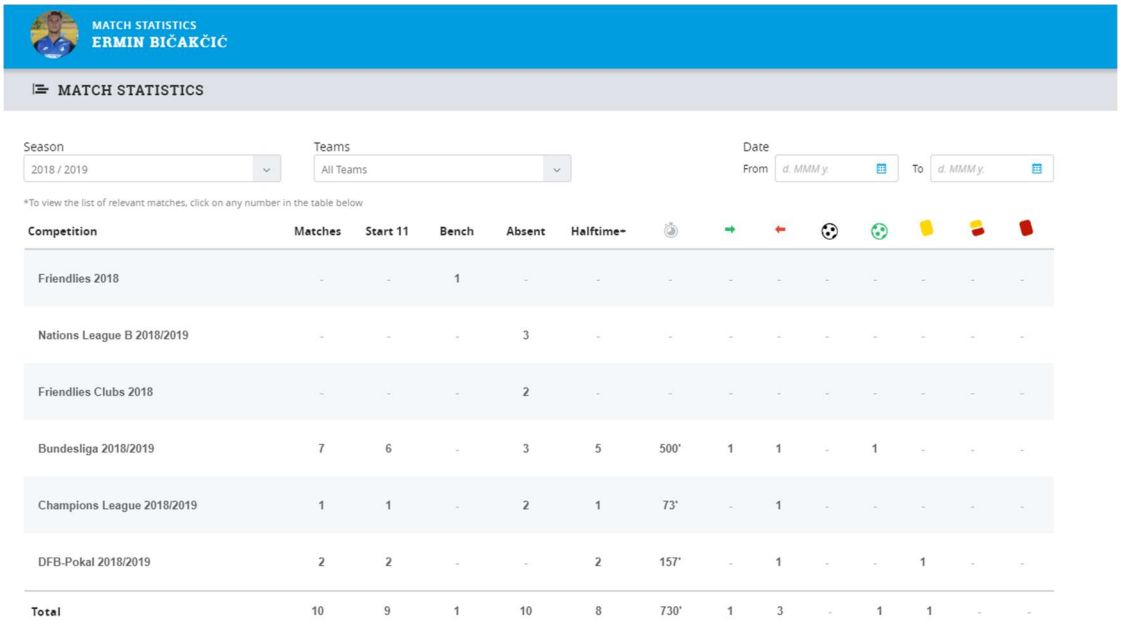
- Team management
- Training management
- Player fitness
- Scouting insights management
- Performance insights

Team management is there for analyzing and tracking player's development, progress and results. Information about players are consolidated into informative profiles, which are very practical and easy to use. This capability also empowers coaches, players and scouts to communicate with each other (SAP, 2018b).

In order to test this capability, free trial puts you in the role of a team manager of TSG 1899 Hoffenheim and guides you through the solution. Guided tour starts with the calendar checking and adding new tasks and activities. After that, as a team manager you can add

new representative and organize a meeting to introduce the new employee. After adding all participants, group chat is created, where you can send text messages or add some attachments. Subsequently, guided tour introduces you to players' profiles. After selecting the player, you can check general information about him, previous clubs and match statistics, as shown in Figure 11. Interestingly, solution allows adding and editing information about player's passport and visa. Guided tour finishes with creating NADA report, which contains presences and absences of all players in selected period (SAP, 2018c).

Figure 11: Player's statistics



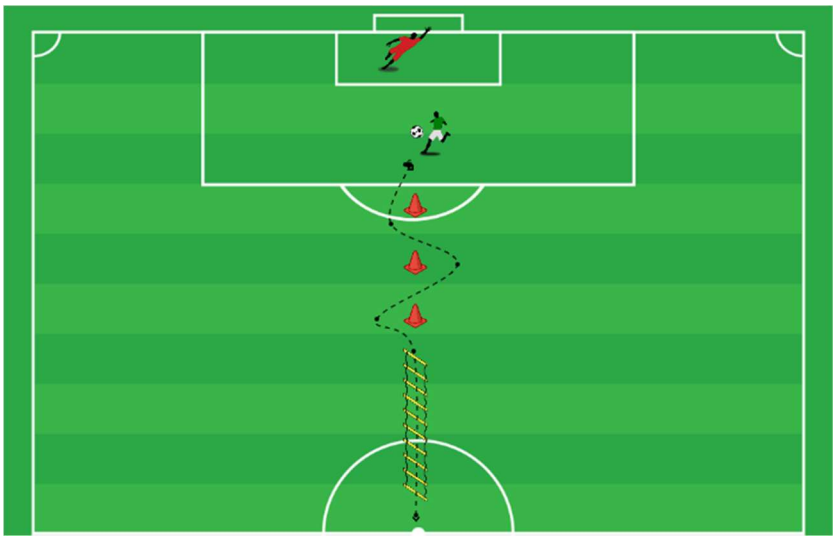
Competition	Matches	Start 11	Bench	Absent	Halftime+								
Friendlies 2018	-	-	1	-	-	-	-	-	-	-	-	-	-
Nations League B 2018/2019	-	-	-	3	-	-	-	-	-	-	-	-	-
Friendlies Clubs 2018	-	-	-	2	-	-	-	-	-	-	-	-	-
Bundesliga 2018/2019	7	6	-	3	5	500'	1	1	-	1	-	-	-
Champions League 2018/2019	1	1	-	2	1	73'	-	1	-	-	-	-	-
DFB-Pokal 2018/2019	2	2	-	-	2	157'	-	1	-	-	1	-	-
Total	10	9	1	10	8	730'	1	3	-	1	1	-	-

Source: SAP (2018c).

Training management is a part of the solution which allows coaches to prepare training sessions based on different attributes such as players' skills, players' position or players' availability. Training sessions can be individual, group or team. In addition, players' progress can be monitored by integrating third-party data tracking solutions (SAP, 2018b).

To efficiently test this capability, free trial puts you in the role of a coach of TSG 1899 Hoffenheim. Guided tour starts with creating new exercises. In this part, it is possible to create different types of exercises such as agility exercises, technique exercises, strength exercises, etc. Besides adding all needed information, coaches can also draw the exercise, as shown in Figure 12. Following, a new training session is created. Creating a training session is combining different exercises created in the previous step. After creating a training session, coaches can choose players and other coaches that will participate in that training session. It is also possible to get a PDF document of the session. At the end, coaches can get Training Days report, which contains information about the participants in training sessions in some specific period (SAP, 2018c).

Figure 12: Exercise drawing

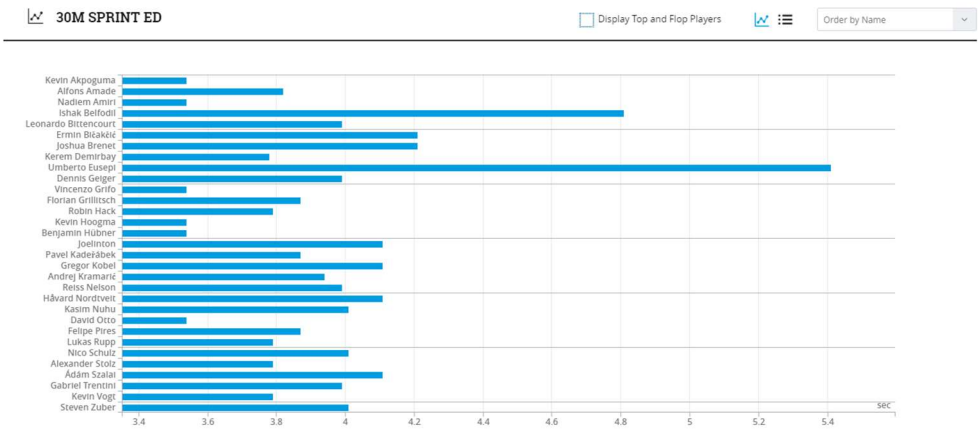


Source: SAP (2018c).

Player fitness ability helps teams to run diagnostic tests and analyze performance of players. In addition, SAP Sports One supports managing schedules for medical stuff and physiotherapists efficiently in order to keep the team healthy (SAP, 2018b).

When testing this functionality in free trial, there are two different roles. First part of the guided tour puts you in the role of a performance diagnostician. First step is to create performance test catalog, where diagnostician can add different types of tests that will be used, such as sprinting, running, jumping, etc. After that, diagnostician can schedule performance test, where he can choose date, location and participants of the performance test. Once the test took place, diagnostician can enter the test results. Results can be added manually in the solution or imported from an excel spreadsheet. Subsequently, as shown in Figure 13, results can be analyzed on team and individual level (SAP, 2018c).

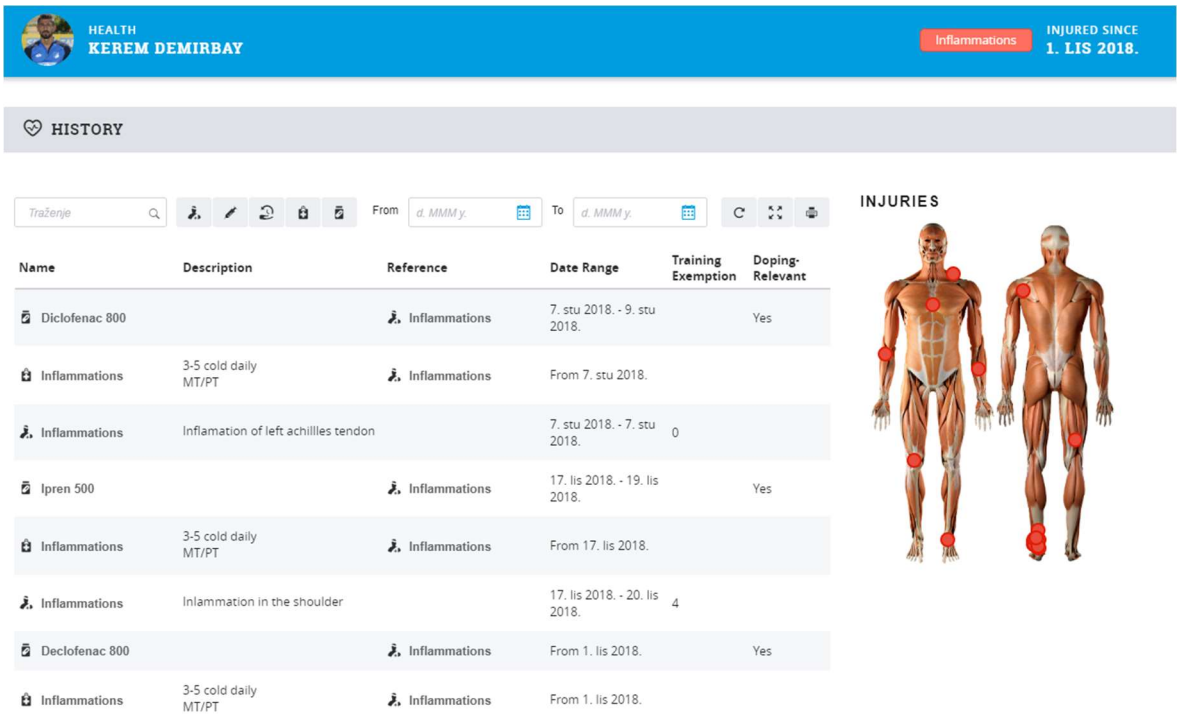
Figure 13: Performance test analysis



Source: SAP (2018c).

In the second part of testing player fitness capability, free trial puts you in the role of physiotherapist of TSG 1899 Hoffenheim. At the beginning, individual overview of player's availability is checked. Data is shown in calendar view and can be filtered regarding player's position. After that, physiotherapist can check individual fitness history for each player and check his previous injuries and treatments, as shown in Figure 14. In case of a new injury, physiotherapist can record it in the solution. SAP Sports One allows entering three different types of the medical condition: injury, sickness and preventive action. Besides that, additional information such as diagnosis, injury date, estimated recovery period and pain level can be added. Interestingly, the solution provides body map, where a graphical indication of the injury is given. After adding the injury, guided tour moves onto the creation of a treatment plan. Solution provides templates for treatment plan, based on the treatments that were used in the past for the same types of the medical condition. To fulfill the treatment plan, needed medication in healing process can be added. In order to make physiotherapist's job easier, solution provides injury catalog, which allows quicker recording of injuries and automatically suggests right treatment plans. In this catalog, physiotherapists can add different injury categories and available treatment plans. At the end, there are three different reports available for physiotherapists. Report Medications show all the medications that are currently used by the players. Report Fitness shows all the injured players in calendar view with the expected durations of injuries. Report Treatments shows the list of injured players together with the types of injuries and used treatment plans (SAP, 2018c).

Figure 14: Player's medical history



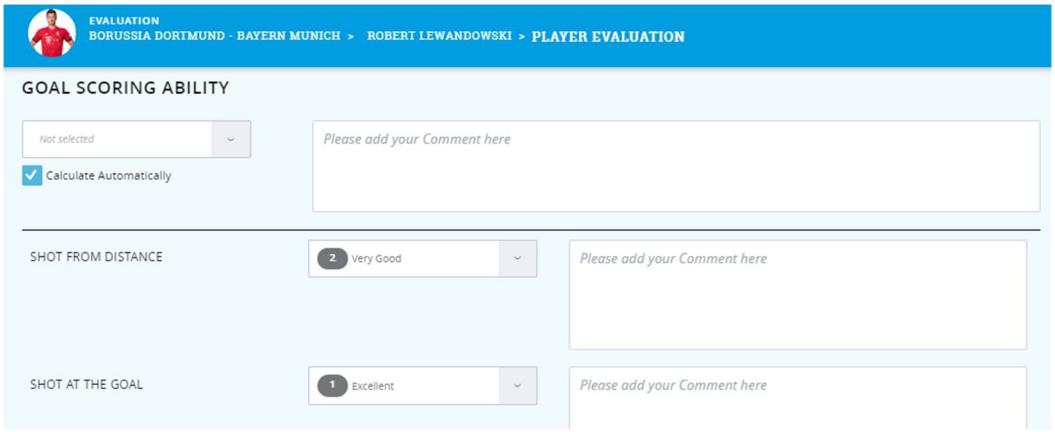
Source: SAP (2018c).

Another functionality of SAP Sports One is scouting insights management. This functionality allows establishing evaluation metrics and scouting catalogs. The main goal is to identify the best players to recruit to them team with advanced scout search and reporting tools (SAP, 2018b).

Free trial is divided in two parts, but in both, you are the head scout of TSG 1899 Hoffenheim. In the first part, scouting activities are planned. It starts with adding favorite competitions and teams. After the selection, SAP Sport One provides the scouting calendar, where all games of favorite leagues and clubs can be found. Following, an evaluation sheet can be created, which aims to compare players playing in the same position. Solution offers many evaluation criteria that can be used, such as personality, athletics, technique, goal scoring ability, etc. Scouts can also establish their own evaluation criteria and rating scales (SAP, 2018c).

In the second part of the tutorial, scouting requests are created and players are evaluated. At the beginning, scouts can create scouting requests for games that are in their calendar. Solution supports adding more than one scout, who will watch the game and choosing between live scouting or watching video recordings. Scouting request also contains the player that will be scouted. In addition to creating scouting requests for games in scouting calendar, scouts can add independent scouting requests for games that are not in calendar, such as friendly matches, youth tournaments or seminars. After the match for which the scouting request was created, players that were scouted can be evaluated, as shown in Figure 15. Players are evaluated through evaluation criteria covered in the first part of the tutorial. In order to have all interesting players in one place, SAP Sports One allows creating shortlists. Shortlists are great way to put all potential new players in one place and organize them by playing position. In addition to this, solution supports advanced player search. Scouts can get a list of players by adding different criteria, such as age, preferred playing foot, position or contract duration. Players that fulfill the criteria can be added to shortlist (SAP, 2018c).

Figure 15: Player evaluation



Source: SAP (2018c).

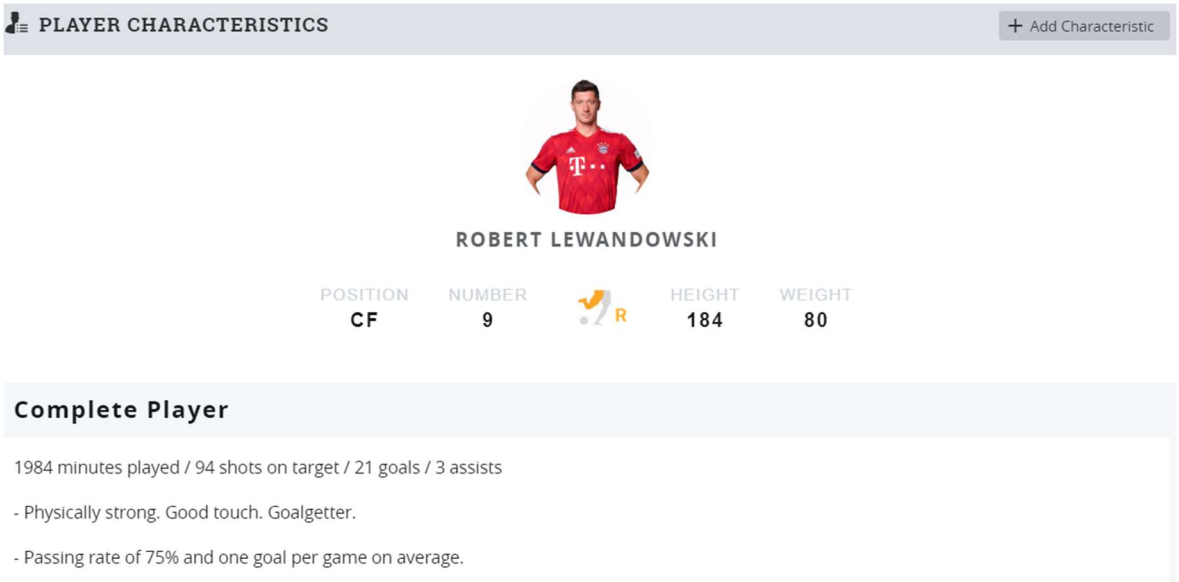
Performance insights functionality helps in preparing for next game by importing, filtering and tracking videos of important parts of matches. The key is to optimize match preparation activities and prepare for next opponent (SAP, 2018b).

In free trial, performance insights can be tested in three parts: video analysis, match preparation as match analyst and match preparation as a coach. Video analysis puts you in the role of video analyst of TSG 1899 Hoffenheim and guides you systematically through the trial. In this part, it is not possible to try something on your own and you have to follow the given instructions. The solution provides different filter options that allow finding relevant game scenes. After selecting the game scene, solution allows analysis in 2D view. Video analysts can mark players, include distances between players, draw areas of free space and show running paths. Following, video analyst can send the material to the trainer team (SAP, 2018c).

Match preparation as a match analyst of TSG 1899 Hoffenheim allows adding individual and team characteristics of the opponent. A match analyst can add injured players and prepare expected lineup. As shown in Figure 16, the match analyst can add strengths and weaknesses of each player in the opponent team (SAP, 2018c).

Match preparation as a coach of TSG 1899 Hoffenheim is offers guided tour without possibility to try something on your own, similarly to video analysis. In this part, coach can review all the information prepared by analysts in order to prepare for the next match (SAP, 2018c).

Figure 16: Player characteristics



Source: SAP (2018c).

4.1.3 SAP's partnership with TSG 1899 Hoffenheim

TSG 1899 Hoffenheim competed on an amateur level for decades. In early 2000s, club rapidly advanced with the support from Dietmar Hopp, former club player and SAP cofounder. By 2008, TSG 1899 Hoffenheim raised from amateur level to 16th place in the German Bundesliga, the top tier of the German football. In 2017, the club recorded 61st place on the world club ranking. Huge part of this success is the result of innovative coaching and digital transformation powered by SAP (Brown, 2017).

TSG Hoffenheim is using the SAP Sports One solution in order to recognize, acquire and develop the talent of players. On the team level, the solution allows them to rapidly evaluate players and prepare winning strategies. During trainings and matches, sensors attached to players' uniforms capture on-the-field data, such as heart rate, playing time and ball touches, and transfer them to coaches in real time. As the result, physiotherapists and coaches get detailed information about players' physical condition, training status and match performance. Based on the gathered data, players receive personalized health and training plans with the aim to optimize their match performance. In addition, players can provide their own input and feedback, which is a very important aspect for TSG 1899 Hoffenheim (Brown, 2017).

4.2 STATSports

4.2.1 STATSports Apex Pro Series

STATSports started very humbly in 2008 in Ireland and have grown since into the world-leading provider of GPS player tracking and analysis gear. Current offices are located in Ireland, London, Florida and Chicago. Besides football and basketball, STATSports solutions can be used in American football, rugby and athletics (STATSports, 2018a).

STATSports Apex Pro Series is designed for professional team sports. Apex is the most advanced performance-tracking device on the market. Figure 17 shows the device, which is placed in STATSports vest that players wear during practices or matches, as shown in Figure 18. It contains augmented 18Hz GPS, 600Hz accelerometer and Bluetooth LE. Apex has the ability to calculate over 50 metrics in the real time, due to powerful and highly optimized embedded processor. Apex generates real time metric results using the on-board metric calculation engine, which gets the data from data sensors working at the highest possible sample rates. All calculations are made on-board the device, while the resultant metrics are transmitted live over Ultra-Wide Band (hereafter: UWB) network provided by STATSports. In case that Apex go out of UWB range, Apex continues to calculate metrics and the receiver gets the updated values, when Apex returns into the UWB range (STATSports, 2018b).

Ultra-Wide Band is a communication method used in wireless networking, which achieves high bandwidth connections by using low power consumption. Simply put, UWB transmits huge amount of data over a short distance avoiding too much power usage. The problem of the UWB is that data rates drop significantly at longer distances (Mitchell, 2018).

Figure 17: Apex device

Source: STATSports (2018b).

All data gathered by Apex can be stored, transferred and accessed from STATSports cloud infrastructure. This infrastructure allows federations, clubs and coaches to get the information they need at any time in any place from different devices, such as mobile phones, tablets and desktops. Company STATSports find data security as fundamental to their strategy, so they guarantee the safety of player data. In addition, Apex device has micro USB port, which allows data downloading and charging (STATSports, 2018b).

As mentioned before, Apex can calculate over 50 metrics in real time. Analyzing 50 metrics at once can be very confusing for coaching team, so STATSports combined them in groups and named them as primary metrics. Primary Apex metrics are following (STATSports, 2018c):

- Total distance – tracks how much ground has player covered during the match or practice. The figure can be displayed in different units of measurements, such as kilometers, miles or yards.
- Speed – checks the maximum speed achieved by each player. Similarly to total distance, it can be displayed in different units of measurement, such as kilometers per hour or yards per second.
- High-speed running – shows how much ground has player covered at high speed. High-speed threshold can be defined differently for each player. This metric can also be shown as high speed running per minute.

- Accelerations – shows different metrics connected with accelerations. Coaches can check maximum acceleration, total number of accelerations, peak acceleration, breakdown of accelerations based on time, duration and distance covered per acceleration.
- Decelerations – in the same way as accelerations, shows different metrics connected with decelerations. Coaches can check maximum deceleration, total number of decelerations, peak deceleration, breakdown of decelerations based on time, duration and distance covered per deceleration.
- High Metabolic Load Distance – shows the total distance covered above a metabolic threshold. This threshold can be achieved through high-speed running, accelerations or decelerations.
- Heart rate – includes maximum heart rate, average heart rate, time in heart rate red zone, heart rate exertion and heart rate variability.
- Sprints – shows how many times player get above a defined sprint threshold. Maximum speed, duration and distance covered in each sprint are also displayed.
- Collisions – shows G force of each collision, tackle, hit and fall. Metric collision load shows a sum of all collisions.
- Fatigue index – shows the players' fatigue caused by the intensity of a match or practice. It can also show the load on athletes over defined period.
- Step balance – shows average forces placed on both foot of each player calculated by 100Hz tri-axial accelerometer. It is very important insight into the force displacement and balance of players.
- Dynamic stress load – displays the external load placed on each player during a match or practice. Each player has a different injury history, fatigue level and biomechanics, which means that each player will deal differently with the external load.

In addition to all the metrics, Apex System allows multiple ways to monitor players. The system offers a simple layout, which allows flexible switching between offered methods of analysis. Coaching team can use following methods (STATSports, 2018c):

- Individual analysis – detailed analysis of one player from one session.
- Session – report of all players or group of players from one session based on chosen metrics.
- Squad period – average for each session in chosen period. For example, average in last 10 consecutive practices.
- Individual period – check performance of one player over a chosen period.
- Total load – check the cumulative values in desired period.

In addition to players' performance analysis, Apex features tactical analysis. Using the GPS technology, Apex can show player positioning and player movement from an aerial aspect, which helps coaches to assess players' tactical aspect of the game. Tactical analysis

features supported by the Apex are session replay, video sync, positional map and activity heat map (STATSports, 2018c).

List of the sports club and national teams using STATSports Apex Pro Series is very long. Most popular football teams that are using the technology are FC Barcelona, AS Roma, Inter Milan, Juventus FC, Manchester United FC, Manchester City FC, Liverpool FC and AS Monaco. Basketball clubs that chose the Apex Pro Series are Memphis Grizzlies, Washington Wizards, Charlotte Hornets, New York Knicks and Portland Trail Blazers (STATSports, 2018d).

Figure 18: Edin Džeko and Daniele De Rossi wearing STATSports vest

Source: AS Roma (2018).

4.2.2 STATSports Apex Athlete Series

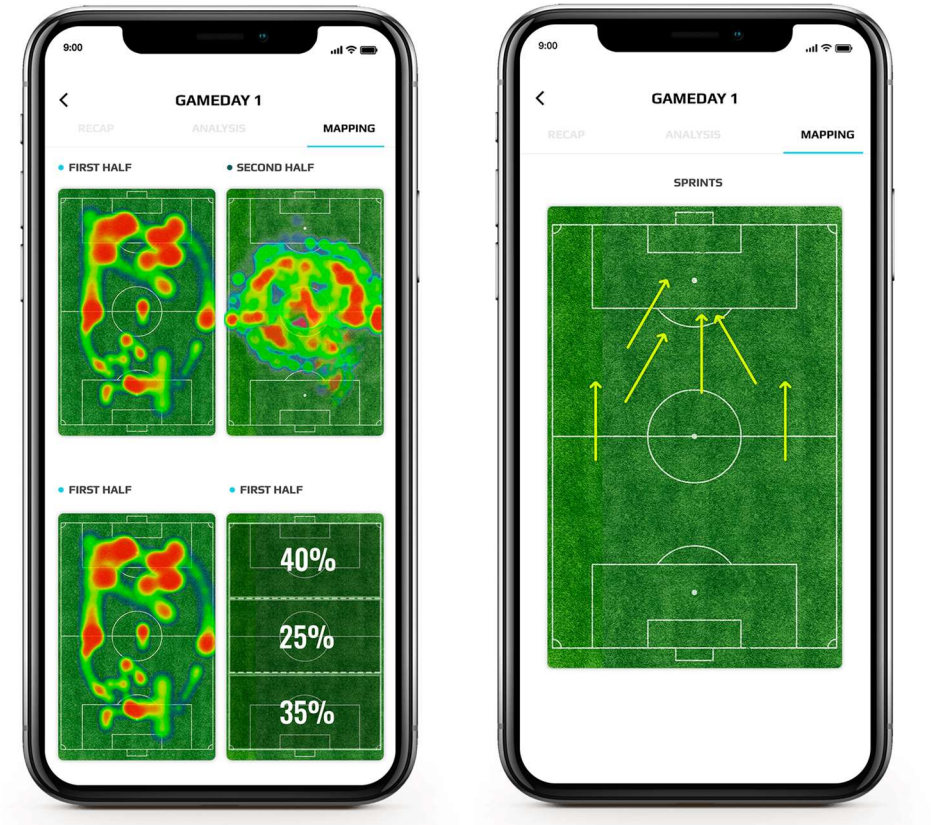
STATSports Apex Athlete Series is a performance-tracking device made for individuals. 10Hz GPS device can calculate over 4,5 million data points during 60-minute practice. The device aims to help players improve their game and get close to professional athletes worldwide. Similarly to Apex Pro Series, Apex Athlete Series device is held by the Apex Athlete vest, which can be worn over or under player's jersey or T-shirt. In addition to football, this technology can also be used in running, field hockey and rugby. Famous

football players using the technology are Neymar Jr., Cristiano Ronaldo and Paul Pogba (STATSports, 2018e).

Apex Athlete Series offers a number of interesting features (STATSports, 2018e):

- Live tracking – on-board processors allow sending live data directly to phone app, so that athletes can instantly see what they are doing, while doing it.
- Wireless syncing – automatic synchronization of statistics from Apex device to mobile app.
- Run & play – possibility to track individual and team sports activities with in-depth analysis.
- Leagues & leaderboards – create leagues, compare and compete with friends and Apex Athlete Series users worldwide.
- Tactical Analysis – do on-field analysis of each session, as shown in Figure 19.
- Multi-session battery – 9+ hours battery life which allows tracking multiple practices or games without recharging the device.
- Heart rate tracking – analyze heart rate information after each session.
- STATSports social – like, comment, post and share practices on STATSports social feed and stay up to date with other Apex Athlete Series users.

Figure 19: Heat maps as the way of tactical analysis



Source: STATSports (2018e).

4.3 Wilson X Connected Basketball

Wilson X Connected Basketball is a smart basketball which can track shooting stats, such as two-point shots taken, two-point shots made, three-point shots taken, three-point shots made, free throws taken, and free throws made. Wilson X Connected Basketball does not require any additional gadgets on the basket or on the court, only the ball and the smartphone app. Wilson X Connected basketball comes in two sizes, official game size and intermediate size, and looks like usual ball for basketball. A small sensor is added into the ball, which can track shooting performance. Only requirement is that basket is 3,05 meters high, which is the official height. The ball uses Bluetooth to connect to Android or iOS device. After opening the app on mobile device, the ball has to be thrown in the air with backspin in order to connect with the app (Graziano, 2015).

Wilson X Connected Basketball offers four different game modes, as shown in Figure 20, that are supported by the app. Game modes are following (Wilson, 2018):

- Free range – shoot-around mode, where player takes shots from different positions on the court and the app shows his/her percentage.
- Free throw – game mode for practicing free throw shooting. The app records made and missed shots and shows lifetime statistics.
- Buzzer beater – game mode for practicing shots while the shot clock or game clock is counting down.
- Game time – game mode that recreates real game situations. The player is put in the position of start player leading his/her team and the goal is to try the win the game by making shots.

The app includes unlocking achievements after reaching certain milestone and sharing statistics on social media after finishing the training session. Interestingly, Wilson X Connected Basketball cannot be charged, but Wilson guarantees that the ball will last for up to 100,000 shots (Graziano, 2015).

Figure 20: Wilson X Connected Basketball game modes

Source: SportIQ (2017).

4.4 Babolat Play smart racket

Babolat Play is a smart tennis racket that allows players to have an overview of their game. The handle of the racket contains six axis sensors, accelerometer, gyroscope and piezoelectric. Built-in rechargeable lithium battery allows 6 hours of playing time without charging. As shown in Figure 21, at the bottom of the racket's handle, there is power on/off button, Bluetooth button and micro USB port. The racket can be connected to Babolat mobile app, which is compatible for iOS and Android, via Bluetooth. The data can also be transferred to a computer via USB. It is important to emphasize, that sensors, two buttons and USB port do not change performance of the racket. Babolat offers three models of smart racket: Pure Drive, Pure Drive Lite and Pure Aero. Difference between rackets are grip, weight and balance (Babolat, 2015).

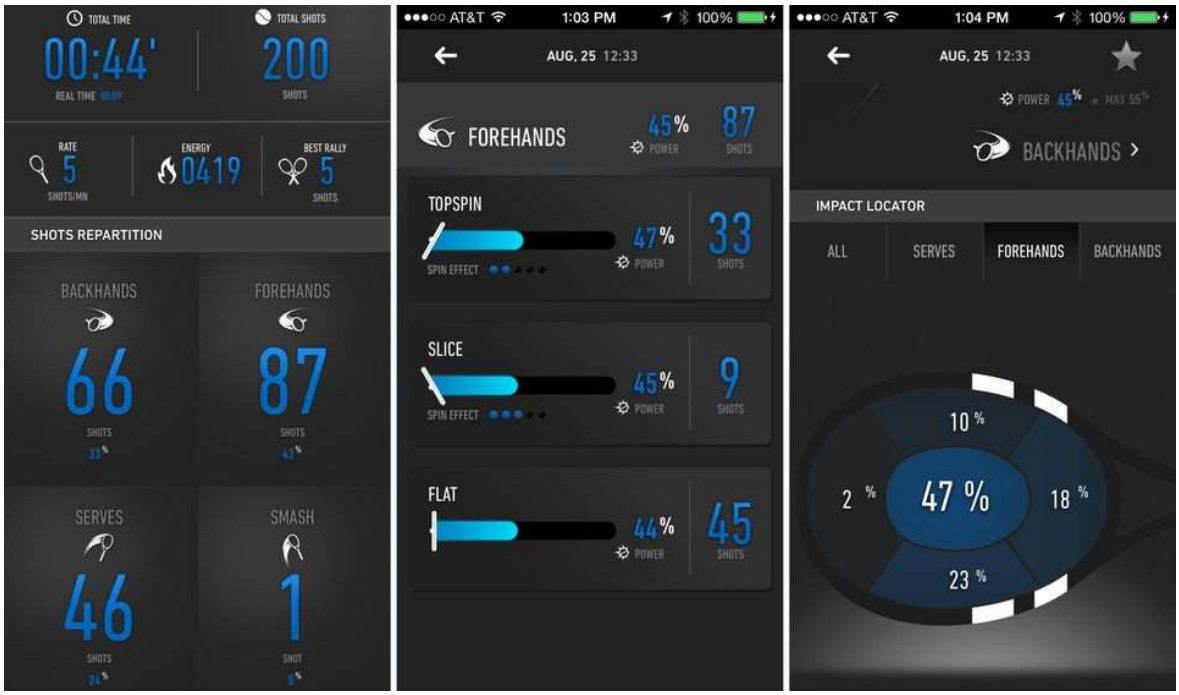
Figure 21: Bottom part of Babolat Play racket

Source: Kasten (2015).

Babolat Play racket helps players to evaluate and analyze their game based on information that the racket collects and transfers to mobile app. As shown in Figure 22, the Babolat app offers different information, such as playing time, number of forehands, backhands, smashes, volleys and serves, power of shots, longest rally, serve speed and impact locator, which shows in percentages with which part of racket player hits the ball. In addition, the app allows sharing and comparing player's performance with the rest of Babolat community (Babolat, 2015).

In addition to information provided by the app mentioned above, Babolat Play users also get information how often they hit their stroke flat, with topspin or slice. Regarding the information about the power of shots, the app provides the information in percentages. The maximum 100% power is equivalent to a serve of 200 km per hour. The reason behind this is that amateur players can find it difficult to interpret power of their shots. Getting information in percentages shows them how close they are to professional tennis players on tour (Kasten, 2015).

Figure 22: Babolat Play app preview



Source: Diallo (2014).

As shown in Figure 23, the most popular player using Babolat Play racket is Rafael Nadal. Nadal has been using Babolat rackets since his youth tournaments and is known as a player who does not like changing rackets. The Babolat Pure Aero model was designed by him and for him in 2004 and he has been using that model ever since. He has made only two minor changes in the model during the years. In 2012, after a series of loses in matches with Novak Đoković, he decided to add 3 grams to the top of the frame in order to get more power in his shots. The second change came in 2017, when he decided to add additional 2 grams to the same place. Nadal is known as a player who has never broken his racket on purpose during his career, which also shows that he does not like changing his rackets. This all shows, how important was for Babolat to add Play technology in rackets without changing any racket specifications. Nowadays, Nadal uses Babolat Pure Aero Play model, which helps him to analyze his game (Babolat Insiders, 2017).

Babolat Play racket helps Nadal and his coaching stuff in many ways. Firstly, it helps them track the number of hits and hours spent on the playing court. This tracking is important for preparation and analysis of training regime. Secondly, very important aspect for Nadal is tactical analysis and preparation for different opponents. Nadal is known as a player with tremendous forehand and one of the best inside out forehands on the tour, which leads to the conclusion that he should base his game on this shot. Nadal and his coaching staff want him to hit about 70% of forehands out of all shots during the match as the optimal winning strategy. Babolat Play app allows them to track that. In addition to this, tracking helps them in analyzing other aspects of his game. For example, if he hits high number of slices, it

means he is playing too defensively, or if he is hitting his shots with bottom part of the racket, it means that he is too close to the ball or that he is hitting it late. All those information help Nadal and his team to analyze his game and improve every day (Tracy, 2015).

Figure 23: Rafael Nadal with the Babolat Play racket

Source: Stanley (2016).

5 TECHNOLOGIES FOR FANS' EXPERIENCE

Sports are played for fans and their support means everything to athletes and teams. Sports are followed by enormous number of supporters which have established a support culture for their teams, players and organizations. Some teams enjoy strong support culture and in turn gain notoriety on account of their fans, rather than sports results and achievements. Typical examples are Borussia Dortmund, Liverpool F.C. or Galatasaray SK (Shekhar, 2018). In addition, fans are a huge source of income for any sports organization.

Technologies for fans' experience analyzed in this chapter aim to positively influence relationship between sports organizations and their fans, as well as increase fans' experience not only during the game, but also before and after it. This chapter contains five different technologies chosen with the intention to show how technologies can differently influence the fans' experience. The first technology in the chapter is SAP Event Ticketing,

an event ticketing software solution for increasing ticket sales and revenues. In addition, the solution helps sports organizations build stronger relationships with the fanbase. Following technologies in the chapter aim to improve fans' experience during TV broadcasts of games. Intel 360 Replay allows fans to see 360-degree replays, NBA VR technology enables fans to watch NBA games in Virtual Reality, while FIRSTVISION cameras provides video footage from players' point of view. The chapter concludes with NBA stats provided by SAP HANA platform, technology that offers fans all NBA stats during and after the games.

5.1 SAP Event Ticketing

5.1.1 About SAP Event Ticketing

SAP Event Ticketing in an event ticketing software for increasing ticket sales and revenues. It helps sports organizations manage event processes, customers and tickets quickly and efficiently. In addition to economic benefits, the solution helps sports organizations build a stronger brand, strengthen relations with the existing fans and attract new supporters. Similarly to SAP Sports One, SAP Event Ticketing is deployed in the cloud, which means that the solution can be accessed from any Web browser on any device. SAP Event Ticketing can be configured for every sports organization and integrated with existing IT landscape. Regarding the security, SAP guarantees securing customer and ticketing data with allowing only authorized access to critical information (SAP, 2018d).

SAP Event Ticketing has four key capabilities (SAP, 2018d):

- Ticket management,
- Ticket sales,
- Fan and customer insights,
- Technological flexibility.

Ticket management helps in maximizing ticketing revenues by selling different types of tickets across multiple channels. The solution allows selling single tickets, season tickets, coupons, vouchers, accreditations and parking permits. In addition, sports organization can add special campaigns, price reductions, promotions and memberships (SAP, 2018d).

Ticket sales supports generating revenue by cross selling and up selling. In addition to tickets, sports organizations can also sell merchandise, parking, food and beverages. This functionality also includes social selling on different social media channels (SAP, 2018d).

Fan and customer insights help strengthening relationship with fans by using advanced marketing, CRM, loyalty features and memberships. The solution utilizes real-time

ticketing analytics in order to maximize sales for each event and each seat on the stadium (SAP, 2018d).

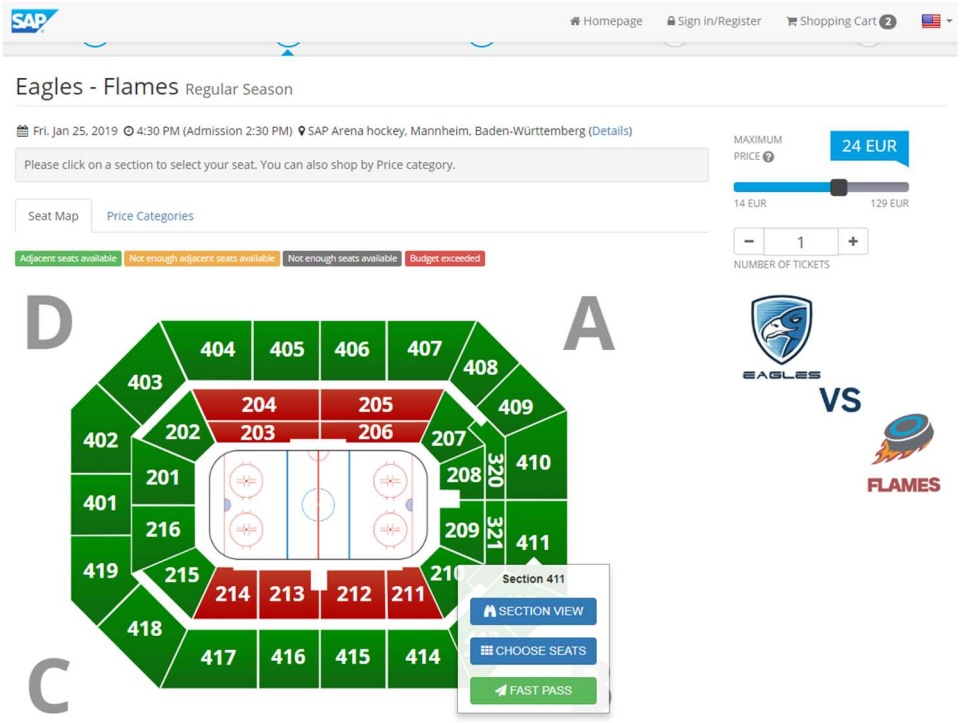
Technological flexibility represents possibility to integrate and connect SAP Event Ticketing with different systems and technologies. For example, the solution can be connected with number of admission control systems with the intention of gathering ticketing data (SAP, 2018d).

5.1.2 SAP Event Ticketing free trial

Similarly to SAP Sports One, SAP offers a 15-day free trial of the SAP Event Ticketing on their web page. All you need to do to get access is to register. Free trial is based on a real-life sample data of German hockey club Mannheim Eagles. Free trial is divided in three parts: Booking a Ticket, Cross-Selling and Social Integration. In all three parts, solution is tested from the fan point of view (SAP, 2018e).

Booking a ticket guided tour starts by choosing a match for which the fan wants to buy a ticket. An incentive to buy a ticket was an e-mail which contained a promotional code with 50% discount for the first ticket purchase. After selecting the match, the fan can filter the tickets based on their price, choose the section of the stadium or hall, check the section view and choose seats, as shown in Figure 24. Option Fast Pass picks the best available seats for selected price range (SAP, 2018e).

Figure 24: Choosing tickets for the match

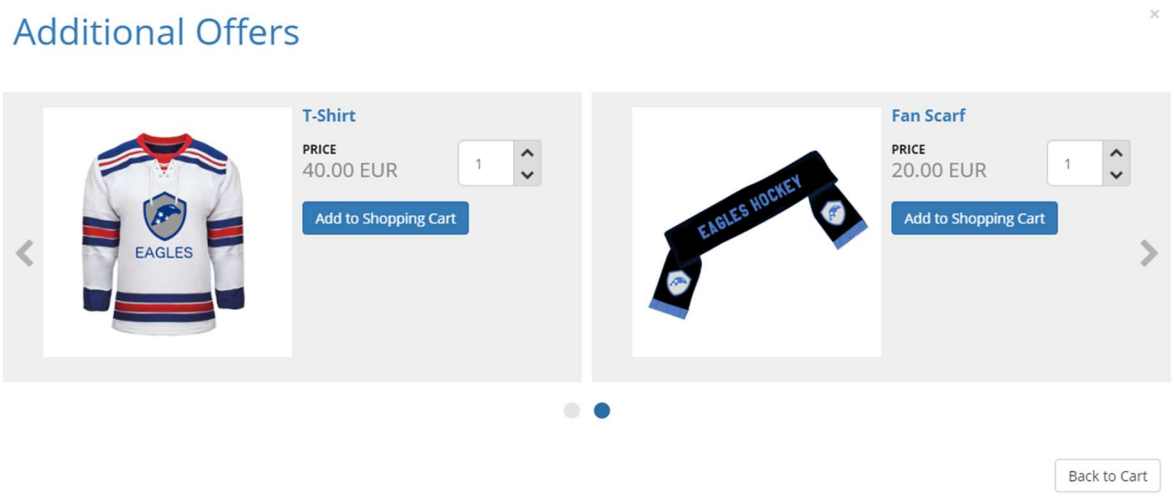


Source: SAP (2018e).

After picking seats, the next step is choosing a shipping method and a payment method. The solution allows choosing between printing tickets at home, getting tickets on e-mail, getting tickets on mobile app (passbook) and picking up the tickets on the match day in the ticket office (will call). Regarding the payment method, the fan can choose between Pay Pal and credit card (SAP, 2018e).

Cross-selling guided tour is very similar to the booking a ticket. After selecting the seats, the solution offers you additional options, as shown in Figure 25. A fan can get the possibility to buy club's merchandise, parking spot for the game or tickets for youth tournament (SAP, 2018e).

Figure 25: Additional offers after choosing seats for the game



Source: SAP (2018e).

Social integration guided tour shows how fans can use Facebook, while buying tickets. Fans have a possibility to share the game event on their Facebook wall and show that they are interested for the match. In addition to this, fans can find out which seats are already booked by other Facebook users. That gives an opportunity for fans to select their seats next to their friends that will also go to the match (SAP, 2018e).

5.2 Intel 360 Replay

Intel 360 Replay, also known as Intel True View, is a technology that enables fans to see the best game plays from every possible angle, even from players' perspective. High-resolution cameras and data-crunching technology are installed in stadiums and arenas around the world with the aim of increasing fans' experience. 360-degree replays are available in Spanish football league LaLiga and basketball leagues NBA and NCAA. The technology can also be found in American football league NFL (Intel, 2018a).

Intel 360 Replay technology is enabled by three key factors: cutting-edge 5k cameras, extreme processing power and proprietary data algorithm. More than 30 5k cameras

surround the stadium or the arena, which cover every centimeter of playing surface. The cameras use 3D pixels, so called voxels, and capture volumetric data (height, width and depth). Extreme processing power is needed to process enormous amount of volumetric data captured by 5k cameras. On-site Intel server farms are responsible for processing the data and creating 3D replays. Proprietary data algorithm enables data processing at remarkable speed. As preview shows in Figure 26, the result is flawlessly rendered Intel 360 replay (Intel, 2018a).

In 2016, LaLiga became the first European league to install Intel 360 Replay technology. Camp Nou, the biggest stadium in Europe and home of FC Barcelona, had the honor to be the first stadium in Europe with this technology. In December 2016 for the first time in European football, Intel 360 Replay was used in popular El Clasico derby, the match between FC Barcelona and Real Madrid C.F. Although it was a first time employing the technology in European football, Intel 360 Replay technology had been used in basketball and American football before. By teaming up with Intel, LaLiga wanted to show that they are open for bringing technology to football and offer broadcasts of the very highest quality to their fans (LaLiga, 2016).

LaLiga aims to install this technology on every stadium used in the league. Stadiums that have already been provided with the technology are Camp Nou (FC Barcelona), Santiago Bernabeu (Real Madrid F.C.), Wanda Metropolitano (Atletico de Madrid) and Ramon Sanchez-Pizjuan (Sevilla F.C.). Next two stadiums that are planned for installing the technology are San Mames (Athletic de Bilbao) and Mestalla (Valencia CF) (Anand & Law, 2018).

Figure 26: Intel True View preview

Source: MktRegistradoTV (2018).

5.3 NBA Virtual Reality

5.3.1 Intel True VR

Intel as the official partner of the NBA league enables watching games in virtual reality with their Intel True VR Technology. NBA on TNT VR app takes fans courtside, allows them to choose their viewpoint and watch the game live or on-demand. In addition, fans can hear TNT commentary, TNT analysts and courtside reporters. All in all, the technology offers an amazing game experience for the fans (Intel, 2018b). NBA used Intel True VR for the first time during the All-star weekend 2018 in Los Angeles and again during the 2018 play offs (Intel, 2018c).

Intel True VR demands great talent and extreme technology. Games covered by this technology are recorded with four HD Intel True VR cameras that are strategically placed around the court, which enables fans to watch the game from the courtside, stands or under the basket. The production crew are in charge for the flawless functioning of technology. The production crew is placed in an on-location production van together with all the controls, electronics and monitors. The crew has eight Intel VR specialists, technical manager and cast producer (Intel, 2018b).

As shown in Figure 27, all what fans need to experience the technology is to buy NBA league pass subscription for watching games and one of Android smartphone compatible VR devices, such as Samsung Gear VR or Google Daydream View, and NBA on TNT VR app (NBA, 2018b).

Figure 27: Reggie Miller experiencing Intel True VR

Source: Intel (2018c).

5.3.2 NextVR

Another official partner of NBA offering games broadcasts in virtual reality is company NextVR. NextVR was launched in 2009 and it is the world's leading virtual reality platform for delivering music and sports. The company has multiple patented technologies for virtual reality and besides NBA, they have partnerships with FOX Sports, Live Nation, International Champions Cup and WWE (NextVR, 2018a).

NextVR usually covers each broadcast with eight different cameras. In each arena, cameras are placed behind the backboards, on courtside and overhead. Besides courtside action shown in Figure 28, NextVR production crews capture locker-room interviews, behind-the-scenes footage and scenes around the city. NextVR is very secretive about their cameras and technology, so it is not publicly available. The only known fact is that they are using 6k stereoscopic cameras (Waniata, 2018).

Figure 28: NextVR broadcast preview

Source: Melnick (2018).

Similarly to Intel True VR, in order to watch NBA in virtual reality, fans need the NBA League Pass subscription, NextVR free app and one of VR devices. The NextVR app is available on every major VR platform, such as Gear VR, Google Daydream, PlayStation VR, Microsoft Mixed Reality, Oculus Go, Oculus Rift, HTC Vive and HTC VIVE Pro (NextVR, 2018a).

NextVR offers live virtual reality and on-demand virtual reality. Live virtual reality represents watching whole NBA game live, which is payable through NBA League Pass subscription. Schedule for VR broadcasts in current season is already published and it

contains at least one game per week. On the other hand, NextVR offers on-demand virtual reality, which is totally free. Fans can check game highlights, top ten plays, best plays of the season or even behind the scenes footage with NBA dance teams (NextVR, 2018b).

To further increase the fans' experience, NextVR offers watching every game in a Virtual Environment. Fans can watch games on the largest screen in their house with NextVR Screening Room, a VR environment in the NextVR app with games appearing on a theater-size screen. Fans that are using the Oculus VR platform can integrate with other fans and share their experience trough Oculus Venues in real time. Every fan that attend a game in Oculus Venues will get an NBA jersey for their Oculus avatar (NextVR, 2018a).

5.4 FIRSTVISION cameras

FIRSTVISION is a pioneer in wearable electronics and market leader in capturing players' point of view in official tournaments. Their mission is to bring true reality of sports closer to the fans with adequate products. In order to accomplish their mission, FIRSTVISION integrates audiovisual and radio transmission technology in players' gear. Their biggest market advantage is that they are capable of transmitting footage of player's point of view live in broadcasts of official matches or tournaments (FIRSTVISION, 2018a).

FIRSTVISION offers experiencing game action in Full-HD just like referees and players do. The company wanted to bring on-field and on-court experience for fans that was not available before in ball sports. In addition to football and basketball, FIRSTVISION cameras can be used in handball and ice hockey. For football and basketball, FIRSTVISION offers three products: Live Jersey, Rec Jersey and VR Body-Cam. Live Jersey is 100% compatible with TV standards and can be included in live TV broadcasts. In addition to Full-HD camera, the jersey contains RF broadcast system. The video footage is broadcasted with 2ms delay and captures 127 degrees of field vision. The jersey records the full content, which can be used as soon as game finishes. The Rec Jersey has all the quality and technological standards as Live Jersey only without broadcast system. The recorded video is available immediately after the game has finished. VR Body-Cam records the action in 360 degrees with two camera lenses attached to jersey, one lens on front side and one lens on backside. Both lenses have 185 degrees of field vision and provide virtual reality experience from players' point of view (FIRSTVISION, 2018b).

Jerseys are 100% wearable and are available in men's, women's and children's sizes. FIRSTVISION offers a possibility to insert their technology on base kits from any brand, so that are no copyright issues with sponsors. Also, very important aspect is that the technology is tested and certified for being 100% safe. It also does not have any positive or negative effect on players' performance and it is invisible. Cameras are placed underneath players' jerseys, while the camera lens peers out of a precise opening adopted for any jersey (FIRSTVISION, 2018b).

In addition to offering amazing fan experience, FIRSTVISION brings some other benefits. FIRSTVISION can include a sponsor's logo in player's or referee's camera, add sponsor's logo on only chosen highlights or add intro and outro sponsorship bumpers for separating point of view footage from the main broadcast cameras. FIRSTVISION video material can also be used for creating game highlights and showing game moments that other cameras are not able to access. On top of that, clubs and leagues can raise impact on social media channels by using a point of view camera angle (FIRSTVISION, 2018c).

With the advanced technology described above, FIRSTVISION managed to get trust from some clubs and leagues at the highest level. FIRSTVISION had an honor to collaborate with LaLiga, Manchester United F.C., Atletico de Madrid, Valencia C.F., VfL Wolfsburg and EuroLeague basketball (FIRSTVISION, 2018d).

FIRSTVISION and EuroLeague have been partners since 2015, when EuroLeague became the first major professional completion to use point of view cameras attached to players' jerseys on match between Real Madrid and Zalgiris Kaunas. Over the years EuroLeague experimented with body cameras and decided to go one step further on EuroLeague Final Four 2017 in Istanbul with FIRSTVISION VR Body-Cam. One referee in every match wore FIRSTVISION jersey with VR Body-Cam, which brought point of view experience for EuroLeague fans, as shown in Figure 29. Footage from VR Body-Cam was available for fans after the games on-demand at EuroLeague's web page. EuroLeague and FIRSTVISION next plan was to include video footage from VR Body-Cam in live broadcast of Final Four 2018 in Belgrade. The EuroLeague Final Four is the most important event for the EuroLeague, so they want to include the best cutting-edge innovations every year and bring fans closer to the action. Their successful partnership and several projects with FIRSTVISION surely help them in that (EuroLeague, 2017b).

Figure 29: FIRSTVISION VR Body-Cam preview

Source: EuroLeague (2018b).

EuroLeague and FIRSTVISION put their plan from 2017 into action and added video footage from VR Body-Cam as a part of live TV broadcasts of Final Four 2018 in Belgrade. Cameras were attached in referees' jerseys and fans could experience on-court action. In addition, for the first time on Final Four fans were able to hear conversations between players, referees and coaches (EuroLeague, 2018a).

5.5 NBA stats by SAPA HANA platform

In 2013, NBA and SAP announced the launch of NBA stats web page which represents statistical destination with interactive access to all official NBA analysis and statistics. Sports fans have a huge passion for statistics because it helps them track their favorite player or team and brings them closer to the game. NBA wanted to provide game statistics for millions of fans that were previously available only to NBA teams and media members. In cooperation with SAP, NBA released web page powered by SAP HANA platform (SAP, 2013).

SAP HANA is in-memory data platform for delivering data-driven insights. It can process analytics and transactions of any data type with built-in advanced analytics and multi-model data processing engines (SAP, 2018f).

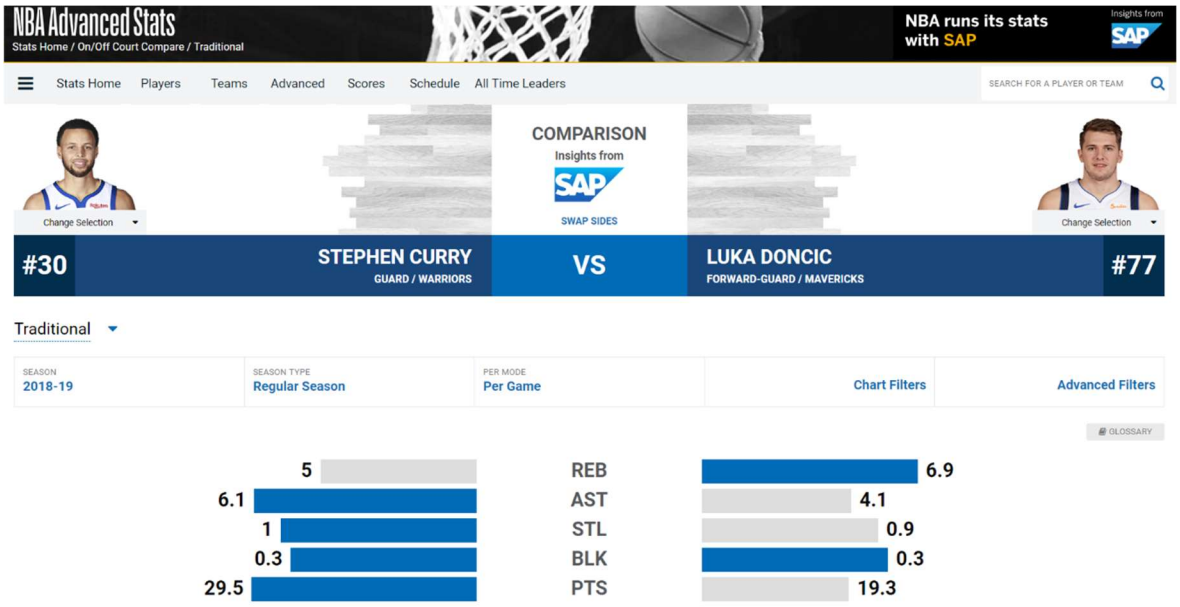
SAP HANA helped SAP and NBA to develop an online stats page that can handle thousands of users checking 4,5 quadrillion possible data combinations. NBA became global league, which is broadcasted in 215 countries in 49 languages. NBA's fan base is expanding rapidly with the fans' desire for more and more NBA information and content, so SAP and NBA needed something extraordinary and game changing. They found solution in SAP HANA platform (DeGennaro, 2017).

First release of the statistical web page included following information (SAP, 2013):

- Every NBA Box Score – all NBA box scores (game statistics) starting from season 1946/1947, including historical matches, such as Wilt Chamberlain's 100-point game in 1962 or Kobe Bryant's 81-point game in 2006.
- Advanced Shooting Charts – comprehensive shooting charts including player's "hot spots" and visual shot displays.
- Top Lineup Combinations – the best lineup combinations based on different statistical data.
- In-depth Statistical Breakdowns – huge variety of statistics per possession, in clutch moments, players' efficiency, comparisons of teams and playersas shown in Figure 30, etc.
- Player Pages for Every NBA Player – individual statistical pages for each player that have ever played in NBA.

Throughout the years, SAP HANA remained the core of the statistical web page, but SAP and NBA are constantly adding new features. The newest addition to the page are so called hustle stats. Hustle stats include loose ball recoveries, drawn offensive fouls, deflections and contested shots. This type of stats helps in understanding real value of players in the defensive part of their game (DeGennaro, 2017).

Figure 30: Comparison of Stephen Curry and Luka Dončić



Source: NBA (2018c).

DISCUSSION & CONCLUSION

Nowadays, technology is everywhere around us. It is very difficult or even impossible to find a segment of life, in which some technology is not incorporated. Therefore, technology have become also a big part of sports.

The thesis started with the theoretical background about history of sports and digital technologies. Although this part represents only a brief overview, it is interesting to see how sports and digital technologies developed through years. From the first sports activities, such as throwing stones or haunting trainings, sports have advanced to one big industry that we are witnessing today. As well as sports, digital technologies also had their own development path. Approximately 70 years after the invention of the first computer, we are talking about latest technologies, such as Internet of Things, Virtual Reality, Cloud Computing, Machine Learning and Artificial Intelligence.

After the history overview, theoretical background continued with one of the biggest trends in digitalization, Internet of Things. In this part of the thesis, it is described what IoT really is and what benefits it brings to companies and final users. On the other hand, IoT also

brings some potential threats which can endanger companies and users in case of avoiding basic protections. Theoretical background also covers security strategies and recommendations for safe usage of IoT. Subsequently, it is explained how IoT is used in sports which represents a great introduction for the main part of the thesis. Finally, Virtual Reality is briefly analyzed due to its usage in some technologies that are in the main part of the thesis. By capturing all this in the first part of the thesis, it can be said that first objective of the thesis was met.

In the main part of thesis, 13 different technologies divided into three groups were analyzed and presented. First group of analyzed technologies are technologies for game regularity. The biggest strength of these technologies is that they are a great support to referees in making the right calls. Another very important aspect that can be considered as a strength is that these technologies do not interrupt matches or cause any significant delays. So far, there have been no examples of big referees' mistakes caused by using some of the technologies, which can also be considered as a strength. On the other hand, these technologies are currently the privilege of the biggest leagues, tournaments and competitions. Small leagues and tournaments do not have an opportunity to use them, which represents the major weakness of these technologies. It will be very interesting to see how these technologies develop in the future. The following stages of development might bring technologies, which can replace referees in taking some types of decisions, such as offside situations in football or outs in tennis, or even at some point in future replace referees totally. This represents the biggest opportunity in this field. As the technologies for game regularity will fatherly develop, cyberattacks might represent a huge threat. Cyberattacks can be different. Attackers might aim to interfere the communication between referees and technologies or even counterfeit the suggestions provided by technologies. To overcome this threat, it will be very important that these technologies have strong security systems.

Second part of analyzed technologies are technologies for player/team performance. Players' or teams' improvement is very complex process. Technologies presented in this part support the whole process or only parts of it. SAP Sports One is team management software which covers all operations of one sports club. It can be used by coaches, medical stuff, directors, scouts and players. On the other hand, STATSports devices are directed into collecting data about physical performance and health. Coaches and medical stuff can use the data to adapt training regime and prevent injuries. Wilson X connected basketball and Babolat Play smart racket are gadgets that aim to improve players' sports skills and are not focused on other aspects of player performance. The fact that these technologies can support different aspects for improving player/team performance represents their biggest strength. Another strength of these technologies is that they enable gathering different data about players that can be used in planning training regimes, preparing tactics and maintaining players' health. Similarly to technologies for game regularity, some technologies, such as SAP Sports One and STATSports Apex Pro Series, are mostly used

by clubs and players competing on the highest level. That bring us to the weakness of these technologies which is their unavailability for smaller clubs and sports organizations. In the future, the opportunity for these technologies is including machine learning and offering automated suggestions for training regimes, tactics and recovery processes.

Another opportunity is the appearance of new technologies similar to Wilson X connected basketball and Babolat Play smart racket and their widespread in different sports. Usage of Virtual Reality also represents a great opportunity in this field. Technologies might offer a possibility for players to practice their skills in virtual environments. In case that those technologies to not become available for smaller clubs and players that are not competing on the highest level, it can be expected that the quality gap between the two mentioned groups would be even bigger, which does not represent the direct threat for technologies, but more for the sports in which they are used. The direct threats to the technologies are cyberattacks that aim to steal players' data, training regimes and tactics. It will be very important in the future that these technologies have very strong security systems.

Third part of analyzed technologies are technologies designed to increase the fans' experience. Fans are an important factor for every player, club and sports in general. SAP Ticketing software helps in managing tickets and merchandise sales, as well as in establishing better relationship with every fan. Other solutions analyzed in this category bring fans closer to the action and make them feel like they are part of the game. The biggest strength of these technologies is that they are able to make fans feel better about the sports and strengthen their connection with sports organizations and players. In addition, they can be used before, during or after matches, what represents a huge benefit for sports organizations. On the other hand, camera technologies covered in the thesis are part of broadcasts of very few best leagues and most important matches in the world. That means that a huge number of broadcasts are still not using these technologies, which can be considered a weakness. However, it is expected that these technologies will widely spread. Future might also bring more Virtual Reality broadcasts and some new camera technologies. Fans might be able to follow their favorite players in warmups, press conferences or practices. In case of huge development of these technologies and further increasing of fans' experience, it might happen that fans would not want to go to games anymore, which represents a huge threat for sports organizations. If TV broadcasts, which offer better experience than watching game from the stadium or arena, widely spread, clubs might face significant drop in number of fans present on games. In addition, these technologies might also face the problem of cyberattacks, which will aim on destroying relationships with fans.

During the analyses of technologies, available video presentations of technologies were reviewed, technology providers' web pages were analyzed, available free trials and case studies were examined, which means that the second objective of the thesis was also met. Subsequently, the main purpose of the thesis, which was to find out about digitalized

solutions and technologies used in sports industry, and contribute to this actual, popular, but also unexplored field, was fulfilled.

As technology is rapidly changing, it is very difficult to make strong predictions as to, how the field of digitalization in sport will fatherly develop. It is also tough to guess how sports will look in near future. The only important thing is that the technologies do not become bigger than sports itself.

REFERENCE LIST

1. Anand, V. & Law, J. (2018). *La Liga amps up football viewing experience with 360-degree videos, thanks to Intel True View*. Retrieved November 19, 2018 from https://www.hardwarezone.com.sg/tech-news-la-liga-amps-football-viewing-experience-360-degree-videos-thanks-intel-true-view

2. AS Roma. (2018). *Gallery: Friday's training in photos*. Retrieved November 11, 2018 from https://www.asroma.com/en/news/2018/7/gallery-friday-s-training-in-photos

3. Babolat. (2015). *Babolat Play*. Retrieved May 10, 2018 from http://en.babolatplay.com/play

4. Babolat Insiders. (2017). *Pure Aero: Rafael Nadal's fatal weapon*. Retrieved November 13, 2018 from http://www.babolat.com/insiders/pure-aero-rafael-nadals-fatal-weapon-0007/#.W-q4cehKhPY

5. Bellis, M. (2018). *The History of Sports, From Ancient Times to Modern Day*. Retrieved December 5, 2018 from https://www.thoughtco.com/history-of-sports-1992447

6. Brown, C. (2017). *TSG Hoffenheim: One Team, One Software Platform*. Retrieved November 10, 2018 fromhttps://news.sap.com/2017/12/tsg-hoffenheim-one-team-one-software-platform/

7. Cambridge Dictionary. (2018). *Sport*. Retrieved December 5, 2018 fromhttps://dictionary.cambridge.org/us/dictionary/english/sport

8. CBS Sports. (2017). *How Hawk-Eye Line Calling Works in Tennis*. [video]Retrieved October 24, 2018 from https://www.youtube.com/watch?v=6wjhSR5Dcyk

9. Chen, K., Zhang, S., Li, Z., Zhang, Y., Deng, Q., Ray, S., & Yier J. (2018). Internet-of-Things Security and Vulnerabilities: Taxonomy, Challenges, and Practice. *Journal of Hardware and Systems Security*, 1-14. Retrieved May 26, 2018 from https://link.springer.com/article/10.1007%2Fs41635-017-0029-7

10. Chula, J. (2010). *In Pictures: Frank Lampard's Disallowed Goal v Germany*. Retrieved October 8, 2018 from http://worldsoccertalk.com/2010/06/27/in-pictures-frank-lampards-disallowed-goal-v-germany/

11. DeGennaro, K. (2017). *Corporate Sponsorships Reimagined: NBA*. Retrieved November 22, 2018 fromhttps://news.sap.com/2017/08/corporate-sponsorships-reimagined-nba/

12. Diallo, A. (2014). *Can Babolat's Smart Racket Improve Your Tennis Game?* Retrieved November 12, 2018 fromhttps://www.forbes.com/sites/amadoudiallo/2014/08/28/can-babolats-smart-racket-improve-your-tennis-game/#7a0b41095fd6

13. Dibrov, Y. (2017). The Internet of Things Is Going to Change Everything About Cybersecurity.*Harvard Business Review*. Retrieved January 16, 2019 from https://hbr.org/2017/12/the-internet-of-things-is-going-to-change-everything-about-cybersecurity

14. Dinha, F. (2018). How To Secure The Internet Of Things.*Forbes*. Retrieved April 27, 2018 from https://www.forbes.com/sites/forbestechcouncil/2018/04/13/how-to-secure-the-internet-of-things/#205f44511cbb

15. English Oxford Living Dictionaries. (2018). *Sport*. Retrieved December 5, 2018 fromhttps://en.oxforddictionaries.com/definition/sport

16. EuroLeague. (2016). *EuroLeague upgrades with Hawk-Eye Innovations SMART Replay solution*. Retrieved October 17, 2018 fromhttp://admin.euroleague.net/euroleague-basketball/news/i/7bjq7kci4camrx73/euroleague-upgrades-with-hawk-eye-innovations-smart-replay-solution

17. EuroLeague. (2017a). *2017-18 Turkish Earlines Euroleague Bylaws.* Retrieved October 17, 2018 from http://www.euroleague.net/rs/89rc6t9mc63fbgqt/84bd1f8d-134d-42a0-a8ee-cd688d29aaa2/562/filename/201718taebylaws.pdf

18. EuroLeague. (2017b). *Experience the Final Four in VR with FirstVision 360-degree Body-Cameras*. Retrieved November 21, 2018 from http://www.euroleague.net/final-four/istanbul-2017/news/i/7tchtshmf8tl4fjr/experience-the-final-four-in-vr-with-firstvision-360-degree-body-cameras

19. EuroLeague. (2018a). *Jordi Bertomeu welcome speech at Final Four Belgrade 2018*. Retrieved November 21, 2018 fromhttp://www.euroleague.net/final-four/belgrade-2018/news/i/8qr6ymbdfj67dldv/jordi-bertomeu-welcome-speech-at-final-four-belgrade-2018

20. EuroLeague. (2018b). *FirstVision body-camera images and sounds from semifinals*.Retrieved November 21, 2018 fromhttps://www.youtube.com/watch?v=OxZ4I1dZCO0

21. FIFA. (2013). *Goal-line technology has arrived in football*. Retrieved October 8, 2018 fromhttps://www.fifa.com/about-fifa/news/y=2013/m=6/news=goal-line-technology-has-arrived-football-2119880.html

22. FIFA. (2014). *First incident resolved by GLT at the 2014 FIFA World Cup in Brazil*. Retrieved October 8, 2018 fromhttps://football-technology.fifa.com/en/media-tiles/first-incident-resolved-by-glt-at-the-2014-fifa-world-cup-in-brazil/

23. FIFA. (2018a). *About Goal-line technology*. Retrieved May 9, 2018 fromhttps://football-technology.fifa.com/en/media-tiles/about-goal-line-technology/

24. FIFA. (2018b). *The benefits of being a licensee*. Retrieved October 8, 2018 fromhttps://football-technology.fifa.com/en/media-tiles/the-benefits-of-being-a-licensee/

25. FIFA. (2018c). *Video Assistant Referees (VAR)*. Retrieved May 9, 2018 fromhttps://football-technology.fifa.com/en/media-tiles/video-assistant-referee-var/

26. FIFA. (2018d). *VAR at the 2018 FIFA World Cup*. Retrieved May 9, 2018 from https://football-technology.fifa.com/en/innovations/var-at-the-world-cup/

27. FIFATV. (2014). *Benzema v Honduras - Goal-Line Technology EXCLUSIVE*. [video]Retrieved October 8, 2018 from https://www.youtube.com/watch?v=-8e_cdg0NDw

28. FIFATV. (2018a). *Tour of the Video Operation Room (VOR)*. [video] Retrieved October 9, 2018 from https://www.youtube.com/watch?v=Mu6jaBb5Low

29. FIFATV. (2018b). *VAR - The System Explained*. [video]Retrieved October 14, 2018 from https://www.youtube.com/watch?v=YdwOL08NfxQ&t=179s

30. FIFATV. (2018c). *France v Australia - 2018 FIFA World Cup Russia™ - MATCH 5*. [video]Retrieved October 9, 2018 fromhttps://www.youtube.com/watch?v=-4_SXeQdIJo&t=7s

31. FIRSTVISION. (2018a). *FIRSTVISION: Wearable electronics pioneers*. Retrieved November 21, 2018 from http://www.firstvision.tv/#About

32. FIRSTVISION. (2018b). *Product*. Retrieved November 21, 2018 from http://www.firstvision.tv/#Producto

33. FIRSTVISION. (2018c). *Benefits*. Retrieved November 21, 2018 from http://www.firstvision.tv/#Beneficios

34. FIRSTVISION. (2018d). *They trust us*. Retrieved November 21, 2018 fromhttp://www.firstvision.tv/#Credenciales

35. Gartner. (2018a). *Digitalization*. Retrieved December 13, 2018 fromhttps://www.gartner.com/it-glossary/digitalization/

36. Gartner. (2018b). *Digital Business Transformation*. Retrieved December 13, 2018 from https://www.gartner.com/it-glossary/digital-business-transformation

37. Giorgio, P., Marzin, K., Lee, S., & Vonderhaar, M. (2018). *Internet of Things (IoT) in Sports.* Retrieved December 19, 2018 fromhttps://www2.deloitte.com/content/dam/Deloitte/pl/Documents/Reports/pl-raport-internet-of-things-sports-eng.pdf

38. Graziano, D. (2015). *Wilson's smart basketball tracks when you make a shot (hands-on)*. Retrieved May 9, 2018 from https://www.cnet.com/products/wilson-x-connected-basketball/preview/

39. Greengard, S. (2015). *The Internet of Things.* Retrieved December 13, 2018 from https://www.britannica.com/topic/Internet-of-Things-The-2032782

40. Hawk-Eye. (2018a). *About*. Retrieved October 22, 2018 fromhttps://www.hawkeyeinnovations.com/about

41. Hawk-Eye. (2018b). *Electronic Line Calling Technology - How it works*. Retrieved May 10, 2018 from https://www.hawkeyeinnovations.com/sports/tennis

42. Hougland, B. (2014). *What is the Internet of Things? And why should you care? | Benson Hougland | TEDxTemecula.*[video]Retrieved December 13, 2018 from https://www.youtube.com/watch?v=_AlcRoqS65E

43. Intel. (2018a). *Intel 360 Replay Technology*. Retrieved May 10, 2018 from https://www.intel.com/content/www/us/en/sports/360-replay.html

44. Intel. (2018b). *NBA + Intel True VR*. Retrieved November 20, 2018 from https://www.intel.com/content/www/us/en/sports/nba/overview.html

45. Intel. (2018c). *Courtside with NBA on TNT VR Powered by Intel True VR | Intel*. [video]Retrieved November 20, 2018 from https://www.youtube.com/watch?v=8h8VZoOyVW0

46. ITF. (2017). *2018 ITF Rules of Tennis.* Retrieved October 24, 2018 fromhttps://www.itftennis.com/media/277603/277603.pdf

47. Kahn, R., & Dennis, M. A. (2018). *Internet.* Retrieved December 13, 2018 from https://www.britannica.com/technology/Internet

48. Kasten, M. (2015). *Babolat Play's Connected Tennis Racket Is the Future of Tennis*. Retrieved November 13, 2018 fromhttps://www.sporttechie.com/babolat-play-connected-tennis-racket-is-the-future-of-tennis/

49. LaLiga. (2016). *El Clasico as it's never been seen before thanks to Intel's 360° replay technology*. Retrieved November 19, 2018 fromhttps://www.laliga.es/en/news/el-clasico-as-its-never-been-seen-before-thanks-to-intels-360-replay-technology

50. Le, D. (2017). Risks Hidden In Your Internet Of Things. *Forbes*. Retrieved April 27, 2018 fromhttps://www.forbes.com/sites/kpmg/2017/08/11/risks-hidden-in-your-internet-of-things/#2aa4c32a3dd8

51. Lorge, B. S., & Bruce, M. G. (2018). *Tennis.* Retrieved December 9, 2018 from https://www.britannica.com/sports/tennis

52. Lowood, H. E. (2018). *Virtual reality.* Retrieved January 15, 2019 from https://www.britannica.com/technology/virtual-reality

53. Magic Logix. (2014). *Infographic: Thanks to technology: A history of digital tech.* Retrieved December 11, 2018 fromhttps://www.magiclogix.com/magic-theory/infographic-thanks-technology-history-digital-tech

54. Marr, B. (2019). *5* Important Augmented And Virtual Reality Trends For 2019 Everyone Should Read.*Forbes*. Retrieved January 17, 2019 fromhttps://www.forbes.com/sites/bernardmarr/2019/01/14/5-important-augmented-and-virtual-reality-trends-for-2019-everyone-should-read/#201d411822e7

55. Melnick, K. (2018). *NBA 2017-2018 VR Highlight Reel Arrives Free On NextVR*. Retrieved November 20, 2018 from https://vrscout.com/news/nba-season-highlights-free-nextvr/

56. Mitchell, B. (2018). *What Does UWB Mean?* Retrieved November 10, 2018 from https://www.lifewire.com/ultra-wide-band-817953

57. MktRegistradoTV. (2018). *LaLiga Intel True View.*[video]Retrieved December 19, 2018 from https://www.youtube.com/watch?v=gs9sQx1VuRk

58. Mokray, W. G., Donald, L. W., & Logan, R. C. (2018). *Basketball.* Retrieved December 8, 2018 from https://www.britannica.com/sports/basketball

59. Morgan, J. (2014). A Simple Explanation Of 'The Internet Of Things'. *Forbes*. Retrieved April 27, 2018 fromhttps://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#2c35f1451d09

60. Moynihan, T. (2014). *The NBA's new high-tech control center is a hoops fan's dream*. Retrieved October 14, 2018 from https://www.wired.com/2014/10/nba-replay-center/

61. Mudric, M. (2018). *Technology and FIFA World Cup 2018 – How will the Internet of Things impact football?* Retrieved December 19, 2018 from https://readwrite.com/2018/06/22/technology-and-fifa-world-cup-2018-how-will-the-internet-of-things-impact-football/

62. NBA. (2014). *NBA Replay Center Video*. [video]Retrieved October 14, 2018 fromhttps://www.youtube.com/watch?time_continue=35&v=YP3fkfOZHEg

63. NBA. (2016). *NBA Referee Instant Replay Trigger Outline*. Retrieved October 14, 2018 from http://www.nba.com/official/instant-replay-guidelines.html

64. NBA. (2018a). *Shot clock reset among rule changes approved by Board of Governors*. Retrieved October 15, 2018 fromhttp://www.nba.com/article/2018/09/21/nba-board-governors-approves-rule-changes

65. NBA. (2018b). *XR Setup Instructions*. Retrieved November 20, 2018 from http://www.nba.com/xr/freecontent

66. NBA. (2018c). *NBA Advanced Stats*. Retrieved November 22, 2018 from https://stats.nba.com/vs/#!?PlayerID=201939&VsPlayerID=1629029

67. NBA Official. (2018). *Replay Center*. Retrieved May 9, 2018 from http://official.nba.com/replay/

68. Newman, D. (2018). Top 10 Digital Transformation Trends For 2019.*Forbes*. Retrieved December 13, 2018 fromhttps://www.forbes.com/sites/danielnewman/2018/09/11/top-10-digital-transformation-trends-for-2019/#2382679f3c30

69. NextVR. (2018a). *NextVR and NBA digital announce expanded distribution for 2018-19 NBA League Pass virtual reality schedule*. Retrieved November 20, 2018 from https://www.nextvr.com/nextvr-and-nba-digital-announce-expanded-distribution-for-2018-19-nba-league-pass-virtual-reality-schedule

70. NextVR. (2018b). *NBA*. Retrieved November 20, 2018from https://www.nextvr.com/nba

71. OmniVirt. (2018). *Examples of Virtual Reality in Sports*. Retrieved January 16, 2019 from https://www.omnivirt.com/blog/virtual-reality-sports-examples/

72. Porter, M. E., & Heppelmann, J. E. (2017). Why Every Organization Needs an Augmented Reality Strategy.*Harvard Business Review*. Retrieved January 17, 2019 fromhttps://hbr.org/2017/11/a-managers-guide-to-augmented-reality#how-does-augmented-reality-work

73. Ran, E. (2016). *UEFA approve Goal-Line Technology for Euro 2016 and 2016/17 Champions League*. Retrieved October 8, 2018 from https://www.sportskeeda.com/football/uefa-approve-goal-line-technology-euro-2016-2016-17-champions-league

74. Ranger, S. (2018). *What is the IoT? Everything you need to know about the Internet of Things right now*. Retrieved April 27, 2018 from https://www.zdnet.com/article/what-is-the-internet-of-things-everything-you-need-to-know-about-the-iot-right-now/

75. Rowe, D. C., Maguire, J. A., Thompson, W. N., & Guttmann, A. (2018). *Sports.* Retrieved December 5, 2018 from https://www.britannica.com/sports/sports

76. SAP. (2013). *NBA.com/Stats Launches as Most Comprehensive Official NBA Statistical Site*. Retrieved May 9, 2018 from https://news.sap.com/nba-comstats-launches/

77. SAP. (2015). *SAP Unveils SAP Sports One Solution for Soccer*. Retrieved October 26, 2018 fromhttps://news.sap.com/2015/04/sap-unveils-sap-sports-one-solution-for-soccer/

78. SAP. (2018a). *What is the Internet of Things (IoT)?* Retrieved April 27, 2018 fromhttps://www.sap.com/trends/internet-of-things.html?url_id=ctabutton-us-icon-iot

79. SAP. (2018b). *SAP Sports One*. Retrieved May 9, 2018 from https://www.sap.com/products/sports-one.html

80. SAP. (2018c). *Welcome to your SAP Sports One Trial*. Retrieved October 26, 2018, fromhttps://my011073.sapbydesign.com/sap/public/testdrive/runtime/run?key=01O%7b3aVk7jYsaWgtiSWxrm

81. SAP. (2018d). *SAP Event Ticketing*. Retrieved May 10, 2018 fromhttps://www.sap.com/products/event-ticketing.html

82. SAP. (2018e). *Welcome to your SAP Event Ticketing Trial*. Retrieved November 18, 2018fromhttps://my011073.sapbydesign.com/sap/public/testdrive/runtime/run?key=01O%7b3aVk7kYwXPSUFV1YG0

83. SAP. (2018f). *SAP HANA*. Retrieved November 22, 2018 fromhttps://www.sap.com/products/hana.html?url_id=CRM-XM17-GTM-SPON_Blogs:text-Coporate_Sponsorships_Reimagined_NBA-Blog-News_Center-Prom_SAPHANA-SAP_HANA

84. Sheikh, K. (2016). *Beyond Gaming: 10 Other Fascinating Uses for Virtual-Reality Tech*. Retrieved January 16, 2019 fromhttps://www.livescience.com/53392-virtual-reality-tech-uses-beyond-gaming.html

85. Shekhar, A. (2018). *10 Football teams with the best fans in the World.* Retrieved December 19, 2018 fromhttps://www.sportskeeda.com/football/10-football-teams-best-fans-world

86. SportIQ. (2017). *Wilson X Basketball*. Retrieved November 12, 2018 from https://play.google.com/store/apps/details?id=com.sstatzz.basketball.wilson&hl=en

87. Stanley, A. (2016). *Rafael Nadal Says Technology Is Changing Tennis As We Know It And It's An Issue All Sports Will Face*. Retrieved November 13, 2018 from https://www.sporttechie.com/advents-technology-making-sports-like-tennis-obsolete/

88. Statista. (2018). *Global digital population as of October 2018 (in millions)*. Retrieved December 13, 2018 fromhttps://www.statista.com/statistics/617136/digital-population-worldwide/

89. STATSports. (2018a). *About*. Retrieved November 10, 2018from https://statsports.com/about-us/

90. STATSports. (2018b). *Apex Pro Series*. Retrieved November 10, 2018 from https://statsports.com/apex/

91. STATSports. (2018c). *Apex software*. Retrieved November 10, 2018 fromhttps://statsports.com/apex-software/

92. STATSports. (2018d). *Clients*. Retrieved November 11, 2018 from https://statsports.com/statsports-clients/

93. STATSports. (2018e). *Apex Athlete Series*. Retrieved November 12, 2018 from https://statsports.com/apex-athlete-series/#pod

94. TOTAL SPORTEK. (2018). *25 World's Most Popular Sports (Ranked by 13 factors).* Retrieved May 26, 2018 from https://www.totalsportek.com/most-popular-sports/

95. Tracy, P. (2015). *An Inside Look At How Rafael Nadal Uses The Data From His Connected Tennis Racket*. Retrieved November 13, 2018 from https://www.sporttechie.com/an-inside-look-at-how-rafael-nadal-uses-the-data-from-his-connected-tennis-racket/

96. van Velzen, J. T. (2017). Internet Of Things: 5 Ways To Overcome Security Challenges.*Forbes*. Retrieved April 27, 2018 from https://www.forbes.com/sites/sap/2017/12/07/internet-of-things-5-ways-to-overcome-security-challenges/#ea1b4462635d

97. Waniata, R. (2018). *How NextVR and the NBA are bringing VR from the sidelines to center court*. Retrieved November 20, 2018from https://www.digitaltrends.com/home-theater/nextvr-nba-league-pass-writing-future-of-vr/

98. Weil, E., Joy, B., Rollin, J., Giulianotti, R. C., & Alegi, P. C. (2018). *Football.* Retrieved December 7, 2018 from https://www.britannica.com/sports/football-soccer

99. Wessel, M. (2014). Don't Compare Virtual Reality to the Smartphone.*Harvard Business Review*. Retrieved January 17, 2019 fromhttps://hbr.org/2014/03/dont-compare-virtual-reality-to-the-smartphone

100. Wilson. (2018). *Meet our X factor*. Retrieved May 9, 2018 from http://www.wilson.com/en-us/explore/labs/basketball/wilson-x

APPENDICES

Appendix 1: Povzetek (Summary in Slovene language)

Tema magistrske naloge je digitalizacija v športu. Pametne naprave in digitalizirane rešitve so postale del vsakdanjega življenja. Razvoj sodobnih tehnologij je omogočil tudi njihovo uporabo v športni panogi. Ker je večina tehnologij, ki se uporabljajo v športu, novost na trgu, področje digitalizacije v športu ni dovolj raziskano, kar predstavlja glavno problematiko magistrske naloge. V nalogi so obravnavani trije športi, ki so izbrani na podlagi izbirnega postopka. Nogomet, košarka in tenis so dobili prednost pred ostalimi športi, ker so športi z žogo in so popularni več ali manj na celem svetu.

Namen magistrske naloge se je seznaniti z digitalnimi rešitvami in tehnologijami v športu in prispevati k temu aktualnemu, priljubljenemu, ampak tudi neraziskanemu področju. Ciljev magistrke naloge je več. Najprej je cilj zbiranje informacij o zgodovini športa in digitalnih tehnologijah ter internetu stvari in virtualni resničnosti iz ustreznih virov, prav tako tudi razlaga koncepta interneta stvari kot teoretičnega temelja naloge. Naslednji cilj pa je analiza različnih tehnologij, ki se uporabljajo v športu. Cilj med analizo je pregled dostopnih video predstavitev tehnologij, pridobitev brezplačnih preizkusov nekaterih tehnologij, uporaba dostopnih študij primerov in poglobljena analiza spletnih strani ponudnikov tehnologij.

Teoretični del magistrske naloge je razdeljen na dva dela. Prvi del zajema zgodovinski pregled razvoja športa in digitalnih tehnologij. V drugem delu sta analizirana dva sodobna trenda na področju digitalnih tehnologij, internet stvari in virtualna resničnost. Analiza koncepta interneta stvari se je začela s splošnimi definicijami in se je nadaljevala z analizo prednosti, slabosti in varnosti. Teoretični del zajema tudi uporabo interneta stvari v športu in kratek pregled virtualne resničnosti.

Praktični del prinaša analizo 13 različnih tehnologij, ki se uporabljajo v športu. Tehnologije so razdeljene v tri skupine: tehnologije za pravilnost igre, tehnologije za uspešnost igralca/ekipe in tehnologije za doživetje navijačev. Prva ideja je bila razdelitev tehnologij po športih v katerih se uporabljajo. Nekatere tehnologije se lahko uporabljajo v več kot enem športu, tako da ta razdelitev ni bila dovolj dobra. Pravilnost igre, uspešnost igralca/ekipe in doživetje navijačev je nekaj, kar je skupno za vsak šport in se je pokazalo kot odlična podlaga za razdelitev tehnologij.

Tehnologije za pravilnost igre imajo za cilj, da pomagajo sodnikom pri odločanju in omogočijo, da bo igra bolj poštena. Poglavje zajema štiri različne tehnologije, od katerih se Goal-line tehnologija in VAR tehnologija uporabljata v nogometu. Goal-line tehnologija pomaga sodnikom v primerih, ko ni očitno ali je žoga prešla golovo črto ali ne. VAR tehnologija pa predstavlja uporabo video posnetkov situacij v katerih sodnik ni prepričan v svojo odločitev. Instant Replay je tehnologija, ki se uporablja v košarki. Uporaba tehnologije se razlikuje v ligi NBA in Euroligi, zato je v tem primeru uporaba tehnologije

analiziranaločeno za vsako ligo. Electronic Line Calling pa je tehnologija, ki se uporablja v tenisu in preverja ali je žogica odskočila izven igrišča ali ne.

Tehnologije za uspešnost igralca/ekipe so tehnologije, ki pomagajo igralcem in ekipam pri doseganju boljših rezultatov. Tehnologije v tej skupini so lahko zelo različne med seboj. Nekatere tehnologije lahko podpirajo celotno športno delovanje ene športne organizacije, tako kot rešitev za upravljanje ekipe SAP Sports One, ali pa se fokusirajo na en posamezni del razvoja športnikov in ekip. Tehnologija podjetja STATSports se osredotoča na pridobitev podatkov o fizični zmogljivosti igralcev in pomaga pri pripravi treningov in taktik. Po drugi strani, tehnologije kot so Wilson X Connected košarkarska žoga in Babolat Play pametni lopar pomagajo pri razvoju športnih spretnosti.

Tehnologije za doživetje navijačev pomagajo pri razvoju odnosov med klubi in navijači in izboljšujejo doživetje navijačev pred tekmo, med tekmo in po tekmi. SAP Event Ticketing je rešitev, ki klubom omogoča povečanje prodaje kart in pomaga pri izboljlšanju odnosov z navijači. Tehnologije kot so Intel 360 Replay, NBA VR in FIRSTVISION kamere izboljšujejo TV oddaje tekem. Z različnimi tehnologijami, ki so vključene v oddaje, se lahko navijači počutijo kot del tekme. NBA stats pa je spletna stran, ki deluje z pomočjo SAP HANA platforme in ponuja navijačem vse možne statistike NBA tekem.

Uporaba različnih tehnologij v športu se je zaenkrat pokazala kot prava poteza. Veliko je uspešnih primerov in prednosti, ki jih tehnologije prinesejo. Na žalost, je večina obravnavanih tehnologij še vedno privilegij najbogatejših klubov, lig in športnih organizacij. V prihodnosti se pričakuje, da se bodo tehnologije razširile in dodatno razvile. Težko je napovedati kaj točno bo prihodnost prinesla in kako bo šport izgledal čez nekaj let. Edino pomembno je to, da tehnologije ne postanejo večje od samega športa.